What Behaviors and Characteristics Do Engineering Student Competition Team Members Associate with Leadership?

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Engineering student competition teams (ECT) are promoted as incubators for the development of leadership, yet we know little about how leadership actually develops within these teams. A case study of two teams at a public university in the central U.S. was performed, with the objective of exploring leadership development at the individual and team levels. Implicit in the concept of team leadership development is the development of individuals as leaders. This paper discusses the behaviors and characteristics that students participating on those teams associate with leaders and leadership. Team members strongly associated five categories of behavior with leadership: Ideal Behavior, Individual Consideration, Project Management, Technical Competence, and Communication. Other leadership behaviors, including Collaboration, Training & Mentoring, Problem-Solving, Motivating Others, Delegation, and Boundary-Spanning, were less consistently recognized, and some behaviors were valued more highly within one team than the other. When asked to define leadership, most team members ascribed to a mainstream view. A few team members revealed a more mature understanding of the nonpositional and collectivistic aspects of leadership.

Background

The Jets and the Sharks are the largest engineering competition teams at this institution. The Jets compete in the Formula SAE Collegiate Design Series (FSAE), and the Sharks compete in the National Concrete Canoe Competition. Both teams are extra-curricular and largely self-managed, and their membership is drawn from all undergraduate levels. Team members can participate over several years, making it possible to examine the contribution of the ECT experience to students’ leadership development.

Formula SAE is one of many collegiate vehicle design competitions sponsored by the Society of Automotive Engineers. The product is a small race car similar in style to a Formula One machine. The vehicle is powered by a purchased motorcycle engine; all other vehicle systems are designed and/or built by the student team members. Each competition consists of several events. Teams earn points on the basis of design, the writing and presentation of a technical report, and, of course, race performance. Competitions are held in late spring and early summer and are not hierarchical. Some teams participate in more than one competition each year, and participation is not dependent on prior performance.

The American Society of Civil Engineers (ASCE) sponsors the National Concrete Canoe Competition. The competition consists of several events, including canoe design and display, a technical paper and presentation, and races. First-level competitions are held annually during the spring at 18 regional student conferences; the winners of the regional competitions advance to the national competition.
Method

Study data were collected in two phases; this paper reports a subset of results from the second phase. Participants for Phase 2 were identified using a social network influence measure captured in Phase 1.

In the first phase, attendees at mid-fall team meetings of the Jets and Sharks teams responded to a paper-and-pencil questionnaire regarding team processes and influential team members. Each respondents wrote the names of the current team members who influenced them. The term “influence” was chosen in an effort to identify members who exhibited leadership behaviors but who might not fit a respondent’s idea of a leader. Framing the list around influential members broadened the scope of analysis and facilitated the investigation of leadership development across the team rather than the development of students who were already considered leaders.

Respondents worked individually. For each person they listed as influential, the respondent used a 5-point Likert scale to indicate the extent to which that person influenced them personally, and the extent to which the team relied on that person for leadership (following the method proposed by Carson and colleagues3). These ratings were used to compute several social network measures. One of these measures, indegree centrality, was used to identify potential interview participants.

A brief explanation of indegree centrality is in order. In social network theory, there are several ways to measure an individual’s connections within a group. The simplest measure, degree, refers to the number of connections a person has to others. It can be an undirected measure, indicating a relationship between two people (as in, Erica is friends with Jeff), or it can be a directed measure (as in, Erica influences Jeff). When directed, degree can be expressed in terms of indegree or outdegree. A person with high indegree influences many other members, while a person with high outdegree is influenced by many others. To ease comparisons between members of different-sized groups, a normalized measure, degree centrality, is often used. Degree centrality is computed by dividing the degree by n−1, where n = the number of people in the group.4

Team members listed as influential and receiving an indegree centrality score in the top half of their team were invited to participate in the Phase 2 interviews. First-year members listed as influential were also invited, regardless of indegree score. Additional potential interviewees were nominated by the team captains and/or were mentioned by team members during interviews.

Participants

At the time of the interviews, the Jets roster listed about 25 members and the Sharks roster listed about 45 members. In total, fourteen students, all engineering majors, participated in individual recorded semi-structured interviews exploring the team experience and their own leadership development journeys. Six participants were Jets, and eight were Sharks. Thirteen were pursuing the bachelor’s degree, and one was in graduate school. Four were women, and four identified as members of nonwhite ethnic groups (1 Hispanic, 1 Asian-American, and 2 Native American). No freshmen were interviewed.
Of the participating Jets, all had been on the team for at least one year, and most held named positions of responsibility. All had completed at least 5 semesters at the university, and experience on the team ranged from about 12 months to 5 years. None had been involved with any other collegiate engineering competition teams.

Of the participating Sharks, eight were returning members and two were first-year members. The youngest had completed 3 semesters at the university; all others had completed at least 5 semesters. With the exception of the new members, all participants were team officers. Experience on the team ranged from about 6 months to almost 5 years. One student had briefly participated in another collegiate engineering competition team.

The Interview

Interviews have been used to explore leadership development among several groups, including athletes, members of the military, and college student leaders. The technique is especially valuable for uncovering participants’ implicit leadership theories, allowing researchers to understand “what people actually mean when they attribute actions to leadership.”

The first author conducted all interviews. With one exception, interviews took place early in the spring semester approximately the midpoint of the competition year for both teams. One Sharks participant was interviewed in June, a few months after the regional competition. Interview durations ranged from 50 to 120 minutes, with most interviews lasting about 90 minutes.

The interview followed a semi-structured format. Participants answered several questions designed to elicit their understanding of behaviors and characteristics associated with leadership. Specifically, respondents were asked “What is leadership?” Later, they were asked to name leaders on the team; for each person named, they answered the question “What makes this person a leader?” They also described their leadership self-identity and gave examples of their own leadership behaviors. Most respondents spent several minutes explaining their views, and many gave multifaceted definitions.

Researcher Bias

The first author and interviewer approached this study with the idea that engineering competition teams would benefit by exercising leadership from a collectivistic and process-oriented standpoint. Because engineering students are developing their technical expertise, they must rely on collaborative learning and the sharing of knowledge in order to produce a quality product. Despite her bias, the author approached the project as an explorer. Her goal was not to support a proposition. Instead, she sought to determine what engineering students understood about leadership and how team participation influenced that understanding.

The second author works with a multidisciplinary research team focused on building a more equitable and diverse cultural climate within engineering education. One focus of the research group has been on issues of diversity and inclusion within ECTs. For this project, the identities of participating ECT members were obscured from this author.
Trustworthiness

The interviewer took care to phrase follow-up questions neutrally, in an effort to avoid suggesting “correct” responses. Occasionally, the interviewer reminded participants that the research team was interested in learning how they understood leadership, not in evaluating their performance as leaders.

The first author transcribed all the interviews. The original recordings were retained, making it possible to review and correct the transcriptions as needed. Thematic interpretations were proposed through an iterative process between the authors and refined through discourse with the larger research team.

Coding

Interview transcription and analysis were performed using NVivo 10 for Windows, distributed by QSR International. The analysis followed a qualitative approach with both structured and inductive coding procedures.

A limited set of a-priori codes was established, including a code for each interview question and umbrella codes for “Leadership Behaviors” and “Leadership Characteristics.” Specific attributes were not identified prior to coding. The umbrella categories were analyzed for emergent themes, which were then compared to existing definitions of leadership and leader behavior found in the literature.

A few notes on terminology are in order. First, respondents typically referred to members with defined areas of responsibility as “leads” or “system leads” rather than “officers.” In this paper, the terms are used interchangeably. Second, in an effort to obscure the identities of the respondents and the teammates discussed, some pronouns, including those in quotations, have been changed. No implications regarding gender are intended. Third, the term “behaviors” will be used as a short reference for both behaviors and characteristics.

What is Leadership?

As expected, most team members ascribed to a mainstream view: Leadership is getting a group of people to work together toward a goal.\textsuperscript{9, 10} That ten of the thirteen team members gave some form of this definition was not surprising. All team members had received some collegiate leadership education through a required professional development course. All but one participant had received additional explicit leadership education through other courses, extracurricular activities, and leadership workshops at both the high school and college levels. Even the one participant who reported no focused leadership training did mention high school sports as a source of leadership learning.

Most students elaborated on the mainstream definition, and their additional comments were revealing. Like students interviewed by Komives and colleagues (2006), team members did not always distinguish between “leaders” and “leadership.” While some scholars promote the idea of leaders and leadership as separate phenomena,\textsuperscript{11, 12} the college students in this study did not generally recognize such nuances. For example, four team members discussed leadership in
terms of the leader’s responsibility to act as an example or ideal. Although most of these students also mentioned other aspects of leadership, one respondent defined leadership exclusively in heroic terms: “Leadership [is] standing up and doing what needs to be done even when… the odds are against you… doing the right thing, making sure work gets done [and] gets done correctly.”

The existence of followers as a necessary condition for leadership was identified by four team members. A veteran Sharks team member who had been an officer in several large engineering organizations said “Leadership is about having people follow you. If you don't have all the skills necessary to make people want to attach themselves to what you're doing, then you're not a leader.” A Jets officer said, “You have to have followers to be a leader. You can't lead by yourself.” The same person believed that he had been chosen as an officer because “I was doing something right that people thought [I was] leading in the right direction. I had a mentality of the team that others liked and then [they] elevated me to a designated role to be a leader on the team.” A Shark expressed a similar view, defining leadership as “[having] abilities or ideas… that people think would be best for them and the team.”

Four team members defined leadership in terms of guidance, particularly in relation to team-related technical and procedural knowledge. Although none used the word “mentor,” their definitions were consistent with the concept. One Sharks officer said “A leader is... a person that knows what they’re doing… I have the knowledge to teach somebody… So after I graduate whoever was [working] with me that’s a younger age, they’ll probably do the same thing or better.” Another said a leader “[makes] sure they know why they’re doing the things that they’re doing… and [that they are] learning along the way.” This view was also expressed by two Jets, one of whom said “leadership is being able to work with other people and use your experiences as a form of guidance or suggestion. And to show through your own actions how your experience has impacted how you do things.”

Two themes indicating a mature understanding of leadership emerged: the concepts of nonpositional leadership and shared leadership. Three Jets recognized nonpositional leadership—that leadership is not confined to those who hold official positions. In the words of one officer, “You don't even have to set out to be the leader... Apparently I was doing something right that people thought [I was] leading in the right direction... and then [they] elevated me to a designated role to be a leader on the team.” Another longtime officer said “There's a difference between having a leadership role or title and actually leading... It's not necessarily what title you have. It's what you do with what you know, and how you interpret situations or impart that information to others.”

These three Jets and one Shark expressed ideas consistent with the concept of shared leadership, although they did not use that term. One officer believed that “If you have a lot of people who are leading, it's easier in my opinion to develop the team... Having a lot of people who will lead in various areas... is helpful to team development and personal development.” Another said that the team competition team experience “showed me that you can’t have just one leader. When you have that, everything does start falling through the cracks.” A system lead spoke at length along these lines: “Leadership is... not about one person. It's much more of a group effort... So it's not any one person being the leader... maybe one guy is organizing it, and he is necessarily a
leader in that instance, but I think it's more the communication between the group as far as working together for one goal.”

A Sharks officer expressed a similar view: “Before I joined Canoe, I always thought leadership is one person. One person should be in charge of everything and making sure everyone plays their part. But when I’m in Canoe, it’s a lot different. We have multiple people who [are] leaders. All the leads, you shouldn’t just have the title, but you actually contribute to the whole… if you’re a leader, then you should always step up and help out the other leaders. It’s more of a group thing I think.”

As the quotations above indicate, most team members gave a conventional answer when asked to define leadership, while a few revealed a more mature understanding of the nonpositional and collectivistic aspects of leadership. The answers to additional questions regarding leadership practice were examined to develop a more complete understanding of the team members’ implicit theories of leadership.

What Makes a Leader?

Shortly after describing their definitions of leadership, team members named the leaders on the team and then explained, for each person named, what made that person a leader. Team members were later asked to identify and describe new members who might become team leaders in the future. Toward the end of the interview, they were asked about their own leadership behaviors. These descriptions revealed a range of depth and understanding. In several cases, the team members’ descriptions of leadership behaviors were much richer than their definitions of leadership.

Because team members used different words to describe similar behaviors and characteristics, responses were grouped by semantic similarity. For example, “looks to the future” and “has a vision for the team” were put in the same group. Another group included such comments as “helps others” and “supports struggling members.” A third group included statements such as “slightly bossy” and “likeable and authoritative.”

Behaviors were also compared to definitions from various leadership constructs, including but not limited to the Ohio State Model (as described by Judge, Piccolo, & Ilies), Transformational & Transactional Leadership, Functional Leadership, Functional Team Leadership, and the Team Leadership Framework. The Ohio State model, developed in the 1950s, proposed the division of leadership behaviors into two major categories: Consideration, which focused on interpersonal relationships, and Initiating Structure, which focused on task accomplishment. Burns and Bass extended these ideas to construct one of the 20th century’s most influential frameworks for describing leadership behaviors: Transformational and Transactional Leadership. Transformational behaviors are exercised when leaders pursue positive organizational change through inspirational motivation, intellectual stimulation, idealized influence, and individual consideration. Transactional behaviors, on the other hand, are those focused on an exchange relationship between leaders and followers: contingent reward is one example. Functional Leadership took a different approach. Rather than focusing on a leader’s charisma and other personal attributes, the functional perspectives held that the “leader’s main job is to do, or get
done, whatever is not being handled for group needs.” The Functional Organizational Leadership Model\(^\text{17}\) proposed that leadership behaviors could be grouped under four categories: Information Search & Structure, Information Use in Problem Solving, Managing Material Resources, and Managing Personnel Resources. Functional Team Leadership\(^\text{18}\) extended this concept (which had assumed a focal leader) to team settings. Burke and colleagues\(^\text{19}\) conducted a meta-analysis of these and other leadership models. Their resulting Team Leadership Framework identified and described the range of leadership behaviors exhibited within teams.

Thematic coding of the ECT transcripts produced 11 categories of leadership behaviors: Ideal Behavior, Individual Consideration, Project Management, Technical Competence, Communication, Collaboration, Motivating Others, Training & Mentoring, Delegation, Problem-Solving, and Boundary-Spanning (Table A). To assess the relative importance of these concepts, team members mentioning behaviors in each category were counted (Table B).

Table A. Definitions of behavioral categories.

<table>
<thead>
<tr>
<th>Behavioral Category</th>
<th>Definition</th>
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<tbody>
<tr>
<td>Ideal Behavior</td>
<td>Behaving as a role model for team members.</td>
</tr>
<tr>
<td>Individual Consideration</td>
<td>Recognizing that each team member is an individual person with particular talents, needs, constraints, and desires.</td>
</tr>
<tr>
<td>Project Management</td>
<td>Establishing and managing team processes for scheduling the work, accomplishing tasks, and meeting goals.</td>
</tr>
<tr>
<td>Technical Competence</td>
<td>Possessing practical and theoretical knowledge and skill relevant to the project.</td>
</tr>
<tr>
<td>Communication</td>
<td>Sharing information via formal and informal channels; discussing the project with team members; listening to team members.</td>
</tr>
<tr>
<td>Collaboration</td>
<td>Working with teammates to create solutions. Collaboration is characterized by a mutual and multidirectional exchange of ideas.</td>
</tr>
<tr>
<td>Motivating Others</td>
<td>Encouraging team members to participate, persist, and excel.</td>
</tr>
<tr>
<td>Training &amp; Mentoring</td>
<td>Helping team members develop relevant technical and administrative skills.</td>
</tr>
<tr>
<td>Delegation</td>
<td>Assigning tasks to team members, and trusting team members to complete those tasks with reasonable competence.</td>
</tr>
<tr>
<td>Problem-Solving</td>
<td>Identifying problems and seeking solutions to technical challenges. Seeking improvement in team functioning and performance.</td>
</tr>
<tr>
<td>Boundary-Spanning</td>
<td>Working with stakeholders outside the team, including the advisor, university administrators, sponsoring companies, and alumni. Also, bridging the gap between factions within the team.</td>
</tr>
</tbody>
</table>

Team members strongly associated five categories with leadership: Ideal Behavior, Individual Consideration, Project Management, Technical Competence, and Communication. The first four were mentioned by all respondents, and Communication was mentioned by all but one member of each team. These categories closely corresponded with the themes they had expressed when defining leadership. “Coordinating a group of people to achieve a goal”—the most common definition given by the team members—requires the exercise of behaviors from all of these groups.

Other leadership behaviors were less consistently recognized. Collaboration, Training & Mentoring, and Problem-Solving were highly valued by the Jets, while Motivating Others and
Delegation were more important to the Sharks. Boundary-Spanning was associated with leadership only by only a few members of each team.

Table B. Behavioral categories and frequency of mentions, by team.

<table>
<thead>
<tr>
<th></th>
<th>Sharks</th>
<th></th>
<th>Jets</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Team Members</td>
<td>Percentage</td>
<td>Team Members</td>
<td>Percentage</td>
</tr>
<tr>
<td></td>
<td>Mentioning</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ideal Behavior</td>
<td>8</td>
<td>100%</td>
<td>6</td>
<td>100%</td>
</tr>
<tr>
<td>Individual Consideration</td>
<td>8</td>
<td>100%</td>
<td>6</td>
<td>100%</td>
</tr>
<tr>
<td>Project Management</td>
<td>8</td>
<td>100%</td>
<td>6</td>
<td>100%</td>
</tr>
<tr>
<td>Technical Competence</td>
<td>8</td>
<td>100%</td>
<td>6</td>
<td>100%</td>
</tr>
<tr>
<td>Communication</td>
<td>7</td>
<td>88%</td>
<td>5</td>
<td>83%</td>
</tr>
<tr>
<td>Collaboration</td>
<td>5</td>
<td>63%</td>
<td>6</td>
<td>100%</td>
</tr>
<tr>
<td>Motivating Others</td>
<td>6</td>
<td>75%</td>
<td>4</td>
<td>67%</td>
</tr>
<tr>
<td>Training &amp; Mentoring</td>
<td>3</td>
<td>25%</td>
<td>5</td>
<td>83%</td>
</tr>
<tr>
<td>Delegation</td>
<td>6</td>
<td>75%</td>
<td>2</td>
<td>33%</td>
</tr>
<tr>
<td>Problem-Solving</td>
<td>2</td>
<td>25%</td>
<td>5</td>
<td>83%</td>
</tr>
<tr>
<td>Boundary-Spanning</td>
<td>3</td>
<td>25%</td>
<td>3</td>
<td>50%</td>
</tr>
</tbody>
</table>

*Ideal Behavior.* Leaders exercised Ideal Behavior by “set[ting] the example,” working “for the benefit of the team,” being “willing to take up any challenge,” and “accept[ing] responsibility for mistakes.” In the words of a Jet, “As a leader you almost have to be perfect or someone’s going to call you out on it.” Regular attendance and hard work were frequently mentioned. One respondent astutely recognized that “If somebody new comes and you’re there every time they’re there, then they’re going to remember you and consider you a leader.” A new member of the Sharks noted that “Time commitment… is another leadership quality you need… I don’t think [the captain] and [another officer] slept for the three days leading up to competition.”

Commitment was regarded as a critical aspect of team leadership. In the words of a senior executive on the Jets team, “As a leader, you have to sacrifice a lot.”

*Individual Consideration.* The association of Individual Consideration with leadership was evident throughout the interviews. The practice of Individual Consideration involves the treatment of each member as a unique person with particular needs and desires. Individual consideration can be exercised through such behaviors as friendly acknowledgement, encouragement, invitations to participate, and personal recognition—in short, treating each member as a valued colleague.

Team members frequently mentioned the nature of the team as a “volunteer organization” and recognized that, as such, there were few material rewards or punishments that could be employed to induce participation and commitment. In environments where contingent-reward behaviors are not effective, individual consideration becomes crucial for recruitment, retention, and good team performance. Several students described systematic approaches for addressing recruitment and retention. According to a Shark, “When we go team meetings… we don’t sit next to our friends who are leads. We all separate and go talk to new people… And so through that we’re forced to build relationships with the new people on the team.” A Jet who frequently works with new
members explained that “you have to figure out what’s the best way to communicate with [a new] person.” According to a teammate, the Jets captain was especially good at this: “If a new guy comes in and… doesn’t have anything to do and nobody talks to him, [the captain] is the first guy that says, ‘Hey, what do you want to do today?’”

Helping others accomplish tasks and helping members find meaningful involvement were valued behaviors in both teams. A member of the Jets explained it this way: “If you can’t do your system, let me help, and then you can help me with mine later… I’m not going to dog you for [struggling]; I’m going to help you out.” A similar philosophy was expressed by a Sharks lead, who said, “[One aspect of leadership is] making sure that everyone can play their part, and making sure that each part is played by someone that can handle it. And if they can’t handle it, helping them out… As a leader I think it’s important to not take [away a struggling member’s] responsibilities but help them out with that.” On the other hand, some team members had learned to recognize and accept others’ weaknesses. Said one officer, “It’s learning how to deal with certain people and knowing where their strengths are, so that you don’t put too much on them so it puts the team back… I’ve realized some people are very good at manufacturing… [but] if you give them a system to [design] they can’t get it done.”

Project Management. Team members clearly recognized the necessity of good structures and processes. The Project Management category included behaviors associated with establishing structure,14 such as keeping the team on schedule and assigning tasks, and broader descriptors such as “getting things done” and making decisions. The fact that all team members considered behaviors in this category as indicators of leadership was unsurprising given the project-oriented nature of the competitions.

For both teams, organizing the team to achieve a goal was the most common project-management behavior mentioned. Many team members associated “making sure everything gets done” with leadership, a perspective corresponding the functional leadership models.17, 18, 21 As explained by a team officer with extensive leadership role experience, “You have to show that you’ve thought things out, you have a plan, and that you’re going to execute it. You’re not just going to attempt to do something; you’re actually going to do something.”

Planning, scheduling, and monitoring progress were especially valued. One lead was described as “very meticulous… he’s very good at putting schedules in order and making sure everyone knows what their job is… So he’s never going to lead a meeting but he’s very good at making sure everyone’s on the same page.” Another lead “has that ability to make sure a project she’s working on comes to completion… she knows where she needs to be at every checkpoint along the way.” A third officer was complimented because she “always has her sights set ahead of where we need to be. So last year we didn’t start [event] practices until maybe two weeks before competition. We’re a couple of months out now and she’s already trying to plan one for this weekend. We had multiple [practices] last semester… She’s really into making sure that she’s doing everything she can to make the team as strong as possible.”

Coordinating schedules and obtaining progress feedback were especially important to the Jets. According to one officer, “during [design] meetings we go through the whole car and the components, and it’s literally my job to talk to everyone and figure out why you’re behind and
why you’re not.” Of course, staying on schedule was rarely easy. One Jet said that it was important for leaders to “Make a note, make a weekly report, and ask everyone’s status. And if you start hearing the same status every week, that’s on paper, you can hold them accountable.”

Two officers on each team mentioned the importance of holding people accountable. The Jet, who had extensive team experience, clearly understood the difficult side of leadership. He mentioned the need to “hold people accountable,” “make tough decisions,” and “relieve people [of responsibility] when necessary.” Speaking from personal experience, he remarked that the exercise of leadership sometimes required “aggressive” behavior, even when such behavior did not come naturally.

Technical Competence was the fourth category of leadership characteristics mentioned by all team members. As one person succinctly stated, “The people who seem the most knowledgeable about the topics are going to be the leaders.” A Jet explained that the “complexity of the project” demanded technically knowledgeable leaders: “Being well-rounded helps. [If you have] manufacturing experience, … you can look at a [design] and within thirty seconds say, yeah, we can machine this here or no, we can’t… and if there’s conflicting designs… you can identify and say [how this will affect the other parts of the car].”

In the view of a Shark, technical competence was more important for leadership in competition teams than in other organizations: “If you ask [a team member] to do [something] and they think you know what you’re talking about, then they’ll do it for you. And if you don’t, then they won’t. And I think that’s different from the leadership experience I’ve had in the past.”

Several team members mentioned technical competence as one of their leadership strengths. In the words of one officer, “I’d say [that others consider me a leader]… They know I’m competent and I can do what I say I’m going to do.” Another credited obtaining a leadership role to her technical skill: “[The previous office holder] liked that I learned really quick, really fast. So he told [the captain] to make me the lead for [activity].”

One Jets member with several years of experience expressed frustration with his lack of ability to lead without relying on technical competence. As he explained, “I can lead people… just because I have a knowledge base… I don’t have influence in [team administration]. But it seems like if I’m trying to teach them about [my vehicle system] they’re wide-eyed, will accept anything, just because they know I did [that system] for four years… I haven’t figured out how to lead people without using my knowledge base.”

Within the Sharks team, valued technical knowledge extended beyond construction of the canoe. Prior attendance at a competition was a prerequisite for a position of responsibility, particularly with regard to the captaincy. “We could have elected a captain before Regionals but it wouldn’t really make sense because we wouldn’t know who… does a really good job helping the team out,” said one longtime member. “Regionals is a… challenging time… It changes a lot of people’s viewpoints on the team. A lot of them come back stronger, wanting to be better next year. We definitely want to go through that before selecting a captain.” Another cited the knowledge obtained by attending the competition. “If you didn’t go to competition last year you can’t see how we are placed with other teams… [and you won’t know] the evolution of all the
concrete techniques that build up over the years… With an inexperienced member as captain, they don’t have that foundation of all that knowledge.”

The willingness to acquire technical competence was an important indicator of leadership potential within both teams. Speaking of a new member, one Shark said, “He asks a lot of questions… I think he would be a good leader because he’s always curious about what we’re doing and wants to come up with new ideas.” A Jet expressed similar thoughts about one of their new members: “She’s picked up CNC manufacturing already, which very few people do freshman year… she’s been interested in multiple aspects of the car… so she’ll be [a leader] in the future.”

Communication is a broad term with several meanings. Team members used the term to refer to informative messages, individual and small-group conversations, and team discussions. Communication was specifically mentioned by seven Sharks and five Jets; in fact, communication was mentioned more times during all interviews than any other behavior. “Communication is the heart of all leadership,” said one senior member. Team members understood the critical role of communication as a tool for coordinating teamwork: “If you’re not communicating, it’s really easy to lose track of what someone’s doing.”

In general, members believed that the leaders did a good job of announcing events and meetings to the groups. Frustration arose when team members did not share project-related information or were not present for informal discussions. One officer recognized his own failure to share timely information; several important tasks had been delayed because he had not requested assistance or notified officers of deadlines. “I don’t like to bug people,” he explained. Another officer complained that a key person had recently moved out of the team’s shared office space and was consequently absent for many informal but important discussions.

Overall, team members were generally consistent in the recognition of the above behaviors with leadership. Recognition of the remaining leadership attribute categories was less consistent, and in some cases marked differences between the two teams emerged.

Training & Mentoring behaviors include those directed toward helping team members develop relevant technical and administrative skills that would enable them to accept greater responsibility. Items in this group included task-oriented training and coaching, sharing mistakes and lessons learned with the team, and apprenticing students identified as potential leads for the next competition season. Behaviors in this category were more important to the Jets (5/6) than to the Sharks (3/8), perhaps because a car is a more complex piece of machinery than a canoe. Interestingly, the one Jet who did not mention training as an indicator of leadership was considered by his teammates to be the foremost technical coach on the team. “He [is a leader because] he’s always someone you can ask questions to. He’ll be happy to teach you.”

The recognition of training as a special form of leadership was evident on both teams. One Jets officer viewed his leadership role as that of an “educator” rather than an administrator. “I try to keep everyone getting better at building the race car. It’s a great thing to be able to design it… but it needs to work. [Last year] we [scored well] in design finals but the car blew up.” A similar view was expressed by a Sharks officer, who asserted that teaching activities were a way of
distinguishing leaders from managers: “I think what makes a good leader is... making sure [the team members] know why they’re doing the things they’re doing... while we are making progress towards our goal, they’re learning along the way... compared to a manager [who says] you need to get it done, there you go, got it done, let’s move on.”

**Motivating Others.** Six Sharks and four Jets members mentioned behaviors associated with Motivating Others. Items in this category included having a vision for the team, motivating team members to achieve, and sharing the excitement of team participation. Said one Shark, “It’s the passion for the team and the passion for each other is what I think really makes them all [leaders].” Having vision was not merely important for team morale; it also helped leaders persist in executing their responsibilities. In the words of Jet, “To have that vision... that’s a very important leadership quality, because sometimes you have to make that tough decision along the way that other people might not see the vision at the end.” On both teams, the person with the longest tenure made the most comments related to this category.

**Delegation.** The Delegation category included two related behaviors: delegation & trust. Behaviors in this group were especially important to the Sharks. Five members, all of whom held positions of official responsibility within both the team and other campus organizations, believed that these attributes were indicators of leadership. While the other behaviors mentioned referred to actions performed by team members, Delegation was mentioned because of its absence. The captain’s failure to delegate was a particular source of frustration to the most experienced members. “I wish he would have asked us for help,” one lead remarked. “I could have taken care of that myself,” said another lead, “but I didn’t want to go behind [the captain’s] back.” A third member remarked, “At some point, you have to trust younger members to talk to companies... They don’t necessarily have much experience working with older people in professional settings. So I can see the hesitancy in throwing them into calling someone on the phone and asking about a donation, but at some point you have to throw people in the fire and get them used to that sort of thing.”

In contrast, this category was less important to the Jets, with only two members mentioning behaviors in this group. Nonetheless, it was clear that the interviewed team members trusted each other and frequently delegated responsibilities. Perhaps these team members all felt fully empowered in their positions and thus did not recognize these as specific leadership behaviors.

**Collaboration.** The category of Collaboration included behaviors that facilitated group decision-making and the coordination of multiple interdependent tasks, such as sharing ideas, learning from others, and being willing to disagree. All Jets and half of the Sharks mentioned collaborative behaviors as evidence of leadership.

The importance of collaborative behaviors to the Jets is unsurprising, given the complexity of the project. Said one officer, “We really don’t know what we’re doing. We don’t know how to build a car. Not one of us could build a car by ourselves.” Sharing ideas and information was particularly important. As another officer explained, “Leadership is... five or six guys that are able to filter down information to some of the newer guys, and five or six guys that make the decisions, and five or six guys that bounce ideas off each other... that communicate frequently, all the time, every day, about certain topics.”
A willingness to discuss ideas was valued. In the words of one Shark, “everybody that’s leading on the team [is] open to discussion, open to new ideas, and receptive on problems that come up.” Another remarked “It’s not about knowing everything. It’s admitting that you don’t know everything, and telling the people that you’re leading that you are also following somebody that knows more about it… How I looked at it in years past is, he leads the team because he knows how to do everything. That’s not necessarily the case. He leads the team because he’s good at communicating, he’s good at taking advice, he’s good at being open-minded to ideas.”

Students recognized that exercising leadership did not rely require a dominant personality, and that dominant team members might actually be detrimental. Said one participant, “I guess [my idea of leadership] has changed a little bit, because now I look a lot more to the quiet person, because they usually aren’t as overbearing in their ideas, so it’s more of a collaborative process.”

**Problem-Solving.** Conventional wisdom holds that engineers are problem solvers. Problem-Solving is also recognized as a characteristic of leaders, particularly those in creative or technical organizations. In addition to behaviors such as identifying technical problems and seeking solutions, this category included seeking improvement in team functioning and performance. Problem-Solving behaviors were mentioned by more Jets (5/6) than Sharks (2/8). Two Jets specifically mentioned the ability to adapt or adjust to situations as evidence of leadership. One officer was described as “a team player. She can adjust to make things work.” Another officer learned from ECT participation that to be a leader “you have to be able to adapt. You have to be able to identify different situations, how different people deal with different situations in different ways, and how to work with them.” As with Training & Mentoring, the between-teams difference may be attributable to the respective levels of project complexity.

**Boundary-spanning** activities are defined as “politically oriented communication that increases the resources available to the team and networking communication which expands the amount and variety of information that is available to the team.” Boundary-spanners can also bridge the gap between factions within a group, helping to facilitate team discussions. Boundary-spanning activities were specifically mentioned as leadership functions by three Sharks and three Jets. The willingness of particular students to talk with sponsoring companies, alumni, departmental and university administrators, and the faculty advisor was much appreciated by their teammates.

Jets complimented their captain’s boundary-spanning ideas and believed that he had exceeded expectations in this regard. A system lead described two occasions in which the captain spanned boundaries to help the team gain knowledge. In one case, the captain called an experienced alumnus to request assistance with technical training. “Nobody really thought to contact him except [the captain].” In another case, the captain proposed visiting the FSAE team at a nearby university. Apparently this was unusual: “Nobody ever does that on our team. We don’t ever look at anyone else’s program—we have a good program!... But he’s new enough that he can say, we don’t have as good a program as they do, let’s see what they’re doing right.”
Intra-group spanning efforts were valued within the Sharks team. When one officer was asked if others considered him a leader, he responded, “I guess so… Everyone comes to me with the stuff they want to take to the captain. So I guess I’m the through-person.” This self-perception was supported by a comment by a teammate, who remarked on the officer’s role in team discussions: “If you don’t agree with someone and you don’t want to say anything out loud, he’s always a great person to get behind…. Because usually when he says [something] he’s not the only one who’s notices or who has thought about it. So it’s kind of like he does the majority of the confrontation for us. We’re appreciative.”

Although boundary-spanning responsibilities were considered necessary, they were not always prized assignments. Most members, it seemed, would much rather work on designing and building the product. Within the Sharks, boundary-spanning was considered an activity for people brave enough to confront team members or oppose the advisor. Within the Jets, boundary-spanning was considered “grunt work” and less desirable than the “fun design work.”

Discussion

As found in previous studies of engineering student teams, ECT members understood leadership from a functional perspective. Team members’ understanding of leadership behaviors aligned with leadership paradigms identified in the professional technical domain. While previous studies of engineering student teams investigated leadership associated with positional roles, the current study revealed that engineering competition team members recognize the value of nonpositional leadership. In fact, several participants noted that the exercise of leadership behaviors often preceded the attainment of a leadership position. Team members who worked hard and often, possessed strong technical skills, treated teammates well, exercised good project management, and communicated effectively were considered team leaders.

Some leadership behaviors were more commonly recognized by one team than the other. Collaboration, Training & Mentoring, and Problem-Solving were recognized by more than 80% of the Jets but were mentioned less often by the Sharks, possibly because a race car is more complex than a canoe. The Jets team has several subteams devoted entirely to building the car. Collaboration is necessary because systems designed and built by one subteam must fit and work with systems designed by other subteams. Construction is conducted over several months, and delays in one area can affect completion of other systems. A concrete canoe, on the other hand, has no moving parts, and the bulk of the assembly is accomplished over a single day. While members do assist with multiple parts of the project, the functional divisions of the Sharks team (paddling, construction, mix design, display, and fundraising) operate independently. Only two of the subteams—mix design and construction—can actually affect the seaworthiness of the canoe. And if one group is behind schedule, the others can usually continue without interruption. Consequently, collaboration between the Sharks subteams is needed infrequently.

Project complexity may also contribute to the Jets’ greater emphasis on Training & Mentoring. Technical skill is a critical aspect in the design and construction of a running vehicle. Knowledge of welding, composites, machining, electronic control systems, fuel pumps, vehicle dynamics, and ergonomics are all required, and a successful team must include several specialists. Members often work on a subteam for a year or more before they gain enough experience to take
responsibility for even a small part of the car. In contrast, technical learning opportunities within a Concrete Canoe team are more limited. Mix design is handled by largely by the mix design lead, with occasional assistance from others. Historically, this team has rarely changed its hull design (“If it works, why change it?” said one team member), and the mold for the hull is milled by outside contractor. Casting—perhaps the biggest technical learning experience for the team as a whole—is a one-day event. Successful casting requires experience with applying concrete to the mold and installing the post-tensioning cables, but the task can be accomplished by a team of “laborers” under the direction of one or two knowledgeable team members.

Sharks were more likely than Jets to mention Motivating Others and Delegation as leadership behaviors. While self-motivation was identified by respondents on both teams as a characteristic of engineering competition team members in general, the ability to motivate others was associated with leadership slightly more often by the Sharks. The reasons are not clear, but the difference in team work schedules could account for the discrepancy. During the fall semester of the year under study, the Sharks held meetings but had little real work to do. Delays in obtaining materials set back the schedule by many weeks. Keeping new members engaged during the slow period may have required effort on the part of veteran members. Involvement of new members on the Jets team, on the other hand, was not constrained by such delays. New members could spend the fall semester learning to use milling machines and CAD software, and experienced members could focus on designing their respective systems. Simply being engaged in a challenging task may have reduced the need for external motivation.

One of the more striking differences between the teams arose in the discussions of Delegation. While most of leadership behaviors were discussed in terms of positive actions performed by team members, delegation was the exception. Sharks saw the failure of the captain to delegate as a flaw in his leadership. Several expressed regret at not having been asked to take on more responsibilities. However, few team members were willing to take action without the captain’s blessing. Even the member praised for being confrontational was willing to let the schedule slip rather than usurp the captain’s authority. In contrast, the Jets hardly mentioned delegation at all. Nonetheless, it was clear that the interviewed Jets trusted each other and frequently delegated responsibilities. Perhaps these team members all felt fully empowered in their positions and thus did not recognize delegation as a specific leadership behavior.

The leadership behavior category recognized by the fewest team members (3 from each team) was Boundary-Spanning. Almost all of the members who mentioned boundary-spanning behaviors had considerable prior leadership experience, within either ECT or other organizations. This suggests that students may not be able see the value of boundary-spanning until they have gained more experience.

Certain leadership attributes may be over-valued within the teams. Within each team, certain behaviors and characteristics are considered part of the ideal and serve as filters for leadership positions. Among the Sharks, team experience was the most frequently mentioned attribute and was cited as the single most important factor in selecting the captain. Only senior team members were considered for the captaincy, despite the acknowledgement that some younger members of the team may have been better suited for the position. For the Jets, commitment, as evidenced by “hard work,” was the most commonly mentioned ideal. While the members associated other
behaviors with leadership as well, they made it clear that a person who does not spend many hours in the work area will never be considered a member of the “core” team.

Conclusion

Previous explorations of leadership in student engineering teams[^25] focused on positional leaders. No other studies were found that examined leadership in engineering competition teams from a non-positional and process-oriented perspective.

In general, leadership behaviors identified in the functional leadership literature were recognized by at least a few members of each team. That said, understanding leadership is not the same as exercising leadership. Respondents were unsure of how to address deficiencies in team performance, and they sometimes failed to recognize deficiencies in their own behavior. Team members expressed frustration with project management and communication in particular. They bemoaned the lack of technical depth and were concerned about the development of members’ skills. They told stories of intense disagreements, toxic teammates, and conflicts that went unresolved. And, despite team members’ claims of excellence, the teams did not perform particularly well at their respective competitions during the year under study.

The students in this study had a good mental conception of leadership and credited the team experience for helping them develop as leaders. But experience alone is an insufficient teacher[^28]. For the engineering competition team experience to be a true vehicle for leadership development, students must learn more than how to define leadership. They must also learn how to exercise leadership. Future work will explore ways that colleges can actively support the leadership development of engineering competition team members.

References


