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

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Abstract

Collaborating at two universities to improve teaching and learning in undergraduate engineering, an interdisciplinary team of researchers, instructors, and evaluators planned and implemented the use of multimedia case studies with students enrolled in an introductory engineering course. This qualitative action evaluation study focuses on results from two semesters of implementation. Employing an action evaluation approach, 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. Focus group data were analyzed using a thematic analysis approach, and frequency counts were conducted to analyze the open-ended survey data. Recommendations and discussion related to design considerations for use of multimedia case studies in introductory engineering courses are included.

Introduction

Recent calls for change in engineering education address the knowledge and skills that today's engineers need in the workplace (Watson, 2009). The Committee on the Engineer of 2020 (National Academy of Engineering, 2005) has encouraged the use of case studies of engineering successes and failures in the undergraduate engineering curriculum. With a focus on better preparing engineers through introductory engineering courses, and with funding from the National Science Foundation (NSF), an interdisciplinary team of engineering faculty, business faculty, and educational researchers worked to improve the design and delivery of introductory engineering courses at two universities in the Southeastern United States. Multimedia case studies were used for the purposes of making the learning experience more appealing and cost-effective. This paper addresses key qualitative findings from the culminating year of this three-year NSF-funded project to improve introductory engineering courses at two universities.

Engineering Instruction

Parallel to broad shifts across education generally (Bransford, Brown, & Cocking, 2000), the field of engineering education has undergone dramatic changes in terms of purpose and pedagogy. In the 19th century, the emphasis was on industrial skills. In the post-World War II era, the focus shifted to scientific and mathematics skills. Beginning in the 1970s and 1980s, such skills as critical thinking, communications, and team work took primacy in engineering education (Brent & Felder, 2003). More recently, industry reports indicate engineering graduates lack skills in creative thinking, design, communication, and other professional skills (Kimber, Biggs, & Leung, 2004).

The identified needs for engineering graduates have spurred university engineering faculty to alter how engineering is taught, moving from a strictly theoretical lecture approach to a more hands-on approach (Brent & Felder, 2003). One NSF-funded model for engineering faculty development centered on modeling, discussing, and critiquing techniques, which encouraged faculty to incorporate more active learning exercises, more team work activities, and more study guides in their classes (Dee & Daly, 2009). Somerville et al. (2005) suggest that students need to be more flexible in their pursuit of learning in science, technology, engineering, and math (STEM) fields and that universities should emphasize cross-disciplinary foundational skills, including teamwork and problem solving. Litzinger, Hadgraft, Lattuca, and Newstetter (2011) suggested that engineering education experiences need to provide opportunities for students to increase their knowledge of concepts and facilitate knowledge transfer of both technical and professional skills through real-world projects, yet current engineering education often does not achieve these objectives. In spite of widespread attempts to utilize new approaches, engineering as a field has been slow to adopt alternative pedagogies to the ubiquitous lecture method (Brent & Felder, 2003).

The 4P Model

The theoretical framework used in this study was the 4P model, which encompasses the concepts of presage, pedagogy, process, and product and extends the Biggs and Moore 3P model (Biggs & Moore, 1993; Nemanich, Banks & Vera, 2009). 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. The process component centers on students' deep learning – "motivation to learn and understanding of causal relationships among concepts" (Nemanich, Banks, & Vera, 2009, p. 127). The fourth component addresses *product* or achievement in student learning outcomes, which is believed to be affected by the intersection of the presage component and the process component (Kember, Biggs, & Leung, 2004). This led the project team to suggest that the pedagogy component may affect the product component – that is, how and what is taught directly influences what students learn. Figure 1 illustrates the 4P model used to guide the study.

The 4P Model led the researchers to develop the following evaluation questions:

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?*

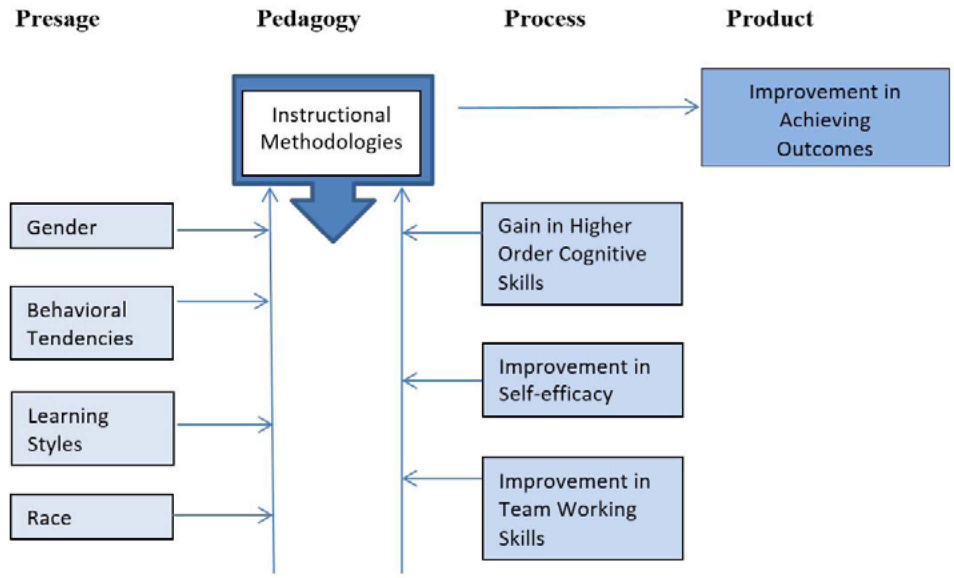

Figure 1: Presage-Pedagogy-Process-Product (4P) Model

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Methodology

The methodological approach for this qualitative evaluation was action evaluation, based on Rothman's (1999; 2009) action evaluation framework. Action evaluation is well-suited to cyclical projects, such as this one where the same introductory engineering course was offered at least three times per year. Through the action evaluation, leaders of an educational program establish program goals, assess them, and refine them for future program iterations (Rothman, 1999; 2009).

The project involved implementing cycles of action, during which multimedia case studies were employed, and data were collected to determine their effectiveness for teaching and 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. 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.

Context

The study was conducted at two universities in the Southeastern United States (USA). The first university, a large public research university (RU) offers 13 bachelor's degrees in the engineering college. Faculty typically offer the introductory engineering course to students in electrical, mechanical, aerospace, civil, and wireless engineering fields in a lecture format of 50 minutes with a student enrollment of 100 or greater. Later in the week, students attend a 150-minute lab session. Lab sessions have small enrollments of 14 to 20 students.

The second university was a small, private, historically black teaching university (TU), which offers three undergraduate degrees in its engineering college. Faculty members serve both engineering and business students in their introduction to engineering course. Students attend one 120-minute class section, which includes both lecture and lab work.

Course Content

In spite of some contextual differences relating to types of student majors and time in class, the introductory engineering courses were co-planned, and syllabi were identical with one exception (e.g., addition of robot labs at RU). Common elements at both universities included the following:

1. Weekly lectures with topics centering on ethics, design, engineering disasters, statistics, and team work, among others. In spring 2012, two 15-minute class lectures on engineering design and communication were recorded by a faculty member at each university and delivered via video to students at both universities.
2. The BlackBoard Learning Management System (Bb) was used to store additional resources, such as PowerPoints used in lectures.
3. The same introductory engineering textbook.
4. Hands-on lab activities. Examples included Hang Time Maximizers (e.g., design a piece of paper to stay aloft as long as possible), Pasta Tower (e.g., construct a tower of spaghetti and masking tape at least 12 inches high to see which design holds the most weight before breaking), and Boat Project (e.g., see which design would carry the most weight across a pool).
5. The same midterm and final exams were administered on concepts from lectures and the textbook.
6. Multimedia case studies were presented as round table discussions by student teams. Each team was assigned a stance to defend in discussions. In fall 2011, the *Chick fil A*, *Della*, and *STS 51-L* case studies were used to address decision-making and ethics; and in spring 2012, the *Chick fil A* and *Mauritius* case studies were used to address decision-making processes and design problems. These cases are characterized as multimedia, as they incorporate audio, video, and visual media as opposed to text-based only. Based on student feedback from fall 2011, the change of cases was made to reduce the time associated with case studies and to try out the Mauritius case study to support course objectives. Case studies were developed by the Laboratory for Innovative Technology and Engineering Education (LITEE, 2011).

Participants

RU participants were predominantly male (92.4% in fall 2011 and 87.0% in spring 2012) and white (92.4% in fall 2011 and 93.5% in spring 2012), all of whom were engineering majors. At TU, responding participants were predominantly black (90.1% in fall 2011 and 90.9% in spring 2012). Of these, half were male and half were female in fall 2011 (50% male/50% female). The spring

Student Participants by Data Collection Method at both Universities, Fall 2011 - Spring 2012

Data Collection Method	Research University (RU)		Teaching University (TU)	
	Fall 2011	Spring 2012	Fall 2011	Spring 2012
Survey	79 students	31 students	23 students	5 students
Focus Groups	20 students	6 students	24 students	6 students

Table 1

2012 group was predominantly female (63.6% females and 36.4% males), and the majority of all TU students were majoring in business.

Data Collection and Analysis Procedures

Data were collected through open-ended survey questions and focus group interviews at the end of each semester. Surveys were administered by course instructors and lab assistants through a login-based online survey tool during a face-to-face class session. Survey questions focused on students' previous experience with engineering, suggestions for enhancing learning in the course, perceptions of relevance of coursework to future work, the most interesting part of the course, aspects most helpful to learning, helpfulness of the multimedia case studies, appropriateness of group work for problem-solving, and overall suggestions for improvement. 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 1.

Focus groups were conducted near the end of each semester. 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, reactions to 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 1. 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.

Evaluators collected two forms of data to foster triangulation of data and increase the trustworthiness of interpretations drawn from analysis (Merriam, 2009). Through open-ended surveys, data were analyzed using thematic analysis (Braun & Clarke, 2006; Kawulich & Holland, 2012), where appropriate, using *NVivo9* qualitative analysis software. The open-ended survey data provided mixed types of information, some of which was coded qualitatively. Some open-ended survey responses were more appropriately analyzed using frequency counts (Kawulich, 2011). The first author conducted the focus group sessions and recorded them using a digital audio recorder. She then transcribed the recorded data into *Microsoft Word*. Focus group data were transcribed and imported into *NVivo9* qualitative analysis software. They were first analyzed inductively using open codes such as *content, major, guest speaker, affective, course design concepts, prior knowledge, assessment, textbook,* and *interaction*. These codes were collapsed into larger themes using inductive thematic analysis (Braun & Clarke, 2006; Kawulich & Holland, 2012). Further analyses (this time of a more deductive nature) were conducted to relate the identified themes to the constructs within the 4P model.

Results

The 4P model was used as the theoretical framework for this research. It incorporates four components: presage, pedagogy, process, and product. Findings are organized by component below.

Presage

Presage components include learner characteristics that exist prior to the learning experience, such as prior knowledge and learning preferences. Students who had already learned certain concepts in high school, such as statistics, perceived the content to be either redundant or reinforcing of their understanding. In terms of working together in groups, some students preferred working alone, although one student who indicated a preference for individual work over group work noted the benefits of working in groups 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.*

Students preferred to remain with the same group for the whole semester, as this enabled them to get to know each other and know what to expect from teammates. In a few cases where students felt that the work within their group was unbalanced, they expressed the desire to mix up the group membership to enable them to learn from other students who were also interested in high achievement and willing to share the responsibility of work as they were.

Students' perceptions of the relevance of the course materials varied with their major. For example, students not majoring in software engineering or electrical engineering at RU found less benefit in the robot programming activities that sometimes occurred during lab time. Further, engineering majors tended to desire more hands-on lab projects related to their particular engineering field. In spite of being "outside of their major," the hands-on labs and multimedia case studies provided critical thinking challenges to some of the TU business majors:

> *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 components refer to the specific instructional methodologies used in the study, such as the multimedia case studies, lecture, and textbook reading. Several questions posed to students via survey reveal findings in this area.

Most helpful instructional methods. When asked on the survey about what pedagogical/instructional methods students found to be most helpful in learning new concepts, fall 2011 RU students made more note of lab sessions as instructionally helpful, while spring 2012 RU students noted lecture and related activities as more helpful instructionally. In fall 2011, 79 RU students made 114 comments (some comments contained overlapping ideas): in 80 comments, projects, group work, or other lab-related activities were noted, and in 50 comments, students found learning through lecture to be most helpful. 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.

In response to the same question at the TU, students seemed to regard each instructional approach as roughly equal in helpfulness. Fall 2011 students made 35 comments, 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. 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. This may make sense when considering that lecture and labs were conducted in a single class, unlike the format used at the RU.

Helpfulness of multimedia case studies. The researchers specifically asked students about how helpful they perceived the multimedia 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 multimedia 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.

As one student noted, the case studies illustrated the problems and risks that engineers make on a daily basis as they make decisions, elaborating on all of the activities in which engineers are engaged. Several students indicated that the multimedia case studies could better connect content from 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.*

Perceptions of IIelpfulness of Case Studies in Fall 2011and Spring 2012

Semester	Fall 2011				Spring 2012			
Degree of Benefit	RU (n=79)		TU (n=23)		RU (n=31)		TU (n=5)	
Very beneficial	12	15.2%	7	30.4%	6	19.4%	3	60.0%
Beneficial	23	29.1%	9	39.1%	6	19.4%	0	0.0%
Somewhat beneficial	24	30.4%	3	13.0%	10	32.3%	0	0.0%
Not very beneficial	13	16.5%	2	8.7%	5	16.1%	0	0.0%
Not beneficial	6	7.5%	2	8.7%	2	6.5%	1	20%
No response	1	1.3%	n/a	n/a	2	6.5%	1	20%
		100%		100%		100%		100%

Table 2

Another student stated that the case studies could have been put online, freeing up class time for other content. One suggestion for improving how the case studies were implemented was to assign different roles or stances to groups to keep presentations from being repetitive, rather than assigning specific stances with which students did not agree or having all students respond to the same aspects of the cases in their presentations. Students felt that being told what stance to defend resulted in their regurgitating information, rather than using their critical thinking skills to think through a decision they chose to defend. Further, students were distracted by dated content (they already knew the outcome of the Challenger (*STS 51-L*) case study, and the software options in the *Chick fil A* case study were outdated technology). Even so, they found the case studies to be helpful to their decision-making skills. The specific parts of the case studies students enjoyed the most were those that required them to do some problem-solving and those that made it clear how the problem related to their future work as engineers. Another problem students mentioned was audio/video quality in a lab setting in which various groups were listening/viewing the cases at different points simultaneously, making for distracting noise levels. One student also commented on the incongruence of concepts within one case (*Mauritius*), noting that "there might be a video about what is going on with the auditorium, and then there is a random video about female engineers," which distracted her from the main point of the case.

Process

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 the lens of process, which also includes team building, a skill engineering employers demand. During both semesters, RU and TU students indicated a preference for working in groups over working alone. Students indicated enjoying group work for solving large problems, brainstorming for possible solutions, or getting help with complex problems. They appreciated having the views of others and being able to test out their ideas in a group. At TU, during the spring 2012 semester, the students (mostly business majors) noted the importance of being able to work in groups on case studies and round table exercises as preparation 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

Table 2 illustrates fall 2011 students' responses to how beneficial they believed the multi-media case studies were to their learning. The majority of students at both universities found case studies to be beneficial to some extent. Most students found the case studies to be at least somewhat beneficial (13% of RU students and 13% of TU students). Twenty-three RU students (29.1%) and nine TU students (39.1%) found them to be beneficial. Twelve RU students (15.2%) and seven TU students (30.4%) rated them as being very beneficial. Less in favor of multimedia case studies, 13 RU students (16.5%) and two TU students (8.7%) indicated that they were not very helpful, and six RU students (7.5%) and two TU students (8.7%) rated them as not being helpful at all.

Table 2 further 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 beneficial, six students (19.4%) found the case studies beneficial, and ten students (32.3%) found them somewhat beneficial. Five RU students (16.1%) found the case studies not very beneficial, and two students (6.5%) found them not beneficial. 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.

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. Based on the findings, the authors highlight potential areas of strength and improvement that student participants identified in relation to how introductory engineering courses are designed and conducted.

RU students, all of whom are engineering majors, indicated an expectation for the course that was somewhat different form the expectation of the TU students, who are either business or engineering majors. RU students expected the course to be instructive of the daily activities of engineers and perceived that the course would be helpful to them in making a decision about which field of engineering to pursue; they further expected to learn engineering design principles in the course. TU students, on the other hand, expected the course to provide them with more coverage of the soft skills, such as teamwork and ethics, used in both engineering and business occupations and showed more enthusiasm about learning these skills. These different expectations may have affected students' perceptions of the usefulness of the course concepts presented and pedagogical tools implemented.

One of the most important findings of this study was that the weekly interaction between faculty members from different disciplines provided the opportunity for members to learn from each other. For example, faculty were able to share ideas for improving instruction through having other research team members think about a variety of ways to present instruction, so that students at one university had no advantage over students at the other university, because of better technology or lab resources. Evaluators were emboldened to think about different ways to assess progress. Together, team members 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 the team 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.

Students also gave feedback that helped the project team improve how the cases were used, and the changes that were implemented made the use of multimedia case studies more effective. For example, early in the study, students were assigned a multimedia case study to complete. Students commented that there was too much verbiage (for example, one link contained 40 pages of text). Their feedback indicated they wanted the cases to be used in a more student-focused, collaborative way; therefore, the project team 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. As a result, the project team reduced the number of cases used to two or three per semester and worked on better focusing the instructional activities around them.

In recent years, engineering instruction has focused on the use of lecture to relate engineering concepts (Brent & Felder, 2003). Today's students are more technologically oriented and may find lecture to be passé. Such was the case with the students in the introductory engineering courses at both universities. After each semester, via surveys and focus group discussions, students were asked about their preferred way to learn new concepts, and each time students indicated a need for more variety in pedagogy to facilitate learning.

Introduction of multimedia 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.

Recommendations

Based on students' feedback and faculty peer review of teaching, several recommendations are made for consideration. For example, 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 (e.g., why certain engineering designs fail) and guest speakers from industry stand to improve the lecture experience and student learning. 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 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.

Course material was often seen as irrelevant to future work or redundant (as when students thought they already knew the material). Their comments would suggest the need for instructors to communicate relevance to students. Particularly with concepts that students view as being familiar (e.g., ethics), it is important that instructors be explicit about why the concept matters in the context of engineering. Greater attention to creating connections between seemingly familiar soft skills and engineering (e.g., ethics in engineering and why it matters) may increase student perception of relevance. The importance of soft skills in engineering may seem obvious to a course instructor, but their importance to students may seem overstated and redundant. Therefore, it is the responsibility of instructors and course designers to ensure the relevance connection is present in the course.

Case studies provided a medium through which students could experience what engineers do and how they respond in real-world situations. They offer a means for connecting what students sometimes perceived as disconnected lecture content and lab content. Students' comments indicated that they would have preferred to be able to choose a stance or decision to defend and would have liked to have each group be assigned a different aspect of the case on which to report to alleviate repetition of presentations. Rubrics for assessing these presentations would enable students to have clear expectations of their assignments.

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.

Limitations

The fall 2011 focus groups were conducted via teleconference. Occasionally during the teleconferences, problems included echo and inability to hear and see clearly, which hindered communication and data collection. 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. In the future, improved efforts to streamline recruitment across and within the universities may be beneficial.

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