Relating Shared Leadership to Team Attributes

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ABET accreditation requires engineering students to demonstrate an ability to function within teams that provide leadership. Recent engineering leadership studies of capstone design teams indicate that shared leadership may relate to better capstone team effectiveness and be a more applicable model than more traditional vertical leadership models. Literature suggests that team attributes may play a role in how shared leadership develops within capstone design teams, but there is little empirical evidence to support that claim. This study examines the relationship between various team attributes and the development of shared leadership for undergraduate, mechanical engineering capstone design teams using an adaptation of the Full Range of Leadership model, specifically Transformational/Contingent Reward (TCR) leadership behaviors. Overall, this study suggests that attributes of the members who are assigned to capstone design teams may relate to the leadership experience these students have. Results indicate that a team's engineering GPA diversity may centralize and diminish the shared TCR leadership in capstone design teams. The average amount of self-reported leadership skills within the team may increase the overall amount of shared TCR leadership with teams.

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Introduction

The project-based, open-ended, and team-oriented nature of capstone design courses may cause challenges for students which may lead to waning engagement in the project[1], degrading a team's effectiveness and result in poor course outcomes. Capstone courses require more self-directed learning by students than traditional engineering courses because both students and faculty are forced to navigate the learning process together to generate a novel solution to new problems while managing the conduct of a student team. Often, faculty may not have the background or knowledge necessary to mitigate team challenges[2] or have experience addressing the design problem at hand[3]. Sustaining self-directed learning may require additional support from faculty or team advisors[4,5].

Helping shape leadership behaviors may be one way to mitigate this potential decline in team effectiveness[5]. Stagl et al.[6] summarize current work in team leadership research and find that, "the totality of research supports this assertion; team leadership is critical to achieving both affective and behaviorally based team outcomes." Empirically, the level of shared leadership in capstone design teams has been shown to predict team effectiveness in the form of extra effort and team member satisfaction (e.g., Novoselich and Knight[5]).

Capstone design team member attributes may relate to the amount of shared leadership that occurs in capstone design teams. Shared leadership is described as a continual ebb and flow of leadership emanating from multiple team members[7], consistent with ABET's student outcome 3.5 where the team itself provides leadership and creates a collaborative and inclusive environment[8]. Beyond engineering disciplines, shared conceptualizations of leadership[9] are calling to question long-held, vertical leadership models. Capstone design faculty have proposed a shared leadership model for capstone design teams, where team attributes may relate to the level of shared leadership achieved within a team[10]. Currently, however, there is no empirical evidence to support the relationship between team member attributes and the amount of shared leadership that occurs in capstone design teams.

The purpose of this quantitative study was to examine how team member attributes relate to sharing the ME Capstone version of the Full Range of Leadership Model[11] within capstone teams. The study addressed the following:

Research Question: How do team-level member attributes relate to the degree of shared leadership in undergraduate mechanical engineering capstone design teams?

Leadership Framework

The Full Range of Leadership model informs this study. This theory focuses on the transactional, transformational, and laissez-faire behaviors of leaders toward the workforce, asserting that transformation leadership behaviors elicit work performance beyond expectations. It has been in existence for over two

decades (refer to[12]) and has a well-established survey instrument known as the Multifactor Leadership Questionnaire (MLQ)[13]. Research by Novoselich and Knight[11] developed a reduced set of 14 items that comprise and ME Capstone version of the Full Range of Leadership model. This version has shown an ability to quantify shared leadership in capstone design teams[14].

The ME Capstone version of the Full Range of Leadership model identified conceptually similar combinations of the eight leadership factors relative to the original model (Figure 1). This modified model includes transformational/contingent reward (TCR), active management by exception (MEA) and passive-avoidant (PA) forms of leadership. The sub-constructs comprising TCR leadership involve developing team member strengths, maintaining a compelling vision, showing strong sense of purpose, and instilling pride in team members for being associated with those enacting leadership. A full description of all constructs can be found in[11].

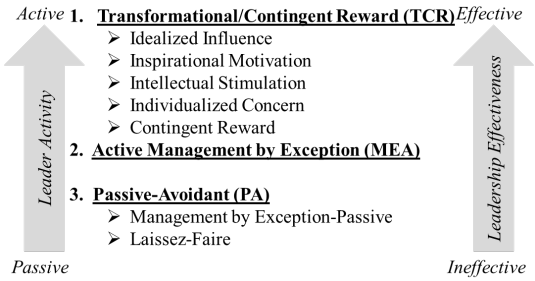

Figure 1: ME Capstone Full Range of Leadership Model[14]

Data and Sample

Data for this study came from the responses of 209 students (49% of survey responses) who comprised 45 complete design teams. Participants were enrolled in year-long, team-based, mechanical engineering, senior-level capstone design courses at a large, mid-Atlantic research university and two military-focused undergraduate institutions. Students provided a Likert scale evaluation of various leadership behaviors based on the MLQ for each team member as well as the faculty advisor. The surveys were administered online at the end of the spring semester during the 2014-2015 academic year. Only full team responses were considered because of the team-level analyses performed by this study.

Variables

The independent variables for this study are a subset of team attributes hypothesized to relate with shared leadership by Novoselich et al.[10] (Table 1).

This study focused on teams' size and team academic and leadership ability primarily because of the capstone design team structure. The three programs included in this study all conduct year-long design projects with only students from the same college. Correspondingly, all teams began their work within weeks of each other and were co-located on campus, limiting variability in team maturity and proximity. Team demographic diversity measures were excluded from this study for brevity but and are an area of further research.

Table 1: Team Attribute Variables

Team Attribute	Measure	Description
Team Size	Team Size	# Students assigned
Team Academic and Leadership Ability	Team Eng. GPA	Team-mean Eng. Course GPA
	Eng. GPA Diversity	Diversity Index of Eng. GPA
	Team Leadership Skills	Mean self-reported leadership skills score

Team size referred to the number of students assigned to each design team. For large teams greater than ten students, students were asked to identify any sub-team structures that were being used by the team.

Team leadership skills used a 6-item scale to measure students' self-reported leadership skills. These items were drawn from the National Science Foundation funded project entitled the Prototype to Production: Conditions and Processes for Educating the Engineer of 2020 (EEC-0550608) (P2P) (refer to[15]). The mean of these six items comprised a single scale variable (α=0.89) at the individual level. The mean team member scores characterized the average level of leadership skills within the team.

Measurement of a student's engineering GPA took the form of student self-reported grades in their engineering specific courses. A categorical item on the survey gathered this information. The *team engineering GPA* variable is the team-wide average of student responses and provides an overall level of engineering course performance for the team. The *engineering GPA diversity* variable determined the heterogeneity of engineering GPAs across the team (refer to[16]).

The dependent variables of this study were two social-network derived measures of shared leadership: 1) *network decentralization* (i.e., a measure of network dispersion) and 2) *network density* (i.e., proportion of influence relationships within the team compared to the total number possible)[17]. These two measures were calculated for each form of leadership within the teams (TCR, MEA, and PA) using the round-robin (360-degree) MLQ-derived leadership survey data. Mayo et al.[17] assert that leadership networks characterized by both high decentralization and density exhibit shared leadership. For brevity, this study only addressed the TCR leadership construct developed by Novoselich and

Knight[11]. All leadership constructs were included in the larger study.

Analysis Methods

To relate the degree of shared TCR leadership within the teams to team level attributes we used Hierarchical Linear Modeling (HLM) (refer to[18] for a full description of the method). Because the 45 teams analyzed in this study were nested within three separate sites, there was a potential to violate the case independence assumption of regression. A significant level of variance was explained by the site in which the team was nested (14% for TCR Decentralization and 19% for TCR Density), so the cases could not be considered independent[18].

To evaluate model fit, the variance explained by the models, adjusted for the degrees of freedom (adjusted R^2), Akaike's Information Criterion (AIC), and the Bayesian Information Criterion (BIC) were all taken into consideration. Including these multiple criteria allowed for better assessment of the complexity of the regression models evaluated. These analyses used the level 1 variance explained value (pseudo R^2) by Raudenbush & Bryk[19] because the multiple random effects incorporated into HLM models make conventional R^2 calculations inappropriate[20].

Analysis proceeded by first considering only univariate, fixed effects models with random intercepts for each independent variable. Those models with significant fixed effects were then further analyzed using random effects models (i.e., varying slope and intercept). Finally, those variables with significant relationships were combined using backward elimination to elucidate the significant relationships while controlling for the effects of the other variables.

Results

The results of HLM models (parsimonious models only for clarity) indicated that *Eng. GPA Diversity* was the only team attribute that related to TCR Decentralization. Both *Eng. GPA Diversity* and *Team Leadership Skills* related to TCR Density (Table 2). Table 2 shows independent variables in columns and dependent (shared leadership) variables in rows.

The parsimonious TCR Decentralization model results indicated that as students with more widely varying engineering course performance are grouped together in a design team, the TCR leadership network becomes more centralized. The parsimonious TCR Density model indicated that the density of a team's TCR leadership network related to both the diversity of engineering course performance and self-reported leadership skills. As students with more widely varying engineering course performance are grouped together in a design team, less TCR leadership occurs, whereas students in teams with greater self-reported leadership skills demonstrate higher amounts of TCR leadership.

Table 2: Summarized HLM Results

N=45	TCR Decen.	TCR Dens.
Random Intercept	Yes	Yes
Random Slope	No	No
Intercept	0.68***	0.62***
Team Size		
Eng. GPA Diversity	-0.29*	-0.18*
Team Eng. GPA		
Team Leadership Skills		0.03*
AIC	-19.62	-57.74
BIC	-12.39	-48.7
DF	4	5
σ^2	0.03	0.01
Pseudo R^2	0.12	0.33

*=p≤0.05; **=p≤0.01; ***=p≤0.001

Discussion

This study indicates that the diversity of engineering disciplinary performance of students, as measured by engineering course GPA, has the strongest, most prevalent relationships with the degree of shared leadership, consistent with expert power providing a source of influence[21]. For engineering faculty wishing to develop effective leadership strategies within the teams as a part of the capstone experience, these results indicate that the GPA of the team members may play a role in determining the types of leadership experiences team members will have. Wide GPA variation within the team may result in a lack of leadership experiences for some team members, as the higher performing students have the potential to serve in what Rottman et al. [22] call technical mastery roles.

Preparing students for the leadership challenges of a capstone design experience may also be important in shaping the shared leadership of the design teams. Faculty may consider how they develop engineering leadership skills in their students prior to the capstone experience as well as the prior leadership experiences of the team members during team formation. The significant relationships between *team leadership skills* and network density shows that how students perceive themselves as leaders plays a role in the amount of leadership enacted in the team. Providing students opportunities to exhibit leadership, assess performance, and reflect on their leadership skills (a type of on-the-job training) may provide them the leadership awareness necessary for them to be more active contributors to the leadership networks of their design team. Although these self-perceptions did not relate to how leadership was distributed across the teams, it did contribute

significantly to the amount of leadership happening within the teams.

Conclusions

This study suggests that the formation of a capstone design team as a function of its team member attributes may predict the type of leadership experience students will experience. Correspondingly, capstone faculty may want to consider their team formation processes. Diversifying students by GPA within teams may decrease the overall shared leadership experience for the team. Students who perceive themselves as leaders may also enact a greater amount of leadership within their teams.

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