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The Effect of Leadership Styles on Team Dynamics and Success in Senior Design Capstone Teams

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Introduction

One of the primary objectives of engineering education worldwide is to train new engineers with the technical and professional skills necessary to address current industry challenges. To this end, many engineering degree programs include a mandatory Capstone Design course, typically taken during a student's final year. In the University of Georgia's College of Engineering (CENGR), the Capstone course spans two consecutive semesters. The course is project-based, introducing students to a real-world problem proposed by a Capstone partner who acts as the "client" for the project. Project proposers often include local, regional, or global companies with which CENGR has established partnerships; however, projects can also originate from CENGR faculty (focused on research), national competitions, or entrepreneurial ventures. After confirming project offerings, students are assigned to teams and tasked with delivering a verified and validated solution to the partner's problem over two semesters. This duration allows students to engage thoroughly with the engineering design process, adhering to predefined project milestones and course objectives. Ultimately, at the close of the Capstone course, students are required to present a design solution to their client that meets expectations.

Literature suggests that project success could depend on many factors which also contribute to team members' overall satisfaction. These factors include balancing team members' project interests, their desire to work with specific peers with varied personalities, and with consideration to institutional project priority [1-3]. Balancing all these factors during team formation is time-consuming for course instructors, but doing so is crucial for teams' success in completing projects. Team formation in the Capstone course is a key activity undertaken by all course instructors in cooperation, as it plays a vital role in the project's overall success (i.e., did the project outcome meet the client's objectives?) and in student satisfaction with the Capstone experience. Instructors use different techniques to develop teams in their Capstone sections, especially if their students need special abilities to solve advanced and technological problems like those in Capstone design projects. The most common approaches to team formation usually include student self-selection [1,4], self-reported interest [3], skillset [5], academic performance [5], and personality characteristics [6]. However, team formation and project assignation are complicated tasks, and some instructors prefer to use specialized software to assign their students to project teams using genetic algorithms that consider student preferences, team size, and academic performance, aiming to facilitate better team performance and work environment [8-9]. Such an example is CATME Team-Maker, which assigns students to teams based on instructor questions, scheduling, and diversity [10]. Instructors working to assign Capstone projects discussed in this paper have not used commercially available software to automate bidding. However, we used an internally developed automated bidding process [9] that takes user inputs and other predictor metrics to match students to projects that maximize the potential to success. Literature suggests that using specialized software to formulate Capstone teams considering students' preferences could improve teams' "happiness," defined as "how close students get to their first choice" project in situations where students have the opportunity to rate or rank projects. The ability to rate or rank projects and be assigned to a desired project could ultimately positively affect project success and how team members work together [7,11]. We hypothesize that teams' performance in Capstone projects is also related to their members' leadership styles, i.e., teams with a diversity of leadership traits are more likely to find success than teams with only one or few personality types among their members [8].

It is suggested that when a diverse combination of leadership styles is represented on a Capstone design team, a project is more likely to succeed in most activities, given students' breadth of skills [12]. Assessed using a simple test, the following leadership styles are defined:

1. *Technical Leadership*: This style emphasizes expertise and technical skills. Leaders with a technical style are often seen as knowledgeable and competent, which can inspire confidence in team members. However, they may sometimes focus too much on technical details at the expense of broader team dynamics[12].
2. *Sympathetic Leadership*: Leaders who adopt a sympathetic style prioritize empathy and understanding. They are attuned to their team members' emotional and personal needs, which can foster a supportive and collaborative environment. This style is particularly effective in maintaining team morale and cohesion[14].
3. *Bold Leadership*: Bold leaders are characterized by their willingness to take risks and decisive actions. This style can drive innovation and rapid progress but may also lead to conflicts if not balanced with consideration for team input and consensus[15].
4. *Expressive Leadership*: Expressive leaders are communicative and charismatic. They excel in motivating and inspiring their teams through clear and enthusiastic communication. This style can enhance team engagement and alignment with the project.

Purpose

This manuscript aims to expand current leadership literature by analyzing teams' performance in the Capstone course and comparing the performance of teams with members with different leadership styles and teams with similar leadership styles by answering the following research questions.

R.Q. 1 What is the difference between the performance of teams comprised of members with different leadership styles and those with similar leadership styles solving capstone projects?

R.Q. 2 What difference exist, if any, between the capstone project ratings assigned by academic instructors and industry-related judges depending on the team members' leadership styles?

Teams comprised of members with diverse leadership styles are represented could be more likely to tackle issues using the abilities innate to a particular leadership style, including building effective relationships among project participants(sympathetic, designated "circle"), innovating and keeping the big picture in focus (expressive, designated "z"), organizing and getting things done (technical, designated "square"), and striving to reach goals (bold, designated "triangle") [12]

Methods

During fall 2023 and spring 2024 semesters, four instructors co-taught the Agricultural Engineering (AENG) and Mechanical Engineering (MCHE) Capstone design courses, each leading a course section comprised of approximately 50 students and roughly 13 projects at CENGR, resulting in 51 total teams for AENG/MCHE with 3-5 students each. Projects were not duplicated, i.e., each project is unique and has its own client. Teams were formed by the Capstone instructors by weighing several main input factors, including: 1) students' project preference; 2) the major/discipline requirements (defined by project sponsor and instructors), and; 3) students' leadership style. Concurrent with weighing these inputs to project assignment, instructors also sought to limit team size from 3-5 students. Team size was also used as one of the input metrics in this study, i.e., does team size affect project success?

Students' leadership styles were an important variable in team formation, given the aim of diversifying leadership styles within teams to promote effective collaboration and team management. A previous paper [9] describes the author's project assigning process in which leadership style, student preference, student skills, and project priority were used to optimize project assignments. Students' leadership styles, the focus of this paper, were assessed in an activity undertaken as part of the College of Engineering's Emerging Engineering Leaders Development (EELD) program [12] developed in conjunction with the Fanning Institute for Leadership Development at the University of Georgia.

Another input metric analyzed in this study was project preference. Students' project preferences were gathered using a bidding platform where students were able to view project information and bid on projects. The bidding function is included in a web-based project management software application where teams can also communicate with clients, course instructors, teaching assistants, and each other, log hours, track budgets, share files, and submit project deliverables. After evaluating the projects available, students rank their top ten project choices to establish what projects are more attractive for them to work on for the following year.

Upon completing the leadership style EELD module, students self-report their leadership style during along with their project bids using the project bidding platform [12]. Leadership styles were assessed as part of the EELD module, "Exploring Leadership Styles," which helps students understand leadership styles by teaching them to 1) identify different styles, 2) recognize expressive ways to work across leadership styles, and 3) create leadership goals. After completing the leadership modules, students selected their leadership style, from technical, sympathetic, bold, or expressive, according to their self-perception. The leadership style classifications and subsequent characteristics are illustrated in Figure 1 in four sectors defined along a horizontal dominance axis and a vertical responsiveness axis. It is worth noting that no one completely falls into one leadership style, but only one style was assigned to each student that best represents their leadership. The project assignment process used only the student's reported leadership style metric.. It is also worth noting that students are selecting their leadership style based on their perceptions. In subsequent data collection and analysis, the authors plan to address the question as to whether students self-identify consistently across the span of the project.

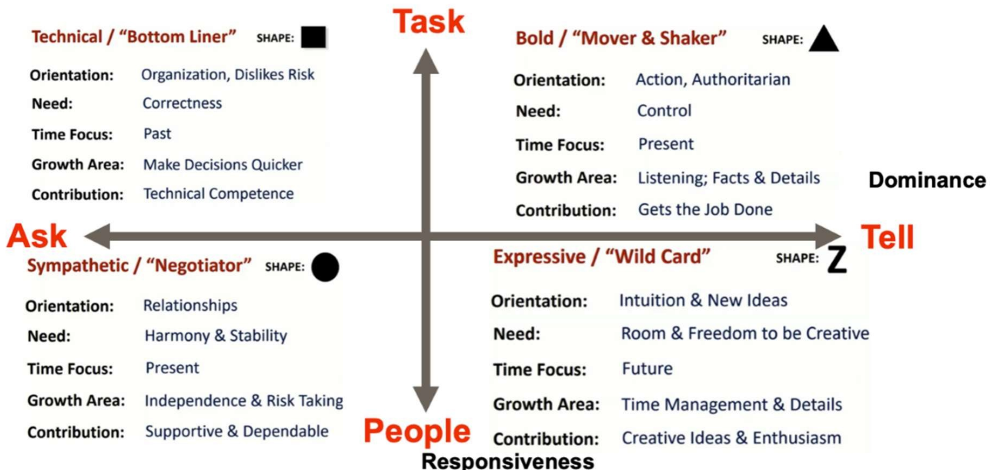

Figure 1. Leadership style characteristics [12].

Table 1. Leadership style values used for mapping leadership distribution.

Leadership	X axis	Y axis
Technical	-1	+1
Bold	+1	+1
Sympathetic	-1	-1
Expressive	+1	-1

Based on the sectors shown in Figure 1, we assigned (x,y) "coordinate" values to each leadership style, as noted in Table 1. The coordinate values for each team member were then summed to obtain an overall value. To account for team size differences, the score was divided by the number of team members, resulting in a normalized value in the range of –1 to +1 in each axis. The normalized values for all teams were plotted on a graph, as shown in Figure 2. These values represent the overall leadership distribution for each team. Nine sectors were designated in the plot (see Figure 2), defining the sector with a balanced leadership style when $-0.5 < x < 0.5$ and $-0.5 < y < 0.5$ (sector 5) and considering the other eight sectors as teams with members with similar leadership styles. Applying this leadership style classification, 25 teams were clustered in sector 5 (teams with members with different leadership styles) and 26 in the other eight sectors (with teams lacking fully diverse leadership styles).

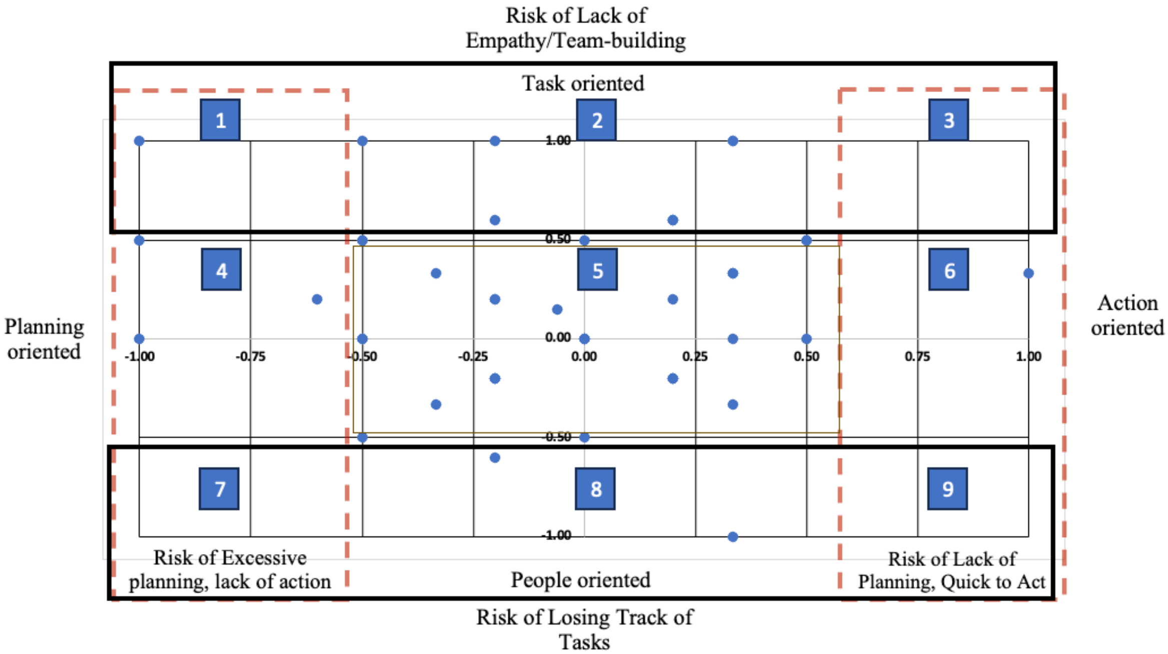

Figure 2. Plot of all teams' average leadership styles. Note that dots can represent multiple teams. The number of teams per sector was as follows: 5, 8, 2, 5, 25, 2, 1, 3, respectively, from sectors 1 through 8, and sector 9 had no teams.

During the annual Capstone Design Showcase, team performance was evaluated by the Capstone instructor and separately by a team of judges with industry experience. ABET Outcomes (1-7) were assessed from 0 to 4. These two ratings were unrelated and were assigned without communication between the instructors and the judges. Two to three judges rated each project's success individually meeting all seven ABET outcomes during 8-minute presentations. The metrics used for the current analysis are the average per Outcome score and a composite rating taken as the average of the seven individual ABET outcome ratings. . Instructors considered each project based on how well teams performed relative to the seven ABET Outcomes. Another metric to consider is how well teams performed in the two-semester course based on evaluations of deliverables and milestones (reports, presentations, etc.). A subsequent paper will focus on this metric.

Quantitative analysis

A two-tail student's *t*-tests [16] were conducted to analyze possible differences between the performance of the 25 teams with members with different leadership styles (sector 5) and the 26 teams with members with similar leadership styles (other eight sectors). The first *t*-test analyzed the difference between the instructor ratings, while the second *t*-test compared the judge ratings. To further investigate possible differences between the performance of teams with members with different leadership styles, a multivariate analysis of variance (MANOVA) was conducted. This test compared the difference between the instructor ratings, the judge ratings, and the bid average of teams classified in the nine different leadership sectors [17-18]. This MANOVA was used to mitigate inflated results that may lead to type I error [17] due to performing several individual *t*-tests.

Additionally, two regression models [19] were used to determine which variables significantly affected teams' performance, aiming to determine if the teams' leadership styles correlated to their project performance. Logistic binomial regression was conducted by clustering the 25 teams with members with diverse leadership styles (sector 5) in one group and the 26 teams with members with similar leadership styles in another group, using these two groups as the dichotomous variable [20]. Ten independent variables were considered for the model: ABET Outcomes 1 to 7 (seven variables), instructor ratings, team size, and bid average. The correlation of these ten independent variables with teams' leadership styles was analyzed to understand better the influence of leadership style diversity on a teams' success. Here, we hoped to address R.Q.1. by determining how leadership styles affected or were affected by various inputs. Additionally for this test to address R.Q.2., a simple linear regression model was conducted to determine the correlation between the instructor's ratings and the judge's ratings to analyze possible differences between the two sets of ratings. All inferential statistics and models were created using the statistics software R [21].

Results and Discussion

The judge's average ratings ranged from 1.28 to 3.7, with a mean of 2.88 and a standard deviation of 0.62. The instructor ratings (Fig. 4) were higher than the judge ratings, ranging from 1.0 to 4.0, with a mean of 3.19 and a standard deviation of 0.70. The judge ratings were calculated using the average of the seven ABET outcomes used to rate each team's Design Showcase performance (See Figure 3).

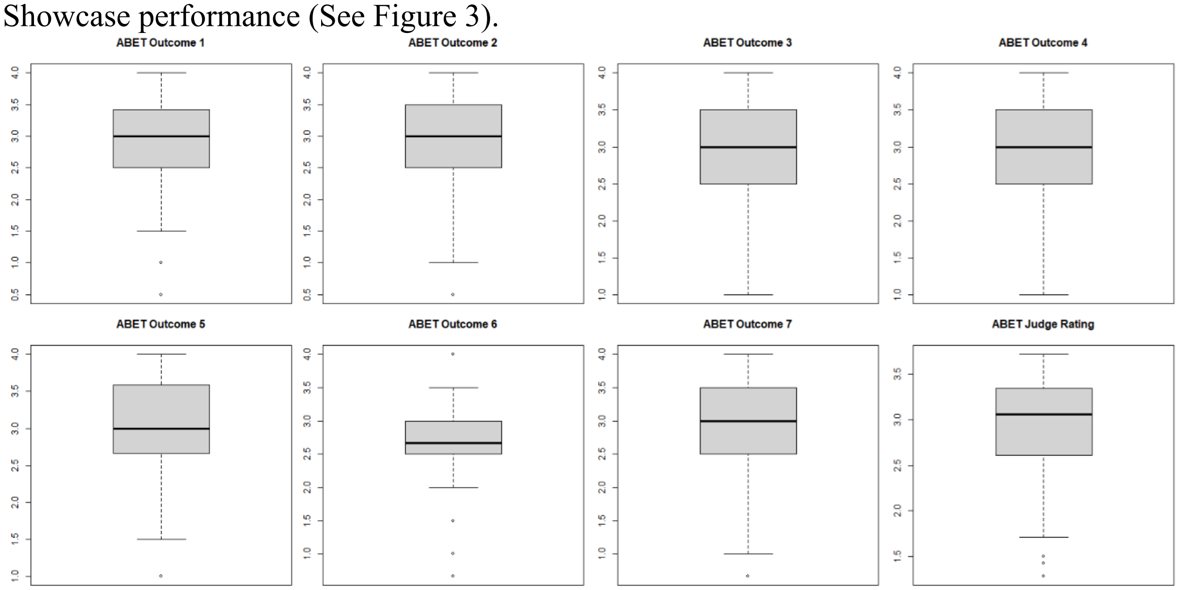

Figure 3. Judge ratings of all seven ABET outcomes and its average rating.

Figure 4 compares judges' and instructors' ratings. The range of judges was wider, with teams' performance as low as one.

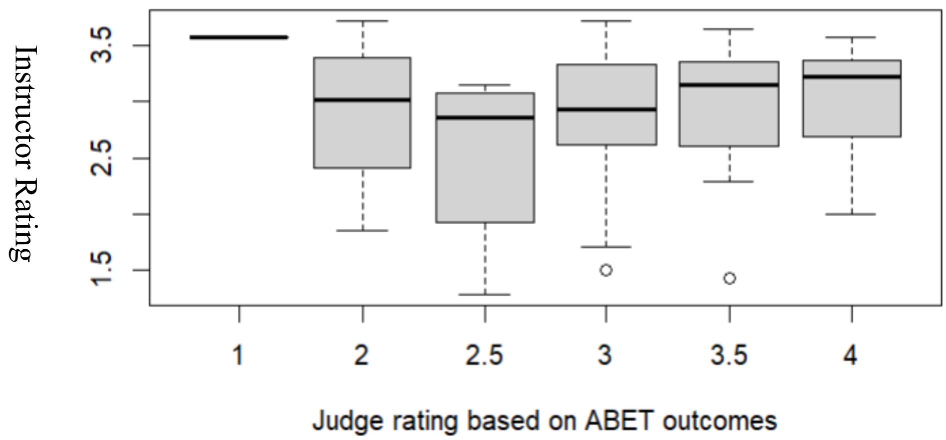

Figure 4. Instructors' ratings are classified according to the judge's ratings

The judges' and instructors' ratings were classified by leadership style sectors, aiming to compare teams' performance based on their teammates' diversity of leadership styles. Figures 5 and 6 illustrate the ratings.

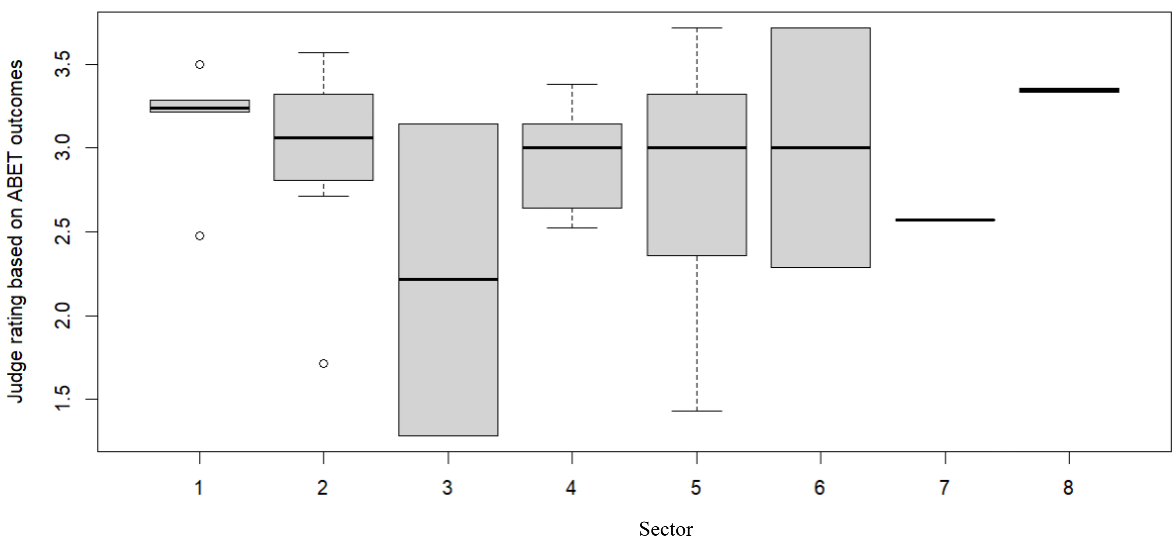

Figure 5. Judges' ratings are classified by leadership sector

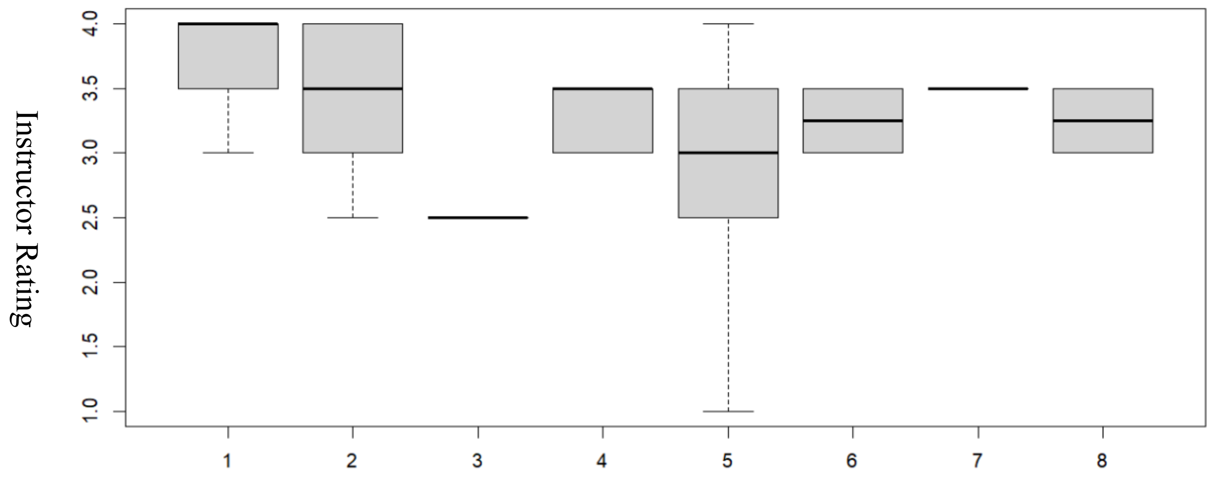

Figure 6. Instructors' ratings are classified by leadership sector

The *t*-tests showed no significant difference between the performance of teams with members with different leadership styles (sector 5) versus those with similar leadership styles. The judges rated the teams with members with varying leadership styles with a mean of 2.81, while the teams with similar leadership styles had a mean of 2.95. On the other hand, the instructor's mean rating for the teams with members with different leadership styles was 3.0, while the mean rating for the teams with members with similar leadership styles was 3.36. Although this difference was not significant, both the judges and the instructors' ratings were slightly higher for the teams formed with members with similar leadership styles.

Table 2. MANOVA results comparing judge ratings and instructor ratings by sector

Independent variables	Df	Mean Sq	F	*p*-Value
Judge ratings	49	0.285	0.676	Not Sig.
Instructor ratings	49	0.529	1.083	Not Sig.
Teams' bid average	49	5.191	2.939	0.014*

Df = Degrees of freedom; * Significant with α=0.05

The MANOVA results showed that the performance of the teams classified in different leadership sectors was not significantly different, with similar judge and instructor ratings for teams in different leadership sectors.

The simple linear regression model analyzing the relationship between the judge ratings and the instructor ratings determined that these two variables are not correlated. This suggests that instructors rate projects differently than Capstone Showcase judges (see Figure 7). This is likely because instructors have two semesters during which to judge project success, while Showcase judges have only eight minutes. However, more studies are needed to assess this question. Here, the goal is to assess whether the team metrics of leadership style, team size, and bid average affect success.

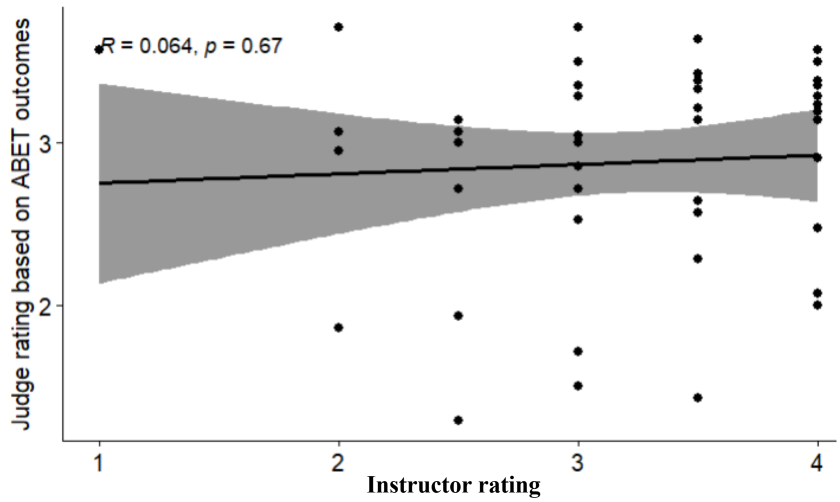

Figure 7. Correlation between instructor ratings and judge ratings.

Table 3. Logistic binomial regression results with teams in the central sector (5) and teams in the other eight sectors as the dichotomous variable.

Independent variables	B	SE	*p*-Value	Odds ratio
ABET outcome 1	-3.341	1.394	0.016*	0.03
ABET outcome 2	0.256	1.183	NS	1.29
ABET outcome 3	-0.096	1.033	NS	0.90
ABET outcome 4	-0.134	0.797	NS	0.87
ABET outcome 5	0.475	0.827	NS	1.60
ABET outcome 6	0.242	0.881	NS	1.27
ABET outcome 7	0.276	1.069	NS	1.31
Instructor ratings	-1.752	0.826	0.033*	0.17
Team size	0.640	0.568	NS	1.89
Bid average	-0.517	0.344	NS	0.59

NS = Not Significant; * Significant

The binomial logistic regression model showed that having a high rate in the ABET outcome 1 was significantly correlated with teams whose members reported diverse leadership styles, sector 5 (see Table 3 and Figure 7). These results suggest that diverse teams had an increased perception from judges on the team's ability to identify, formulate, and solve complex problems and their ability to apply principles of engineering, science, and mathematics (ABET 1). This finding supports the literature [7] that proposed that diverse points of view will enhance the problem-solving capacity of the team.

The quantitative analysis showed no significant differences between the teams' performance in the nine leadership styles sectors (see Table 2). The average judge and instructor ratings, separated by ABET outcomes, were similar for project teams formed with diverse leadership styles. Although teams with members reporting similar leadership styles among members were rated slightly higher than teams with members with differing leadership styles, the *t*-test showed that the difference between these teams' perceived performance was not significant. These results suggest that team members' leadership styles do not predict perceived high performance in this two-semester-long Capstone project, given the output of externally judged Showcase scores and course instructors' ABET ratings (except for outcome 1). It is possible that having to adapt to different leadership styles in these engineering team projects presents an additional challenge to engineering students, making them spend time determining roles and adjusting to each team member's way of planning and doing things. Subsequent work is focused on determining whether performance varies from semester one to semester two of Capstone design for diverse vs non-diverse teams.

On the other hand, having a similar leadership style may help team members create bonds and a good work environment in the short term, facilitating task assignments and helping the team start working without spending time adapting to other leadership styles. Figure 6 shows that while not statistically significant, instructors rated teams in sectors 1 and 2 higher than those in different sectors, which aligned with a team make-up of more technically competent students who are task-oriented and plan well. From the judges' perspective, Figure 5 shows that groups in sector 3 that are quick to act and task-oriented were hit-and-miss groups where either they were rated above average among the cohort or low rated. Potentially, these groups suffered from a lack of planning and understanding of customer requirements. Preliminary data from course grading reflects this sentiment. Again, it is noted that these practical observations are not supported by the statistical analysis of the present data but certainly supports the need for further study.

Although teams' performance was typically rated high by the instructors and the judges, the instructor ratings were consistently higher than the judges' (see Figure 4). This certainly is, to some extent, the result of the limited time that judges have to review projects, as it consists of an 8-minute presentation at the Capstone Design Showcase. In contrast, instructors have had two entire semesters to reflect upon teams' success and accomplishments. While instructors also rated down to 1, most of the projects were rated above 3.0, suggesting that based on instructors' perceptions, most of the teams accomplished their project goals. The gap identified can potentially show that students cannot communicate the breadth of content effectively in front of judges, given the time constraints. Alternatively, this gap could represent that the academic expectations do not align with what the professional industry is seeking. Thus, it highlights the need for Capstone instructors to continue working with relevant industries to adapt the course to better align with the real world. Misalignment between college-level design and industry-level design could hinder engineering students' development and future adaptation to their professional lives, creating a misunderstanding of the industry's needs and generating difficulties in designing and developing technological solutions to solve the current industry's needs efficiently [22]. Aligning Capstone design with industry needs is the overarching goal of the College of Engineering's Capstone design program.

Ongoing and subsequent studies could help analyze how teams work when they are formed with members with various leadership style combinations to determine what combinations have the best chance of success. Teams lacking a balanced leadership style could struggle in some tasks; for example, do we observe teams in the 3, 6, or 9 sectors struggle to plan their project activities?

Or do we observe teams in the 1, 4, or 7 sectors hesitant to move from the project planning to the action stages? These are questions the authors hope to answer in future studies.

Conclusion

In this work, the authors sought to answer the question as to whether leadership styles represented among students on Capstone design teams significantly impact the quality of project results as assessed by external industry judges and Capstone instructors. We hypothesized that teams with diverse leadership styles would perform better at the Showcase and in the course. Both internal and external evaluators rate projects on their ability to meet ABET outcomes criteria. When analyzing for significant differences between teams in different sectors compared with the 7 ABET outcomes, only ABET outcome 1 resulted in significant differences for those teams with diverse leadership styles (sector 5). When put under the spotlight of a public showcase (external judges) or with a snapshot of a project's success (instructor ratings), differences fail to show significance across the different criteria.

The use of the leadership style matrix introduced in Figure 2 to quantify teams' leadership style combinations is a novel and useful tool to predict Capstone teams' eventual success in the course or at the Showcase in the eyes of experts and the public. Additionally, if data shows that some combinations of leadership styles are more successful, the information can be used to build better teams that can better meet the needs of clients and society. However, in the real world, our engineers will not get the liberty to choose the leadership styles of those they work with, so getting the experience in a controlled environment of Capstone design provides a useful experience that will help them negotiate the challenges of differing personalities as they move through their careers. This study raises many questions that the authors hope to address in subsequent work.

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