Engineering Leadership Development using an Interdisciplinary Competition-based Approach

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Abstract

Use of experiential learning has been demonstrated to be an effective tool for engineering leadership development. However, experiential learning involving the integration of disciplines outside of engineering, specifically leadership development experiences including business majors, seems to be an untapped area. This educational gap could be problematic, as an abundance of anecdotal evidence, documented by Rogers and Freuler, and calls by professional engineering organizations, including ASEE and NAE, suggesting that engineers must learn to work with accounting, marketing, communications, and other functional groups within the business structure to attain project success in the "real world."

In response to calls from our alumni advisory board for a leadership experience integrating business and engineering disciplines, a leadership development competition was designed using sustainability as the theme. Students developing leadership skills from both engineering and business were organized into teams to identify and solve a sustainability problem. Each student was not only focused on the overall competition, but also in defining their roles and leadership opportunities. Both teams and individual students had periodic metrics to report, as well as detail their plans for influencing stakeholders or teammates in specific action areas. While the competition was finalized by selecting the best project based on team "pitch," the leadership development continued with the students developing a leadership plan to launch their projects.

This paper will present the details of the pedagogical approach, with a step-by-step explanation of the structure of a "capstone" leadership development project incorporating team dynamics, structured deliverables, and techniques of engagement of the business and engineering majors in the context of a competitive sustainability challenge program. This paper will present collected assessment data, an analysis of the data, and provide recommendations for improvement.

Introduction

The work described in this paper focuses on a capstone engineering leadership experience for engineering students participating in a single-semester class on leadership development. All selected students in the class have some level of previous leadership experiences. Therefore, while the information presented here may be useful to the general community of engineering leadership development, it may not directly apply to all curricular circumstances. Having stated that, there are many aspects of the presented pedagogy that may be translatable, because they are based in similar approaches taken in other leadership development programs.

Driven by studies and calls that engineers must learn to work with other disciplines within a business structure to attain project success in the "real world," the capstone leadership experience described in [4] was used as the overarching tie in the leadership "S-triangle" pedagogy, which is illustrated in Figure 1. This approach links understanding of self, style, and situation through hands-on application of leadership experience and discussions with

experienced leaders, as well as exploration of focused activities to help students reflect on leadership roles and characteristics.

This work is the third evolution of an assessable "hands-on" capstone project for the semester-long leadership development course. The original effort was added to the curricula as a separate and late-in-class activity to reinforce learning through application. [5] This effort was the first done by the author to bring hands-on leadership experience to the students in an assessable environment. The second evolution of the capstone leadership experience was as an individual effort integrated into the S-triangle pedagogy throughout the entire semester as described in [4].

This third-evolution capstone program relies on individual milestones for assessing development, but does so in a team environment consisting of engineering and business students solving a problem they have identified in the community or campus related to a sustainability issue. This paper will discuss the methodology of implementation, results of both external stakeholder assessments and student learning and satisfaction surveys, and present conclusions and recommendations going forward.

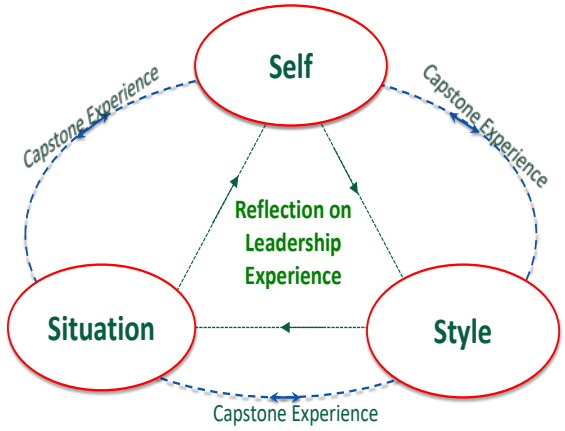

Figure 1. S-Triangle with capstone project

Methodology

While it is highly recommended that the reader review the paper discussing the general pedagogy of the S-triangle with a capstone project approach to leadership development [4], a brief summary is presented here. The S-triangle consists of three legs (understand **s**elf, leadership **s**tyles and characteristics, and **s**ituational dependence on application of leadership principles), with each leg linked through reflection on personal leadership experience. Students engage in learning activities to understand the three legs of the S-triangle with reflection on previous experiences being used as the first level of integration for the legs.

The learning activities include several readings with classroom discussions. Goleman's styles [6] of commanding/coercive, visionary/authoritative, pacesetting, democratic, affiliative, and coaching are reviewed and compared. Characteristics, such as integrity, vision, passion, emotional intelligence, storytelling, persistence, risk-taking, and competence are discussed and analyzed. Students compare and contrast roles of successful leaders including connecting people to people, connecting people to the vision for the organization, changing or setting the culture, making decisions, motivating and affirming followers, listening, and asking questions. A variety of literature is used for the readings and a number of TED talks have also been instructive. [7-12]

Several personality inventories are used to help the students understand self, include the Myers-Briggs Temperament Indicator, True Colors personality spectrum, and the Bolton personality test [13-15]. One Piece of Paper [16] maxims are developed and a personal five-minute video autobiography development exercise are used to help the students articulate their core beliefs

related to leadership. And teambuilding exercises are also used to help the students understand how they relate to others, such as a low-ropes challenge course and team-based case studies.

Interviews of alumni leaders by the students demonstrate the importance of situation using "real life" leadership cases. While significant effort is required to prepare the students to conduct effective interviews, the interviews of successful alumni leaders provide the students with personal leadership case studies. These interviews also provide a chance to integrate skills learned in the other legs and speculate on how application of those skills and ideas could have influenced the "leadership outcome" of the case situation.

Students are also tasked with identifying a leader of interest, describing why that leader has value to them (personally), and then exploring their leadership through their historical actions. This analysis provides a greater understanding the role of situation in leadership. The students are asked to identify the leader's key styles and characteristics within the context of the leadership event, describing how the situation was influenced by the leader.

The final part of the original S-triangle pedagogy is reflection of leadership events experienced by the students at each segment of the triangle as it was developed. Students were instructed on how to identify key leadership concepts learned in the leadership study and then to reflect on a leadership memory they held that was related to the concept. The student then identifies how their experience was either enhanced by correct application of the concept or could have been addressed differently using their new-found knowledge.

Capstone Leadership Project Structure

Spurred by a generous donation and personal drive by an alumnus, the structure of the capstone leadership project was redesigned around a team-based competition. The initial goal was to foster engagement between the leadership development students in the College of Engineering and leadership students in the College of Business. The competition was added as a mechanism for this engagement to incentive the teams in a "real-world" framework with the potential reward being a tangible result visible on their campus or in their community that they could point to as having accomplished. To that end, the entire framework was owned by the student teams. The teams were tasked with identifying and selecting a sustainability problem on campus or in the nearby community that they would address and to solve the problem with the final deliverable being a team presentation in a business "pitch" format to a board of experts from the associated colleges, the university's Facilities Management group, and the alumni donor.

While the team-base competition framework provided potentially exciting opportunities for student learning and incentives for action beyond that of a classroom grade, it created challenges for execution and assessment of learning for the instructors. For example, the team-based approach, which fostered interdisciplinary (business and engineering) exchanges also made it difficult to assess the leadership roles and development of the individual student. Further, the requirement that the students identify and select a sustainability-related problem that could actually be addressed and accomplished by working with a viable stakeholder, such as Facilities Management, introduced ambiguities and collaborative difficulties. Not only did the teammates have reach a consensus among the four members on which problem they would ultimately

address, they had to quantify viability by working with an external stakeholder to assess if resources would be available should the project win the competition and move forward.

Procedure

The launch of the capstone leadership experience was a kickoff meeting in which the two groups of collaborating students met and were given the framework of the competition. The students were told they would be competing (with prizes) by working in mixed teams to identify and propose a solution for a problem related to energy, sustainability, or infrastructure that they would identify on campus or in the local community with the following caveats:

- The problem must be solvable within reason. For example, nothing requiring more funds than are likely to be acquired, no need for action by the Trustees (unless they can show they will get it), no need for legislation or similar action.
- The problem selected must require a team effort for solution.
- The solution must be "pitched" to a board of experts for further consideration.

Team composition was selected by the program directors of the two leadership development organizations. The selection was done by using the known strengths and weaknesses of the students in an iterative process. Accounting for conflicts in schedule and other factors also played a role. Once the teams were formed, team-building exercises were used to aid in dealing with conflicts and different viewpoints to enhance the experience. However, it should be noted that the students had to work through their team's problems and the program directors did not intervene except to aid in student communication.

After ten days, the teams presented their potential sustainability problems in short (1-2 minute) discussions. It is interesting to note that even though most teams had multiple ideas, they easily determined their consensus problem of interest without external intervention. As a result, no external (to the team) decision-makers had to intervene.

While teams were connected to some potential stakeholders related to their problems, most teams were tasked with identifying the key stakeholders that they would have to influence for a successful resolution to their stated problem. This primarily consisted of finding constituencies that could either authorize or fund their suggested solutions. This was made more urgent by a mid-project milestone of presenting a two-year return-on-investment analysis for their solution.

The teams were presented with a rubric for the "pitches" that were to be the basis for selection of the winners of the competition. Scoring percentages and categories included 25% for "Validity and relevance of claimed benefits," 25% for "Implementation practicality and risk," 20% for "Rigor and believability of the ROI analysis," 15% for "Adequately addressing potential concerns of all stakeholders affected, getting "buy-in", and professionalism in dealing with experts," and 15% for "Clarity and completeness of presentation."

To assist the teams in meeting their deliverables, instructions were provided by faculty from the College of Business on ROI analysis, pitch content, and presentation delivery style. This was augmented by instruction from engineering faculty on energy analysis, cost-benefit ratio

analysis, and logistics. These lectures were delivered to the teams as they developed their projects and were aligned with the schedule delivery of project milestone.

By week seven, the teams created videos of their draft pitches which were analyzed by the program directors. Each team was provided written critiques. In addition, each team was given the opportunity to get oral feedback from the competition sponsor.

The actual pitch competition was held as a formal event with the judging panel present for the entire day, which was needed to evaluate six projects. Teams were given 25 minutes to pitch their solutions and financial analysis with a question and answer period included. Teams were given written and oral critiques of their pitches, with emphasis on potential improvements. An awards ceremony was held in the evening of the competition to announce winners.

Once the competition portion of the leadership development effort ended, the students were tasked with follow-up efforts to emphasize individual development. Specifically, they were tasked with four deliverables that transitioned the team effort into individual concerns.

- Describe your revised work scope. Explain your vision for changing your project and why you think it is appropriate to undertake, especially describing what information you have gathered that would support your decision(s).
- Describe which task(s) you will lead in implementing your project. Provide enough detail to explain how you will address additional stakeholders that you need to influence, obtain resources you need to acquire, and overcome potential barriers.
- Present a timeline for implementation for your individual work (working with your teammates) broken down by tasks and expected times to implement.
- Identify and contact your key stakeholder related to this change to get their feedback on how to implement your change. You must describe their feedback and your interpretation of their implementation guidance.

Results

Six projects were developed around local sustainability problems, including reducing water consumption in high traffic building restrooms using low flow aerators, installing solar panels on covered parking, replacing exterior lighting around the basketball arena with high efficiency LEDs, installing sensors to control building lighting in off-peak hours, reducing automobile traffic on campus by implementing a bike rental program, installing solar-powered lighting on the bicycle path the follows the local river through campus. Of the six projects, one was selected as definitely moving forward. This project focused on replacing outdoor lighting around the basketball arena with LED lights. Two others projects remained in consideration at the time of writing this paper.

The team with the “winning” pitch was able to convince the judges that their solution was not only the best return on investment, but the one most grounded in tangible analysis. Using data collected on actual lumens produced, vendor costs, installation costs, and projected electrical prices, they generated a return on investment analysis showing that the $36,250 investment would be recovered in less than three years with an additional annual savings of $2,884 in

maintenance costs. They also demonstrated that the new lights would save 82,000 pounds of CO_2 emissions per year.

Stakeholder Feedback

Generally, the key external stakeholders of this project were notably pleased with the results of the competition. Various quotes, provided to local media, included [17]

- *Dan Squiller, the alumnus who helped initiate and fund the program stated "I knew that something good was happening when we started to have initial coaching sessions with the teams. Diversity, which can be uncomfortable to some, was yielding great ideas and bringing team members together."*
- *Stephen Wood, Eco-Challenge judge and Ohio University's associate vice president of Facilities Management and Safety, served as an expert through asking probing questions about the practicality of the concepts. He also discovered new ideas that could further OHIO's current sustainability plan, which focuses on supporting carbon footprint reduction, energy conservation and renewable resources. "I think that the students' ideas contributed to multiple goals in our sustainability plan and there are certainly three ideas that we would like to follow-up on and see if we can get executed here at OHIO," said Wood. "The Eco Challenge provides a win, win situation. It's a win for the students and my staff as an opportunity to get some fresh ideas on improvements for our campus."*
- *"They faced some challenges along the way, but the students discovered how they could combine their technical and business backgrounds in order to create a sound proposal with return on investment," said Tim Reynolds, director of the Ohio University College of Business Select Leader program.*
- *"The challenge helped us all to utilize teamwork and leadership skills in a new way. Partnering the College of Engineering with the College of Business required us to work with others with a different background, mindset and problem-solving approach than ourselves," Melinda Nelson, said in an email. "It required us to trust each other with various tasks in the projects and use our skills to bring our project together as a whole."*

Student Surveys

Two surveys were done to quantify student outcomes for the capstone leadership project. One survey was done immediately following the "pitch" competition and the other was given as an end of the class exit surveys of the students. Three key questions, evaluated using a Likert scale of 1-5 (1=none at all to 5=extreme), were statistically compared to previous year's results. The results are shown in Table 1 and the questions were

a. "Rate your overall satisfaction with the leadership development experience"
b. "Rate the level of challenge offered by your leadership development experience"
c. "Rate your increased understanding of leadership concepts"

The results, shown in Table 1, were compared to the previous year's capstone project effort, which was the second year for an integrated capstone learning experience. None of the results for the three questions showed a statistically different change from the previous year, where the

leadership development effort was an individually focused project. Some improvement was made in terms of satisfaction and challenge, but there was a marked decrease in the estimation of the overall understanding of leadership concepts.

Table 1. Student Survey Results

	Question (a)	Question (b)	Question (c)
$\bar{x}_{\text{current (1)}}$	4.75	4.33	4.08
$\bar{x}_{\text{previous (2)}}$	4.61	4.02	4.47
s_1	0.45	0.65	0.79
s_2	0.47	0.88	0.61
n_1	13	13	13
n_2	18	18	18
T	0.84	1.13	-1.49
P (one tail)	0.205	0.134	0.076

Conclusions and Future Direction

While there is only a small sampling of data to back this, it seems preliminary results for the integration of a challenged-based team-focused capstone leadership project to the teaching of the S-triangle for leadership development has had some success. Students have indicated they appreciated the tangible connection of leadership concepts to practice through the competition. Yet, the results also indicated that there was no real improvement compared to the individual capstone projects done in the prior year. With that in mind, several issues could be improved.

Specifically, there are few articulated expectations for cadre behavior other than to support each other and provide thoughtful feedback to each other. While this has worked in the limited context of this class (so far), clearer definition of roles and responsibilities should be developed. Further, the time demands for successful implementation of the leadership project will require scaling back of other class assignments for the students. However, it may be possible to integrate some assignments with the project reports and reflections. Additional assessment to understand the impact of the interdisciplinary nature of the project is required. Additional assessment and subsequent refining of the overall course based on student and stakeholder feedback will be necessary for continued improvement. This will be easier now that the general structure has been established. Finally, support for this project has been renewed and these recommendations will begin to be implemented in the upcoming year.

Acknowledgments

This work would not have been possible without the efforts of several individuals, including Steve Wood, Associate V.P. of Facilities at Ohio University, Mr. Tim Reynolds, Director of the Select Leaders program in the College of Business at Ohio University, and especially Mr. Dan Squiller, Distinguished Graduate of the Russ College. Dan’s vision, drive, and resources were instrumental in the launch and execution of the EcoChallenge program.

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