Identifying Effective Student Leaders to Improve Capstone Design Team Assignments

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Work-in-progress abstract: Identifying Effective Student Leaders to Improve Capstone Design Team Assignments

Abstract

Engineers in industry are required to work in teams to accomplish large goals. Similarly, engineering students often work in teams in course projects cornerstone through capstone. The stakes of capstone design projects are often high as teams work together to address a large design problem. However, the success of these student teams is highly variable and often related to key team personnel, especially those students whose work catalyzes their team to work successfully toward achieving project objectives. This work-in-progress investigates the common characteristics of effective student leaders in engineering team projects. This multi-method study employed purposeful sampling to identify top-performing teams from the past four semesters of a capstone design course in a mechanical engineering program at the University of Illinois at Urbana-Champaign. In the first phase of the study, faculty advisors of those teams were contacted for complete semi-structured interviews to share their perspectives regarding individual students' contributions. The second phase of the study focused on the students of these successful teams (i.e. alumni), especially any team members who are identified as the catalyst for the team's success. Alumni of the course (n = 5) participated in semi-structured interviews concerning their backgrounds, college leadership experiences, and leadership preferences. The research team inductively coded all transcripts from the interviews to develop common themes that could relate to personality traits, upbringing, education, work experiences, and others. Results of this study suggest "servant leadership" style is a common theme across students and have implications for the development and implementation of new leadership curricula in project-based courses, which may be implemented earlier in the degree program rather than the senior year.

Keywords: Leadership, Qualitative Methods, Capstone

Introduction and Motivation

There are many definitions of leadership and numerous tools to assess leadership and related personality styles, such as DISC, KAI, Meyers-Briggs, and the Clifton Strengths assessment [1–4]. Rather than conducting one of these assessments, we are interested in the formation of the skills that help students to develop an effective leadership style, as well as the self-identification of said leadership style. We observe individuals that are identified as good leaders by their capstone project adviser and attempt to understand and identify their personal attributes that seem to be critical aspects of their approach to leadership. We seek to understand the role that early experiences, norms, and values may play in the formation of effective leaders.

This Work-in-Progress paper will give an overview of our interview procedures, recruitment methods, and selected participants. The larger project examines development of leadership skills

in engineering students. We are specifically focused on understanding how different student characteristics impact the leadership in their capstone design projects and overall project success.

For engineers' success, they need to develop technical competencies as well as leadership skills. ABET, NAE, and NRC all say that the development of leadership skills among engineering students is critical for individual success as well as America's sustained dominance in the technology sector [5–7]. In that spirit, one goal of this project is to develop a leadership curriculum that can be integrated into the existing design course sequences throughout our college in order to maximize the effectiveness of the leadership training.

In his book on leadership, Northouse acknowledged the ever-evolving conceptions of leadership and distilled the common themes into a reasonable definition of leadership as a process whereby an individual influences a group of individuals to achieve a common goal. Leadership has more to do with how an individual affects the other members of their group as they work together than whether they are assigned to some position of authority within the group [8].

The review paper on engineering leadership development programs by Crumpton-Young, et al. showed common agreement between professional engineers and engineering students about which skills are most useful for an engineer in a leadership position [9]. But their work showed that there is a need for richer qualitative data, which our study may be able to help provide. One such study is by Cox et al., who asked engineering faculty members to assess students strengths, weaknesses, and future learning opportunities [10]. While leadership skills of engineering students may develop in many contexts, Knight, et al (2017) found that curricular emphasis on leadership development is more reliable than student engagement in co-curricular activities [11]. Schell, et, al. indicated that students with a strong engineering identity tend to be able to make accurate self-assessments of their growth in leadership skills. Their work also suggested that courses where students develop engineering skills are ideal for incorporating leadership training, because those courses are most effective for the development of engineering identity [12]. The design courses in our college are believed to be where students are most likely to develop an engineering identity due to the emphasis on skill development while working on group projects with peers. Similarly, Handley, et al. suggested that students need to develop a self-awareness of their leadership development by working on engineering projects, and they need to be able to communicate those experiences [13].

The work of Larsson, et, al. indicated that certain leadership styles are best suited for certain types of engineering projects, depending largely upon the project duration. For example, they found that "Integrators," whose tendency is to ensure that the team works well on an interpersonal level, tend to be best suited for complex projects that require timely completion. Their results suggest that discovery of a leadership style that is effective for the projects that we do in our courses may lead us to develop a leadership curriculum that teaches leadership in that style to achieve better course outcomes [14]. In this work we hope to solve this question in the inverse manner by discovering the leadership styles that led to the best outcomes by first identifying teams that had the best outcomes and then assessing the leadership style of the student(s) who are identified as the team leader(s).

Research Methods

Research Participants & Classroom Context

This research is based on student experiences in a mechanical engineering capstone design course at the University of Illinois at Urbana-Champaign. This one-semester course is a required component of a mechanical engineer's curriculum and is offered each semester. Between 100 and 130 students take the course in a semester. The typical class enrollment is about 80% male, 70% in-state students, 86% U.S. citizen or permanent resident, and 14% non-US residents. The course solicits projects from industry (about 80%), national competitions (about 15%), and the rest are usually humanitarian or research for a professor.

Twenty-four teams of three to five students each are formed and each team is assigned to work on a single project for the semester. All projects are required to have some hands-on design, build, test content in order to produce a single proof-of-concept prototype to the project sponsor. Additionally, the course satisfies the campus advanced composition requirement; students are required to deliver written updates to their project sponsors each week, weekly written and oral updates to their faculty adviser, three major project reports and oral presentations over the course of the semester, as well as a project video at the end of the course. At the end of the semester, faculty members vote on the top teams in the class, who are then given awards for their achievements. Awards were departmental merchandise valued at about $45/student.

All research was conducted following approved IRB procedures, including anonymization of the research participants through the use of pseudonyms and IRB-approved interview protocol (see Appendix). In order to investigate student leadership characteristics, we first conducted interviews with 18 faculty advisors in order to identify a potential pool of alumni/students for interviews through purposeful sampling. The approach of seeking engineering educators as experts in understanding students' strengths finds precedence from the work of Bayless, et al. [15] and Cox, et al. [10]. We asked the faculty members who advised award-winning teams if they could identify one or two students who they felt "catalyzed" the team to be successful.

Table 1. Interviewee characteristics

Pseudonym	Gender	Race	Tuition category	Capstone Teammate also interviewed?
Hugh	Male	Caucasian	Out-of-state domestic	No
Randall	Male	Caucasian	In-state domestic	No
Martha	Female	Asian	Out-of-state domestic	Yes: Thomas
Laura	Female	Caucasian	In-state domestic	No
Thomas	Male	Caucasian	In-state domestic	Yes: Martha

Through use of this language we hoped to avoid mis-identifying students as leaders merely because they were the most confident communicator with the faculty adviser. Instead, we urged the faculty members to carefully assess who were the individuals whose presence helped to organize, inspire, and focus the entire team in its work, without whom the project would not have been a success. Upon identification, those alumni of the program were then sought for an interview with a member of the research team. From this pool we were able to interview five alumni/students (See Table 1). Interviews were semi-structured and open-ended in nature. They were conducted via Zoom video conference, recorded, and transcribed. The interviews ranged between 32 and 53 minutes.

The interview protocol is provided in Appendix 1. The protocol aimed to understand the development of leadership skills and attitude and included questions centering around students' prior experiences, students' general characteristics, and students' leadership values. All interviews were transcribed. We also asked probing questions allowing a look at their perceived strengths and weaknesses in their university curriculum in terms of leadership in order to consider relevant modifications to the current offerings.

Data analysis

We thematically analyzed the transcripts of the five interviews looking for both emergent themes and coding for experiences that led to their leadership style, experiences of positive and negative team experiences, and leadership preferences [16].

Results & Discussion

Formative Experiences

Formative experiences were a common but unique theme from the research participants. When responding to the interview prompt, "What formative experiences in your life do you consider most important in your development as a leader?" students discussed family life, work/internship experiences, campus ministries, high school extra-curricular activities such as theater and athletics, leadership education, and scouting. Hugh, for example, was a unique student in that he entered engineering school after earning a degree in business and working for a few years. Finding himself bored with the work, he learned programming in order to automate the repetitive tasks of his job, which ultimately inspired him to pursue engineering. He continued to develop these skills in engineering school and he took the lead on programming for his capstone project. This experience was a strong motivator for him. When asked to compare his motivation to that of his colleagues in engineering school, he said:

> *"I ran into a lot of people who were far more motivated than me, but those were the type of people you tended to see doing engineering things, being parts of clubs, studying. I was more likely to run into those people than the ones who were less motivated, staying in their apartment drinking more than they should. I mean, getting a second chance at an undergraduate degree is pretty rare. I tried to use it as best I could."*

Thomas felt that his leadership skills developed as a result of his participation in scouting, in which he participated from kindergarten through his junior year of high school. He also felt that respect is more important than great skill for a leader, as a group must have respect for a person before accepting them as a leader, which implies that acceptance of the group is foundational to leadership. He said:

> *"I gained good leadership experience interfacing with the adults and planning some events for the troop. And in high school I was on my basketball team and I was one of the senior captains. That was also a leadership experience. Even though I wasn't the best basketball player, you have to really earn respect to be given that title. Respect is critical in the acceptance of a leader."*

College Experiences

We are also interested in how college experiences affected the development of the student leaders. We asked them about meaningful activities that helped them to develop their skills as a leader during their time as a student. Common themes that arose included working on projects with difficult team members, working on projects with diverse team members, and working on projects when not being motivated to work on them. Randall pointed out that working on a project in a team where nobody was willing to make decisions led him to view the importance of his role in terms of making decisions more so than being a leader of the team. He said:

> *"I never felt in any of the teams that I ever got this feeling of 'who made you the leader?' or anything like that. It was usually a very fluid conversation, too. It wasn't like a dictatorship. That's why I almost hate to call it leadership. It was more just kind of providing the team with some structure so that they could work together well, At least in my experience even now, that's kind of the role of a leader. A leader should be to provide direction, but ultimately give structure and direction and get the heck out of the way so people can do what they need to do to get their job done.*

On diversity as a benefit for the development of leadership, Randall said:

> *"One more item that I thought was important from a leadership standpoint was my first opportunity to work with a truly diverse group of people. You learn how to work with a lot of different people and how to lead their personalities."*

To gain insight from a different perspective, we then asked the interviewees to share an experience that they had as a student where poor leadership resulted in a bad or negative experience. Themes that arose were centered around poor communication and/or poor coordination, and teammates lacking motivation or enthusiasm for the project. Multiple interviewees talked about each team member developing their component of a project independently and being unable to successfully integrate the components, especially in the first two years of the program. Team members were often unresponsive to communication attempts, and others were critically unmotivated for working on the project. In some cases, lack of trust compounded the poor communication. In one case, the interviewee had to serve as a mediator between clashing teammates.

Self-Description of Leadership Style

Having touched on formative experiences before and during their college years, we then pivoted toward the style of leadership that each student used. To provide them a descriptive and intuitive framework to describe their leadership style, we shared "10 Common Leadership Styles" that listed the following leadership styles in order: Coach, Visionary, Servant, Autocratic, Laissez-faire or hands-off, Democratic, Pacesetter, Transformational, Transactional, and Bureaucratic. After reading through each item on the list and providing brief explanations of each, as shown in Table 2, the interviewees used the terms to describe the leadership style or styles that best described their own [17].

We phrased the question as "How would you describe your leadership style when working in engineering project teams as a student?" Most of the interviewees gave nuanced descriptions of

Table 2. The ten leadership styles referenced in the student interviews.

Indeed.com 10 Leadership Styles	Brief Description
Coach	Recognizes others' strengths, weaknesses, and motivations to help each improve, often by helping them set goals and providing them feedback
Visionary	Drives progress by inspiring new ideas among the team and earning trust for the new ideas. They tend to foster confidence among team members.
Servant	Has a people-first mindset that emphasizes employee satisfaction and collaboration, which tends to result in higher levels of respect.
Autocratic	Tends to focus mostly on results and efficiency, often making decisions alone and expecting employees to do exactly what they are asked.
Laissez-faire	Delegates tasks to team members with little or no supervision, trusting that they are competent to work successfully without oversight.
Democratic	Asks for input and considers feedback from team members before making decisions.
Pacesetter	Focuses on team member performance, setting high standards and holding accountability for them hitting performance goals.
Transformational	Focuses on communication, goal-setting, and employee motivation with a focus on organizational objectives rather than individual success.
Transactional	Focuses on team member performance with predetermined incentives and punishments for success and failure, while providing mentorship and training to help team members achieve their goals.
Bureaucratic	Expects team members to follow set rules and procedures while working on fixed duties properly within a set hierarchy to fulfill their responsibilities.

Table 3: Self-description of personal leadership styles during time as a student

Martha	Randall	Thomas	Laura	Hugh
Democratic Servant Visionary Transactional	Servant Pacesetter Autocratic	Democratic Servant	Servant Transformational	Servant

their leadership styles, invoking multiple styles to describe themselves. Table 3 shows in order how each student explained their personal style.

Notably, all five interviewees referred to Servant leadership at least in part to describe their individual style. Martha and Thomas, who worked on a team with each other in the capstone course also described their style as primarily Democratic, with Martha noting that she really liked all members of the team. In their interviews, both noted that Martha strongly motivated the teammates to work toward winning the award for best project at the end of the semester, which could be considered emblematic of Transactional leadership. But concerning Servant leadership, she said the following about herself:

> *"I don't ever want to be someone who makes all of the decisions and tells people what to do but then does not follow through and do work myself. It's definitely a 'lead by example' kind of thing where I'm putting in my fair share of work and people can see that. It's also, I think, a respect thing too. If I have an idea, they would listen. In everything, if you are just throwing on a bunch of stuff but then don't have anything to back it up, it's harder for people to want to follow those suggestions."*

Martha clearly feels that leadership and healthy team dynamics stem from each team member earning the respect of the others, and that to earn respect from one's teammates a person must demonstrate their own commitment to doing the work that the project requires. She believes that by setting the example of steady contributions to the work, she will earn the respect she needs from her teammates to be trusted to share her ideas. To her, a leader must first earn the respect of the people they intend to lead, similar to the feelings that Thomas shared when asked the first question of the interview.

Leadership Preferences

Given that the students were so inclined toward Servant leadership, which invokes images of humility and equality, the question of leadership motivation arose. We wondered whether being a leader required a particular valuation or identity of leadership. We asked whether these students who were identified as leaders actually aspired to be leaders themselves, or if they preferred following. Randall preferred to follow as he is somewhat risk-averse and would only prefer to lead if nobody else will. Martha stated that her preference would be situation-specific; similarly, Hugh preferred to follow, but only under someone who he thought to be a good leader. He also explained that he liked the Laissez-faire style of leadership, provided the project team members all possess self-motivation and competence. Laura and Thomas both prefer to lead in order to be

Table 4. Leadership style preferences for superiors and colleagues

	Style Preference for Superiors	Style Preference for Colleagues
Martha	Coach	Friendly, approachable, committed to the work, willing to share their life outside of work
Randall	Coach	Concerned for the people they work with as well as for the outcomes of the project
Thomas	Servant/Laissez-faire	Democratic
Laura	Transformational	Servant leader who is collaborative and trustworthy
Hugh	Servant/Bureaucrat/Pacesetter	Trusted leader who has a mix of the Bureaucratic and Pacesetter leadership styles

able to control the situation. Thematically, the student leaders seem to prefer to lead if they are confident that the expertise of the team fits the goals of the project. In that sense they all, like Randall, do not like the risk of failure.

We then asked what kind of leader they would most prefer to have as their superior and as their colleague, the results of which are tabulated in Table 4. It is noted that the interviewees tended to use the heuristics from the "10 Common Leadership Styles" article when describing their ideal leader in a superior role, but they shifted to a more descriptive answer when asked about colleague leadership styles. Themes of friendliness, trustworthiness, and commitment to the success of the project arose. Laura, for example, noted that she is more open to receiving criticism from people who know her personally, whose relationship with her is deeper than just ensuring that the project gets completed successfully.

Interestingly, student values of their own leadership and of what they value in other leaders varied substantially. For example, Martha remarked, "The kind of leader that I would like is the kind of leader that I try to be when I am leading, and it must be someone who is really good at communication." while Hugh stated, "What I care most is are they competent? The actual style itself matters less to me that the result."

Finally, we wrapped the interview with a quick question to solicit feedback about the leadership training in our curriculum. Admittedly, there is no specific leadership training. All of the respondents stated that the many group design projects from the freshman through senior years served as the only form of leadership training due to the opportunities to solve problems and develop prototypes in a social context. Unlike the others, Laura actually earned a Leadership Minor that is offered by one of the agriculture programs on campus, so she took the opportunity to suggest some features of that curriculum for ours to adopt.

Conclusions

Preliminary results suggest student leaders of successful teams tend to gravitate toward Servant leadership style, a result that seems to corroborate the observations of shared leadership by Novoselich and Knight (2018) [18]. This tendency seems to be driven by a sense of humility and equality with one's teammates. Because effective leadership begins with earning the respect of one's teammates, to earn the respect of them requires that the leader demonstrate commitment and effort to the project on which the team is working, leading them to adopt a lead-by-example approach that models a healthy work ethic.

Future Work

Future work will expand our pilot to a larger set of capstone design alumni from the same mechanical engineering department before expanding the data collection to all four years in the same department, beginning with the 100-level introductory design course. This longitudinal study will follow students from their beginning engineering leadership through capstone. We may be interested in using methods like those of Özgen, et al., who measured leadership effectiveness via a 360-degree assessment, interview both the leaders and the followers [19]. Additionally, due to the fact that the college years represent such a formative period in the development of future engineers, the team may conduct a tracking study of students as they develop as leaders from entry to college through graduation. Ultimately, we hope to use our findings to inform the development of leadership education modules that can be deployed in design curricula.

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Appendix: Interview protocols for student leaders

What formative experiences in your life do you consider most important in your development as a leader?

> (If they struggle to identify any, suggest experiences in sports teams, school clubs, coursework, religious organizations, home/family environment to jog their thought process.)

What was a meaningful activity that helped you to develop your skills as a leader during your time as a student?

> Tell me about an experience at UIUC that led to a successful engineering project experience.

What was an experience that you had as a student where poor leadership resulted in a bad or negative experience?

> Tell me about an experience at UIUC that led to a disappointing engineering project experience.

How would you describe your leadership style when working in engineering project teams as a student?

> Indeed 10 leadership styles: coach, visionary, servant, autocratic, hands-off (Laissez-faire), democratic, pacesetter, transformational, transactional, bureaucratic
>
> If time allows, ask if they identify with the DISC leadership styles: Dominance, Influence, Steadiness, Conscientiousness

What do you prefer: leading or following (see CATME likert-like scale)

Describe the kind of leader you most prefer to have as your superior? Why?

Describe the kind of leader you most prefer to have as your colleague? Why?

What are some strengths and deficiencies that you perceive in leadership development in the curriculum?