Leadership in Capstone Design Teams: Contrasting the Centrality of Advisors and Graduate Teaching Assistants

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Waning student engagement during year-long capstone design projects may decrease team effectiveness and create challenges for team faculty advisors and graduate teaching assistants (GTAs) who oversee team progress. As an influence process, leadership may be a potential tool to bolster student effort and overall team effectiveness, but little is known regarding how faculty advisors and GTAs enact leadership within design teams. This study examines how faculty advisors and GTAs enact leadership within capstone design teams and how their prominence in the teams' leadership networks relates to team effectiveness. Results indicate that faculty advisors tend to be more active in leadership networks than GTAs and that prominence in the leadership networks correlates with enhanced team extra effort and satisfaction but not course grades.

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Introduction

Capstone design courses can be challenging for students because of their project-based, open-ended and collaborative nature, leading to waning involvement (see Blumenfeld et al.[1] and Jones et al.[2]) highlight the challenges involved with maintaining student motivation and thoughtfulness over the duration of a prolonged project based learning experience. When faced with challenging academic work, students may attempt to negotiate less demanding requirements[1]. With time, this degradation in effort may decrease team effectiveness.

The applied nature of the projects, where a prototype design must perform for a customer, separates capstone courses from conventional classroom environments and requires increased self-directed learning from students[2]. As a result, both faculty and students undergo a learning process in real-time. Faculty do not necessarily know how to address the design problem[3] or have the knowledge to navigate various team issues[4]; thus, students may navigate these challenges on their own. Sustaining this self-directed learning may require additional support from faculty or team advisors. Pembridge and Paretti[5] found that faculty describe a need to maintain student involvement and motivation within capstone design courses. Some design faculty (e.g.[3]) also use graduate student project managers as a means for ensuring student adherence to project requirements.

Helping shape leadership behaviors may be one way to mitigate this potential decline in team effectiveness. Yukl[6], in his discussion of processes affecting team performance, states that "leaders can improve team performance by influencing these processes in a positive way"[6]. Stagl et al.[7] 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, leadership has shown to significantly predict team outcomes such as team effectiveness and team performance (e.g.[8]) in a wide variety of contexts outside of engineering design.

Faculty may be unaware of the potential benefits of leadership, however. Extensive research has been conducted related to self-managed teams in engineering design work and faculty facilitation e.g.[9]. This literature lacks in the assessment and operationalization of leadership within undergraduate engineering design teams. Pembridge and Paretti[5] contend that the engineering education literature lacks in identifying the skills faculty need to address teamwork related issues, and Rottmann et al.[10] describe an aversion to leadership concepts by some practicing engineers.

Consequently, little is known regarding how faculty or graduate teaching assistants (GTAs) enact leadership in undergraduate engineering design teams and how leadership may relate to team effectiveness. This study addresses this gap in literature by examining the types of leadership faculty and GTAs enact and how their prominence within team leadership networks relates to team effectiveness.

Leadership Framework

The Full Range of Leadership model informs this study, which has been in existence for over two decades (see[11]) and has an associated, well-established survey instrument known as the Multifactor Leadership Questionnaire

(MLQ)[12]. Recent work by Novoselich and Knight[13] examined the full 36 leadership descriptive statements of the MLQ in the capstone design team context. Their study resulted in a reduced set of 14 items which were used to validate an ME Capstone version of the Full Range of Leadership model for shared leadership research[13].
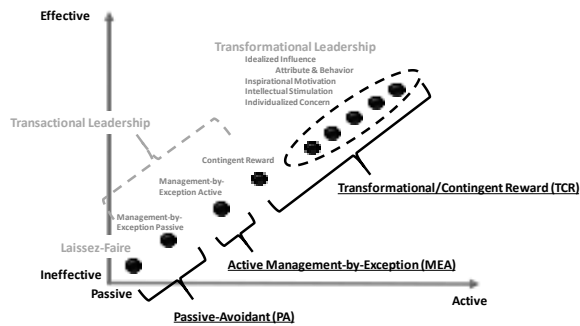

Figure 1: ME Capstone and Original Full Range of Leadership

Using factor analysis to examine the model for capstone design teams, Novoselich and Knight[13] identified conceptually similar combinations of the nine leadership factors relative to the original model (Figure 1). Their modified model includes transformational/contingent reward (TCR), active management by exception (MEA) and passive-avoidant (PA) leadership scales (Figure 1). Avolio et al.[14] conclude that constructs such as these may constitute a more parsimonious model of team leadership. TCR leadership involves 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[13]. MEA leadership primarily utilizes negative reinforcement, having a consistent focus on maintaining standards in addition to identifying and tracking mistakes among team members[15]. Passive-avoidant leadership means a delay in action until serious issues arise or a total absence of involvement, especially when needed[16].

Purpose Statement and Research Questions

The purpose of this quantitative study was to examine the ME Capstone version of the Full Range of Leadership by faculty advisors and GTAs and determine how these leadership behaviors relate to team effectiveness. The study addresses the following:

Q1. To what degree do capstone design team faculty advisors and GTAs practice the ME Capstone Full Range of Leadership within student design teams?

Q2. To what degree do faculty advisors and GTAs differ in their leadership prominence within student design teams?

Q3. How does the leadership prominence of faculty advisors and GTAs relate to student design team effectiveness?

Data and Sample

Student surveys were administered online during the 2014-2015 academic year at the end of spring semester. Participants were enrolled in a year-long, team-based, mechanical engineering, senior level capstone design course at a large, mid-Atlantic research university. This study examined the responses of 118 students (50.4% of students surveyed) who comprised 21 complete design teams; analysis required a team-level 100% response rate.

Variables

Leadership scale variables identified by Novoselich and Knight[13] (TCR, MEA, and PA) were used to address Q1. Team members assessed their advisor, GTA, and teammates' leadership behaviors based on 14 MLQ-based leadership descriptive statements (see [13]) collected in a round-robin (360 degree) fashion. All three scales showed adequate reliability ($\alpha=0.92$, $\alpha=0.82$, $\alpha=0.88$ respectively).

For Q2, we measured leadership prominence for each form of leadership (TCR, MEA, and PA) using normalized indegree centrality (NIC). Common in social network analysis, NIC is the sum of all weighted leadership ties attributed to an individual by the team members divided by the number of team members within the team (see[17]). For these analyses, ties between team members were filtered such that a frequency rating less than or equal to three on the Likert-type scale (i.e., sometimes) was deemed too infrequent to be considered. Thus, results present a conservative estimate of leadership prominence.

Team effectiveness was a composite measure of group process, individual satisfaction, and task performance, consistent with Wageman[18] (Table 1).

Table 1: Team Effectiveness Variables

Effectiveness Component	Measure	Source	Description
Group Process	Extra Effort Scale	Survey MLQ form 5X	Team average 3-item scale ($\alpha=0.90$)
Individual Satisfaction	Satisfaction Scale	Survey MLQ form 5X	Team average 2-item scale ($\alpha=0.90$)
Task Performance	Final Presentation Grade	Course Coordinator	Grade 100 pt scale
	Final Report Grade	Course Coordinator	Grade 100 pt scale

Because faculty highlight challenges with maintaining student motivation and thoughtfulness during a prolonged project based learning experience[1; 2], group process was operationalized as the team's ability to garner extra effort from its members. Team members rated the frequency by which the rated member got the rater to exceed their expected level of work and willingness to succeed.

Individual satisfaction was operationalized as the team's overall satisfaction with the leadership and teamwork of its members. The two items of this scale

required team members to rate the frequency by which the rated member worked with and led them in satisfactory ways.

Task performance was operationalized as the team's performance on their final design presentation and final design report, reported as numerical grades by the course coordinator using a 100-point scale.

Methods

For Q1, descriptive statistics and a paired sample *t* test identified the amount of and statistically significant differences in student ratings of their advisors and GTAs on the three forms of leadership. For Q2, a paired sample *t* test identified statistically significant differences in the network centrality of the advisors and GTAs. To address Q3, we examined Spearman's rho because of the non-normal distribution of the centrality measures[19].

Social network analyses were performed using the SNA package in R, and the remainder of the analyses were performed using SPSS version 23.

Results

Addressing Q1, results of paired sample *t* tests (Figure 2) indicated that faculty advisors enact more leadership than GTAs and that TCR leadership is enacted more often than MEA or PA.
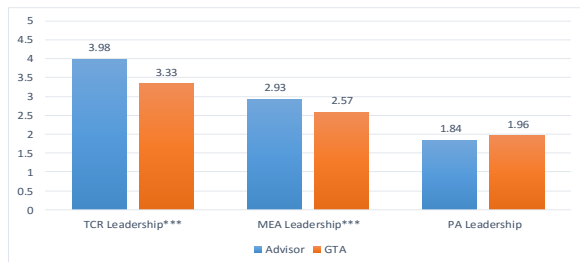
Figure 2: Leadership scale rating differences[a,b].
[a]Likert-type scale: 1: Not at all; 2: Once in a while; 3: Sometimes; 4: Fairly often; 5: Frequently if not always
[b] ***= mean differences significant at the α<0.001 level.

Based on the rating scale, faculty advisors enact TCR leadership 'fairly often' (mean=3.98), MEA leadership 'sometimes' (mean=2.93), and PA leadership 'once in a while' (mean=1.84). GTAs enact TCR leadership 'sometimes' (mean=3.33), MEA leadership 'sometimes' (mean=2.57), and PA leadership 'once in a while' (mean=1.94). Paired sample *t* tests showed statistically significant differences between the advisors and GTAs in the amount of TCR and MEA leadership they enact, but not PA leadership.

For Q2, results of paired sample *t* tests (Figure 3) indicated that faculty advisors are more prominent than GTAs in the TCR and MEA leadership networks of their design teams.
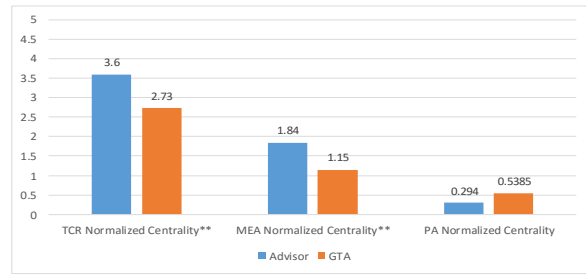
Figure 3: Advisor and GTA NIC differences[a].
[a] **= mean differences significant at the α<0.01 level.

Mean NIC of advisors were higher than those of GTAs for the TCR and MEA networks and the differences were significant at the α=0.01 level. These results indicate students attribute leadership to faculty advisors more than GTAs. No significant differences in PA leadership prominence were found.

Addressing Q3, correlation analysis results (Table 2) indicated that the advisor's prominence in the TCR and PA networks and GTA prominence in the TCR network related to measures of team effectiveness.

Table 2: Correlation Analysis Summary.

	Extra Effort	Satisfaction	Presentation Grade	Report Grade
Advisor TCR Prominence	.835**	.716**	-.155	.083
GTA TCR Prominence	.475*	.373	.043	.054
Advisor MEA Prominence	.246	.227	.114	.052
GTA MEA Prominence	.344	.302	-.267	-.337
Advisor PA Prominence	-.516*	-.379	.092	.071
GTA PA Prominence	-.184	-.052	-.134	-.118

*=p<.05, **=p<.01

Advisor prominence in the TCR network showed strong, positive relationships with teams' extra effort and satisfaction while prominence in the PA network had a strong negative relationship with extra effort only. GTA prominence in the TCR network also exhibited a moderate positive relationship with extra effort only. Prominence in the MEA network showed no significant relationships with measures of team effectiveness. Course Grades had no significant relationships.

Discussion

The results of this study show that the leadership enacted by team advisors and GTAs both relate to team effectiveness; faculty advisors, however, exhibited more leadership than GTAs within teams. For faculty and GTAs charged with advising or managing capstone design teams, this study indicates that enacting TCR leadership may enhance a team's willingness to put forth extra effort in their project and their leadership and teamwork satisfaction. Minimizing PA leadership by staying engaged (and not just leading at times of failure) may also increase team extra effort. Capstone course coordinators may consider training faculty and GTAs on effective team leadership fundamentals. This training may lead to more engaged and satisfied teams, enhancing the learning process.

The accountability behaviors associated with MEA leadership showed no relationships with team effectiveness. Correspondingly, these results indicate that keeping track of student mistakes may not be an adequate form of leadership by itself.

For course coordinators considering the use of GTAs to assist with the rigors of managing capstone projects, these results indicate that on average, when a team advisor is involved, GTAs may not be considered a sufficient replacement for the advisor in terms of leadership.

The lack of significant relationships between leadership and course grades are inconsistent with previous research in other contexts and highlights the complexity of evaluating capstone design teams. Further investigation to uncover more purposeful measures of task performance that may better relate to leadership is warranted.

Conclusions

This study shows that Advisors who enact TCR leadership may enhance the extra effort and satisfaction of their teams. Students also generally recognized Advisors as more prominent leaders than GTAs. Capstone design faculty may consider leadership behaviors as an additional resource when interacting with capstone design students. Training both Advisors and GTAs in effective leadership practices may enhance the Capstone learning experience for students.

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