Lessons Learned: Teaching Engineering Leadership in an Undergraduate Class using Case Studies

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Introduction

Leadership is an important skill that employers look for when hiring engineering undergraduates[1-4]. Although there has been progress on developing engineering undergraduates' leadership skills during their college years, faculty members have encountered many challenges[5]. One of the challenges includes ways to incorporate leadership development into engineering courses. This paper describes a leadership course which used case studies to develop engineering students' leadership skills.

Usually written in narrative forms, a case study is a situation or issue that includes facts and opinions that contribute to the decisions made by involved people[6]. In the engineering education context, case studies can help convey the complexity and ambiguity of the practical world, develop students' positive attitudes towards learning, and provide realism to students' learning[7,8]. Despite these advantages, the use of cases in engineering undergraduate curriculum has been limited due to faculty's lack of understanding in effectively linking cases to other course's materials[5,9]. To highlight some of the challenges and lessons learned, the author team used cases in a course that taught engineering leadership to undergraduates. These cases explore and engage student's interpretations of the definition of engineering leadership as a repertoire of "exemplary attitudes, behaviors, and skills necessary for an engineer to be an effective leader"[10].

The course described is a core class engineering undergraduates are required to take to earn a minor in Engineering Leadership in the College of Engineering at a large Midwestern university. As one of the course activities, students are charged to solve a sample case by applying what they learned from previous class sessions. Upon discussing and debriefing students' solutions, the instructor had students develop their own cases based on their own leadership experiences or past or current events. The instructor provided additional information on what needs to be included in the case (e.g., people involved, setting, problems, etc.). The students are also charged to develop open-ended assessment questions that allow readers to engage in quality reflections about engineering leadership. Once students developed their cases, they share them with their peers and solve each other's cases. Finally, they discuss and/or debate the solutions that they each developed.

Information about the course, students, and cases

In Fall 2013, a one credit course titled [*identifier removed for blind review*] was taught for the first time as the first of three core classes in a new minor in Engineering Leadership. The course is geared towards undergraduate students who are interested in exploring and expanding their understanding of engineering leadership. Some of the course's learning objectives are defining engineering leadership; applying engineering leadership knowledge to everyday situations and to a variety of technical environments; exploring factors that contribute to effective and ineffective leadership within organizations; and creating a professional leadership plan tailored to students' current and future career goals. Particular focus was made upon ways that students can align their technical interests with leadership. The class involved a combination of lecture (based on articles or papers by Kotter[11], and Northouse[12]), experiential exercises (e.g., attending leadership seminars and writing reflections), discussions, in-class presentation, videos, individual

assignments, and team assignments. Seven students took the course in Fall 2013 and were either freshmen or sophomores in the College of Engineering. As part of their requirement in the course, each student developed a leadership case and analyzed a case with assistance from the course instructor. The case development and case analysis of another student's case comprised 50% of a student's grade in the course. Information about the students and their cases are shown in Table 1.

Table 1. Information about students' cases and student discipline

Case #	Case setting	People involved	Case description	Student discipline
1	San Francisco Bay Area	Chief engineer and his engineering team.	Construction and fall of the Bay Bridge connecting San Francisco and Oakland.	Industrial engineering
2	San Bruno, California	Administrative law judge, senior engineer, public utilities commission, and gas and electric corporate leaders.	Explosion of a gas line due to a faulty weld joint.	Mechanical engineering
3	Small engineering firm	Small business owner, business employees, and outsourcing companies.	Change in company strategy for a specific product line or type of product to sustain company growth.	Agricultural and biological engineering
4	Food industry	Farmers, customers, agricultural chemical company, and governmental bodies in the United States and European Union.	Implication of Genetically modified organisms (GMO) in the past, present, and potential future.	Agricultural and biological engineering
5	Engineering classroom	Students, teaching assistant, professor, and administrators.	Issues involved with a professor teaching an engineering class.	Biomedical engineering
6	Industry	Young engineer and senior electricians.	New engineer completed a project without verifying facts and asking coworkers.	Mechanical engineering
7	Student organization	Chief engineer, president, and team members.	Due to a leadership problem the organization of the club is not efficient.	Mechanical engineering

Common themes in case descriptions developed by students

Students were given opportunities to develop cases that aligned with their interests, with prior experiences, or with general engineering leadership topics taught in the course (e.g., power or management vs. leadership). As a result, some students developed cases about engineers who overlooked important issues (e.g., safety or ethical) or failed to mention concerns to a proper authority. By overlooking the issues and failing to highlight concerns to the proper authority, the students believed an engineer was directly or indirectly responsible for a resulting catastrophe. Elements of cases are found below:

- One student's case (Case #1) involved the construction and collapse of the San Francisco-Oakland Bay Bridge. The case centered on the head engineer who overlooked the seismic activity in a nearby area when designing and constructing the bridge. A number of years after the bridge was built, the area experienced an earthquake and, as a result, a portion of the bridge collapsed, resulting in a fatality.

- Another student (Case #2) covered the story of a gas explosion in San Bruno, California. The case centered on a gas company that failed to correctly examine and report their gas lines to safety authorities. As a result, an explosion occurred, resulting in the loss of lives and collateral damage to a nearby residential area. Although the gas company was at fault for not listening to the lead engineer who warned the company hierarchy about the dangerous pipeline, the student argues that the lead engineer was also responsible for not bringing his concern to a proper safety authority.

These two student cases were developed based on *true stories*. The students decided to examine the role of the engineers in the cases and their leadership skills in order to assess what could have prevented the catastrophic incidents. The two students conducted their own research on these historical incidents, discussed what had happened, and shared their thoughts on what the engineers or others who worked with these engineers could have done to prevent the incident. Ultimately, these cases showed that students were able to reflect and to transfer what they learned in class regarding past engineering incidents.

Other students developed their cases based on their *personal experiences* in academia. The students chose to develop their cases based on their struggles to exhibit engineering leadership in class and student-run organizations.

- One student described his time in a class where a new professor was given the responsibility to teach a core engineering course (Case #5). The problem faced by the student and his peers was that the professor did not explain content clearly and did not give enough attention to the students. The student claimed that he learned more from the teaching assistant (TA) than the professor and asked in his case how the students in the class should respond and display leadership to resolve the situation.

- Another student's case was based on a student-led automobile organization (Case #7). The club consisted of a group of students from various engineering disciplines who were responsible for designing, manufacturing, and racing an off-road, single-person vehicle. The main issue surrounding the organization was the inability of two leaders in the club, the "Chief Engineer" and the "President," to collaborate. Due to the unclear description of leadership roles, the student described the inability of the organization to achieve its goals.

Lastly, one student's case was vastly different from the others. This particular student's case involved a *controversial technical topic*, genetically modified organism (GMO) products.

- The student was concerned that GMO products do not face much regulation (Case #4). Because GMO products do not face much regulation, the risk for consuming the product as well as risk to the natural environment exists. The student argued for understanding of the consequences of developing GMO food products and better ways to regulate GMO food, and questions the role of engineers in such circumstance. The discussed context involved multiple stakeholders (e.g., consumers, government representatives in the US and abroad, farmers, and GMO corporations) who could and would decide on the amount

of GMO food on supermarket shelves, and GMO foods' impacts on society (i.e., health and energy-related issues as GMO has the potential to be used as alternative fuel and vaccines) and the natural environment (impact on living organisms located close to areas where GMO foods are grown).

This last case showed the student's ability to think broadly about the impact of GMO products in terms of economic, social, and environment issues.

Common themes in assessment questions posed by the students

After writing their cases, students randomly selected a peer's case to analyze. Students created assessment questions and submitted their cases and corresponding questions to a peer. One common theme found in the student assessment questions was *students' ability to recognize that one of the engineering leaders' roles is to make trade-offs between important variables or factors* (e.g., economic gains, safety factors, and ethical issues). In Cases #1 and #2, students asked:

- "Should a leader focus on economic gain or rare environment disasters?"
- "What were the ethical decisions that the [senior engineer] made or ignored in designing the bridge?"
- "What level of leadership should an individual have to be seen as successful in a role that involves the safety of others?"

These questions highlight students' awareness that an engineering leader is required to make trade-offs and balance time-interdependent factors.

Another common theme in students' assessment questions involved t*he identification of important traits or skills of an engineering leader*. Students wanted to know what traits or skills defined engineering leaders. The following questions highlighted students' desires to identify engineering leaders beyond the titles or positions that they hold but by defining engineering leadership through traits and actions of engineering leaders.

- "What makes [the name of the engineer] a transformational leader rather than a transactional or task-oriented?"
- "What made [the name of the senior engineer] stand out as a leader rather than a manger?"
- "Is a leader defined by their actions or position?"
- "What makes an individual leader?"

The final common theme identified from students' assessment questions involved *students' desires to examine the cases' situations from multiple stakeholders' perspective and their roles in the given situation*.

- In Case #5, the student asks readers how students in the engineering class, TAs, the professor, and administrators should respond to the problem in class. Students recognize different roles and stakes that each of the people involved have in making sure students learn class materials. The student forces a reader to think what these stakeholders' obligations are in helping undergraduate students make the most of the classroom learning.

- Similarly, in Case #6, the student author forces the reader to think about the roles a young engineer and a senior engineer can play to prevent undesirable situation such as loss of resources. The questions highlight students' abilities to think that different stakeholders have different level of power or influence to prevent or remedy a problem situation.

Benefits from having students answer case assessment questions

The research team found clear benefits to having students read their peers' cases and answering the assessment questions. Upon reviewing students' answers, the assessment questions did engage students in quality reflections about engineering leadership. Students applied what they learned in class to identify important leadership qualities or characteristics that the people in the cases could and should have exhibited. For example, a student who reviewed Case #6 highlighted the importance of communication skills among a team of engineers. The student explained how asking and answering questions and verifying facts between the young engineer and supervisors (i.e., the people involved in Case #6) could have prevented loss in time and money. Similarly, the student who examined Case #7 assessment questions highlighted a number of important attributes and abilities of engineering leaders, such as being humble, trusting others to do their jobs, and the ability to delegate work. Another example is from the student who answered Case #1 assessment questions. The student highlighted the importance of considering all constraints in a project by an engineering leader. In addition, the student recognized that the safety of the general public outweighs any economic benefits and thereby an engineering leader should not overlook any safety issue. Furthermore, facts, history, or knowledge relevant to the engineering project should be thoroughly researched by the lead engineer before and during the project. These student answers showed the instructional team that the cases developed by the students, along with assessment questions, helped undergraduates focus on engineering problems and apply what they learned in class to diverse settings with multiple stakeholders.

In addition to highlighting important qualities of an engineering leader, many students provided recommendations on ways to resolve problem situations if similar situations arise in the future. For example, the student who examined Case #7 suggested defining the roles and responsibilities of each member in a team. The student recommended a way, based on the student's own experiences, to elect a leader. The student who examined Case #6 suggested ways to prevent young engineers from making the same mistake by having proper oversight from upper management to ensure that workers are communicating and that personnel from different teams get to know each other in the earlier phases of a project. Finally, the student who examined Case #5 assumed that the professor was having a difficult time balancing the loads of teaching, research, and service work at the university, and recommended that the university administrators intervene to help the faculty member, students, and other teaching staff in the course.

Students' answers show that the case studies help to present a context where an example of engineering leadership is needed and that the students can readily apply what they learned to identify what types of engineering leadership can be portrayed. As each student shared his/her own case and a potential solution with colleagues in the course, the student whose case was being examined learned of other leadership skills to apply in his/her case setting. In addition, many of the cases that students developed aligned with what many of their classmates in the course experienced but in different settings (e.g., industry settings or academia) or with different stakeholders (e.g., senior engineer or professor). Therefore, not only were many students in the classroom engaged in sharing their ideas, but students and the instructor were able to discuss a wide variety of solutions and their transferability across different settings.

Lessons learned

Although there were benefits from incorporating case studies and corresponding assessments in the course, there were a number of lessons learned and improvements that could be made in the future. Below are points that the instructor team leaned and possible suggestions for instructors planning to develop students' leadership skills through case studies.

- This was the first time that the students had engaged in case study development. Undergraduates wanted everything prescribed (i.e., the topic that they should choose for the case) and viewed the assignment from a right or wrong perspective; they kept asking the instructor if what they were doing was correct. An instructor has to guide students as they identify engineering leadership topics of interest and create cases that are realistic, interesting, and tell a clear story to others.

- Many of the students did not know how to write a case that contained multiple stakeholders and did not reflect their own personal views about the case. Other students tried to interpret their cases only from their personal perspectives. The instructor believes that subjectivity is a skill that needs to be taught to engineering students.

- The instructional team suggests that engineering courses should include some subjectivity so that students get accustomed to "thinking outside of the box" and pulling together ideas in ways that their peers can understand. Courses like this are challenging from multiple perspectives, so an instructor would have appreciated a bridge course that connected students to larger issues of writing. (This is similar to how engineering students enter engineering education courses.)

- Some students had issues creating assessment questions that encouraged the reader to critically think about a problem. An instructor needs to help students generate open-ended, high-order questions that enable readers to engage in thought-provoking exchanges with the content. An instructor can help students develop assessment question by sharing with the students a sample case with sample assessment questions. An instructor can spend time identifying features of good assessment questions prior to having students develop on their own.

- There is a learning curve for defining cases and giving students a "safe space" for learning and making mistakes. Failure is a large part of engineering leadership, and

undergraduate classes don't seem to be natural places for students to fail and learn from these failures without being penalized (i.e., earning a low grade for getting something wrong with few, if any, opportunities to revise and resubmit).

- The instructor approached this assignment much like a graduate study assignment. For this reason, the instructor had to teach graduate school skills, such as the ability to investigate, critique and reflect, as well as engage deeply in engineering leadership content. The instructor continuously reminded students to integrate and/or apply engineering leadership content discussed during class periods when developing cases or answering assessment questions.

Conclusion

This paper described common themes found in student-led cases studies and assessment questions. It also described the advantages and lessons learned about developing students' leadership skills through case studies. The instructional team believes this paper will inform current and future faculty members who are responsible for teaching leadership courses on ways to develop undergraduate students' leadership skills through case studies.

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