

**AC 2009-907: ORGANIZATIONAL LEADERSHIP AND EFFECTIVE TEAM  
PROBLEM-SOLVING STRATEGIES IN ENGINEERING DESIGN PROJECTS: AN  
ANALYSIS OF STUDENT PERCEPTIONS**

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# **Organizational Leadership and Effective Team Problem Solving Strategies in Engineering Design Projects: Analysis of Student Perceptions**

## **Abstract**

As engineering educators, we seek to promote types of effective and satisfactory team experiences that will be required in professional practice. This project expands findings from a previous case study examining the perceptions of individual team members working within teams to determine each team's processes of communication, problem solving, and leadership strategies used in Capstone Design projects. Our objectives in this study are to identify and categorize this perceptual data at both individual and team levels in order to identify any consistent factors or characteristics that may contribute to each group member's perception of a shared experience.

Findings from a previous case study involving one team of Capstone Design students consistently indicated links between each team member's perception of shared team experiences and the team's overall levels of effectiveness. Based on these findings, it seems reasonable to conclude that analysis of perceptual data from a larger number of team members would yield increased levels of understanding of these interactions. For these reasons, this expanded study shared research questions similar to the original case study:

- How do individual members of Capstone Design Teams perceive and describe types/forms of team communication and collaboration?
- How do team members support their own perceptions?
- Does a relationship exist between team members' perceptions of shared group experiences and the ability to transfer "lessons learned" from the design project to future leadership skills?

The results of this study further reinforced the findings of the previous case study. The success of an engineering capstone design project is influenced to a large degree by the perceptual alignment of the individual members of the team. Students' perceptions regarding the level of communication and work distribution in a group are integral to group alignment and agreement. Instructors should understand these facts and take steps to both measure and influence student perceptions to promote group alignment. Additionally, groups that have a balanced attribution between external and internal factors and a balanced level of leadership have greater perceptual alignment as well.

## **Introduction**

This project presents the results of three case study examinations of individual group member's perceptions of shared experiences as members of Engineering Capstone Design Teams over a period of two academic semesters, from Fall 2007 to Spring 2008. As engineering educators, we acknowledge the critical importance of effective problem solving teams and leadership skills. At the same time, we recognize the inherent difficulties associated with documenting and

characterizing problem solving interactions between team members. One consistent characteristic is the role of individual perceptions related to shared team experiences.

In other words, studies of Organizational Leadership assert that each student in a design team brings varying degrees of both content knowledge and communication strategies, and an instructor's understanding of these characteristics is essential to modeling and promoting effective teams. Our study integrates theories of Organizational Leadership, Engineering Education, and Educational Psychology to investigate our students' perceptions, attributions, and lessons learned in relation to team experiences.

The methodological approach of this study was designed to elicit team members' perceptions of shared team experiences through a mixed-method research approach. Primary data for this study was obtained from a Reflective Essay assignment, submitted by all Capstone Design students at completion of the project. Each student was required to submit an essay where they looked back over the entire course of the project and commented on strengths and lessons learned. Using these instruments, the researchers were able to expand on a previous case study, which focused on a single group.

## **Literature Review**

### *Organizational Leadership Theory and Engineering Design Project Teams*

Traditional engineering design education has stressed the end-product of the design process, however, more contemporary engineering design education pedagogy acknowledges the importance of examining a team's processes of communication, collaboration, and problem solving as critical components essential to the end-product of design. While traditional engineering design is grounded in technical knowledge applied to problem solving, contemporary engineering design expands design to reflect the importance of human connections through clear communication, strong problem solving strategies, and dynamic leadership.

### *Communication Processes and Group Productivity*

Since the early 1970's, research studies of effective group characteristics have consistently demonstrated strong links between the levels of group communication and group performance.<sup>1, 2, 3, 4, 5</sup> Tschan's 1995 study reported that "groups engaged in high-quality 'cycles' of communication, including interactions that involved orienting the group to the task, planning how the work would be done, and evaluating the outcomes outperformed other groups who did not have systematic cycles of communication".<sup>2</sup>

Technological advances have also increased group members' access to varied types of communication including cell phones, e-mail, virtual meetings, and web-based project forums.<sup>4</sup> According to Riggio, the opportunity for diverse modes of communication has increased both group productivity and team members' satisfaction with collaborative projects.<sup>4</sup>

Clearly, effective communication systems are critical to collaborative group processes, however, the communication system in and of itself does not always result in positive group outcomes.

Most adults have worked as members of unproductive teams that have had access to communication systems.<sup>6</sup> What factors are behind these unproductive teams? How can we explain why two members of a three-person team report satisfaction with the team's communication and collaborative processes while the third member indicates dissatisfaction in the same areas? Research studies in Leadership Communication and Organizational Behavior suggest that differences in evaluation of communication levels within teams often stem from each group member's perception of particular situations.<sup>4,7,8</sup> Put another way, communication patterns found in engineering design groups suggest that effective groups adopt an intricately-connected web of both cognitive and social interactions.<sup>9,13</sup>

### *Perceptual Factors*

Perception is defined as “the process of receiving information about and making sense of the world around us”.<sup>7</sup> In engineering problem solving, processes of perception are related to “mental models” that each member contributes to the larger group. Perception requires both cognitive and social processes. Information from an individual's “mental model” represents a form of cognitive data, much like a folder within the individual's internal knowledge bank, which is representative of previous experiences and lessons learned from similar experiences. These lessons learned also represent the social component of perception through the individual's continual process of assessment and evaluation of situational results through a series of decisions. The cognitive portion of perception stores conceptual knowledge while the social portion makes sense of results through a process of assigning responsibility for a specific outcome or result. These processes are defined as attribution theories.

### *Attribution Theory*

Attribution Theory is a perceptual process of deciding whether an outcome or event is caused by external or internal factors. In other words, it is a matter of attributing an outcome to one's personal effects (internal) or an environmental effect which, many times, include other team members (external).<sup>4</sup> Complete external attributions, where a student always blames others or situational factors, may not result in perceptual prowess. At the same time, total internal attributions, where a student sees themselves as always at fault, will probably not reflect clear or accurate perceptions either. This is important because attributions link perceptions to cause-effect relationships which tend to lead to more decisions based on previous attributions. It is important to note that attribution issues can be both positive and negative. This explanation might then account, in part, for two members of the same group having completely opposite perceptions regarding a shared project or experience. As a student learns negative lessons from application they then tend to attribute negatively in future events.

There are multiple levels of description in Attribution Theory. As explained in the preceding section, the first type of differentiation comes from the member's attribution of the situation or behavior as either external or internal attributions<sup>4</sup>. These attributions generally answer the questions of “what or who is responsible for this situation or behavior?” or “who's fault was it?”

The next level of identification in Attribution Theory attempts to further explore the initial characterization by identifying what are known as attribution errors. Because perception itself is

highly subjective, certain types of errors are frequently and consistently demonstrated. Such examples include:

- *Fundamental Attribution Error*: This type of error is often found in conjunction with external attributions where a person attributes the situation or behavior to other group members. Frequently, the perceiver interprets these types of attribution to specific internal characteristics of the other person/people. For example, a group member might attribute low levels of group communication to another group member's chronic lateness for group meetings. The perceiver could then make the assumption that the group member is lazy or doesn't value the other group meetings, and these types of personalization and or characterization attributions without real evidence are known as fundamental attribution errors.
- *Self-Serving Attribution Error*: This type of error occurs when "people tend to attribute their favorable outcomes to internal factors and their failures to external factors."<sup>4</sup> These attributions can be both external and internal, but essentially, the perceiver claims internal attribution when situations are positive and employs external attribution when situations are negative.

For the purposes of brevity, other explanations of attribution error and types of attribution effects will be discussed where relevant or necessary in each of our case studies.

## **Methodology**

### *Participants*

Data for this study was obtained from undergraduate engineering students enrolled in ME496: Mechanical System Design at the United States Military Academy during the spring of 2008. The Engineering Design course is a required class for all mechanical engineering students, and must be completed successfully for graduation. It is the culmination of a three-course sequence. The first class teaches students how to build individual parts of machines in Manufacturing and Machine Component Design: ME403. Students then learn the basics of the engineering design process as individuals in the first half of Mechanical Engineering Design: ME404. During the second half of the ME404 instruction, students select a project to work on as a group. The project is referred to as their Capstone Design and by nature includes problem solving and teamwork skills, and is designed to reflect the types of activities and situations students are likely to face as professional engineers. The teams range in size from 3 students up to multidisciplinary teams of 10-12. The primary focus of the remaining portion of ME404 is to utilize the engineering design process to develop the basic design. Students then take ME496: Mechanical System Design, where they must build and demonstrate a working prototype of their design. Of approximately 12 Capstone Design Teams, three teams were selected for this study based on the faculty advisor's interest in team problem solving processes and willingness to participate in this study. The three teams in the case study represented the full spectrum of team sizes as one had 4 members (Team Design-Build-Fly), one had 6 members (Team Spirit Tank) and the largest team had 10 members (Team Baja).

### *Data Collection Instruments*

The primary instrument for data collection consists of each team members' narrative response to an end-of-project reflective essay assignment required of all students enrolled in the Capstone Design Course. Instructions for completing the assignment were as follows:

*Reflect on your experiences with this project. What were three strengths and three areas needing improvement? How have you personally grown from this experience? What lessons from this Capstone experience will you take with you as a Lieutenant in the Army?*

There was no specified length requirement for the Reflective Essay, and all Capstone students were allowed to choose between two formats for submission: (1) the traditional, written narrative form, or (2) verbal responses recorded via video-tape. This assignment was submitted during the last week of the semester, approximately one month after completion and presentation of team projects.

### *Procedures for Data Analysis*

Students responded to the questions with little supervision. Once the reflective essays were complete each project advisor ensured that the reflective essay for everyone on his or her team had been submitted electronically; either as a word file or as an mpeg movie file. This lack of direct contact resulted in several of the students completely failing to answer the questions or responding with feedback that, while enlightening, failed to answer the assigned questions. Analysis of the essay data was then performed in two stages:

- In Stage 1 of analysis, each team's individual essays/videotapes were reviewed, and specific responses were extracted/excerpted in each of these categories:
  1. Perception of the team's processes of communication and collaboration
  2. Attribution factors of reported processes of communication and collaboration
  3. Application/Transfer of "lessons learned" through the Capstone Design Project to Army leadership and/or professional practices
- In Stage 2 of analysis, these excerpts were further analyzed to determine the team's general sense of alignment between the individual members' perceptual and attribution responses. The final part of analysis examined the "lessons learned" as related to team members' overall project experience.

Results of each case study are reported as excerpts from the Reflective Essay assignment, and these excerpts are presented in a series of three tables (one representing each area of analysis). The data was evaluated using a system of dual-categorization. In the category of communication and collaboration, excerpts were deemed either positive or negative based on the perceptual information. In the category of attribution, excerpts are broadly classified as either internal or external. Excerpts from the leadership category were characterized as either leader-centric or follower-centric. Leader centric is defined as a lesson learned that helps the student guide and direct others such as an excerpt from the essay that remarks on the importance of clarity in communication with others. Conversely, if a student remarks at how much they have learned

about the need to persevere and overcome adversity, that is seen as a lesson that helps the individual perform better due to internal factors and would be categorized as follower-centric.

## Findings

### Case Study 1: Team Baja (10 Total Group Members)

Table 1: Perception of team processes for communication/collaboration		
Excerpt #	GROUP MEMBER RESPONSE	Perceptive Rating
1	<i>As the project leader, I saw on a daily basis how the group dynamic was affected by my actions. I had to strike a delicate balance with my teammates, since everyone needed to work hard to get the project complete (but asking too much of them could have a negative effect).</i>	+
2	<i>Our team was fun. We learned things from each other, and if somebody didn't know how to do something, chances were good that someone else in the team could step in.</i>	+
3	<i>....we sometimes had to juggle schedules, but we always worked it out so that we'd work together and meet our deadlines. My group was good about that.</i>	+
4	<i>We learned early on that we needed to do a better job communicating with each other as a group.... I would recommend that teams hold meetings more often and that instead of working separately that everyone work together down in the shop at the same time.</i>	+

Table 2: Attribution factors of communication and collaboration		
Excerpt #	GROUP MEMBER RESPONSE	Attribution Classification
1	<i>The dedication to finishing the car on time was one of our strengths. Our team members repeatedly put in long hours of work at night and on weekends to ensure that it was completed in time for competition.</i>	Internal
2	<i>Our knowledge and experience machining and working with tools was one of our strengths for it allowed us to be efficient with time we spent working on the car, and ensured that we produced a sound product.</i>	Internal
3	<i>The initial timeline our project leader came up with was over ambitious and didn't take a realistic look at how long processes would take.</i>	External

Table 3. Transfer of “lessons learned” to leadership		
Excerpt #	GROUP MEMBER RESPONSE	Type of Leadership Transfer
1	<i>...I have learned some important lessons on how to work effectively on a group and how to motivate the other members of the group to work as well. This is also probably the most important lesson that I will take with me to the Army... because I will be in charge of a group of my peers and need to motivate them to accomplish a task.</i>	Leader
2	<i>...as a leader in the Army, I will use this knowledge to get the best out of everyone and get the mission done as best as it can be. Also, I learned time management skills I think it will be the same way in the Army. All things need to be done but some things are crucial and need to get done and be done well for the mission to be a success.</i>	Follower
3	<i>The project was very beneficial to my future engineering an officer career because it presented a problem with constraints that could be solved in many different ways. Like the real world, there was no correct solution; it was up to the team to deliver the best solution that they could both mentally and physically achieve.</i>	Follower

*Interpretation of Findings for Case Study #1 Team Baja*

For the most part, the excerpted data from Team Baja indicates that team members shared a common perceptual basis and had a high degree of alignment in Categories 1 and 2:

- All four excerpts indicated positive experiences with the team’s processes of communication;
- Excerpt 4 expressed the value of clear communication channels between group members, and suggested a method of increasing the group’s ability to collaborate more frequently;
- In the category of Leadership, two of three excerpts identified the transfer of “lessons learned” to future leadership opportunities as follower-centric, while one excerpt (#1) was categorized as leader-centric.

These results tend to demonstrate that a high degree of alignment and cohesion existed within Team Baja. Though there were setbacks and failures during the overall project, the individual team members demonstrated a shared perception that had high alignment. Additionally, the attribution of the team was balanced with individual team members seeing both internal and external factors as contributing to the overall success of the team. Additionally, there was a balance of both follower and leader centric transfer to future leadership. Both of these indicate a highly perceptive team that was balanced.



Case Study 2: Team Design-Build-Fly (DBF) (4 Total Group Members)

Table 4: Perception of team processes for communication/collaboration		
Excerpt #	GROUP MEMBER RESPONSE	Perceptive Rating
1	<i>The initial enthusiasm we collectively had in the first semester of the project evaporated shortly after coming back from Christmas leave. Routinely, I found myself trying to organize teamwork only to have one or two group members who always seemed to have an excuse to not work and let someone else pick up their workload.</i>	-
2	<i>Even when our team failed, we were able to remain persistent and positive...</i>	+
3	<i>We truly never escaped the storming phase as a group. There was always some argument over what would work better...there needs to come a time when the team can place personal issues aside and work together.</i>	-

Table 5. Attribution factors of communication and collaboration		
Excerpt #	GROUP MEMBER RESPONSE	Attribution Classification
1	<i>...I was faced with the daily dilemma of either cross-loading extra work on the rest of the group, or letting the team suffer the consequences by turning in an incomplete assignment...essentially cutting off my nose to spite my face. I found myself choosing the former more than the latter simply because I refused to allow the team's grades to slip because of a single individual.</i>	External
2	<i>I never imagined that some of my group members, whom have worked side-by-side with me for years, would openly refuse to put forth their fair share of effort. As a peer, I have no actual authority (besides my leadership title) to compel them if they refuse to comply, which unfortunately happened more times than I would like admit.</i>	External
3	<i>The time given to work on this project is way less than most of the other teams at the competition. Several of us would pull 40 to 60 hours a week working on the vehicle.</i>	External

Table 6. Transfer of “lessons learned” to leadership		
Excerpt #	GROUP MEMBER RESPONSE	Type of Leadership Transfer
1	<i>It taught me about persistence, and the “never quit” attitude. I am very grateful that I was a part of Design, Build, and Fly.</i>	Follower
2	<i>Completing this capstone project has been the most challenging academic and leadership experience I’ve had thus far. Not only is it extremely time-consuming and laborious, but it involves peer leadership which has been a very difficult task for me as team leader. I’ve also garnered several lessons that will be highly relevant to my Army experience; particularly in regards to group management, project planning and goal-execution. Despite the difficulty, the project was a rewarding experience,</i>	Leader
3	<i>From this project, I will take the process of getting a problem that has limitations and find a way to solve it. As a lieutenant, it is my job to find solutions, to emphasize teamwork, and to lead by example. The experience of Design, Build, and Fly developed and strengthened these qualities. This experience also showed me that the real world does not always follow the plan on paper; there will always be set backs or obstacles to conquer. I have learned to remain persistent until the mission is accomplished. Problem solving, Teamwork, deadlines, innovation, and persistence were all qualities that I gained from my capstone and every one of them will be used as a lieutenant and on while serving in the United States Army.</i>	Leader

*Interpretation of Findings for Case Study #2: Team Design-Build-Fly (DBF)*

Team Design-Build-Fly’s excerpted data suggested significant disparity between the group members’ perceptions. There was no clear alignment demonstrated in the excerpts in any of the three categories of analysis; at times, it seemed the data presented completely different perceptions of the shared Capstone Design Project. A summary of the excerpts in all categories follows:

- Two of three excerpts in the communication and collaboration category indicated strongly negative experiences, while the one positive response was strongly enthusiastic;
- In the category of attrition, all three of the excerpts attributed the team’s communication to external factors. In addition, the excerpts consistently identified the action/inaction and/or behavior of other team members as sources of poor communication.

- In the category of Leadership, two of three excerpts identified the transfer of “lessons learned” to future leadership opportunities as leader-centric, while one excerpt (#1) was categorized as follower-centric.

The results showed a large degree of misalignment within Team Design Build Fly. The team members fought about what to do and had no common picture of what was happening. It is illustrative that the preponderance of attribution was external and was indicative of a fundamental attribution error. The comment that the group “never escaped the storming phase” coupled with the preponderance of leader centric lessons would indicate a significant amount of too many leaders within the group. This is a common occurrence within student groups as peer leadership is one of the most difficult.

*Case Study 3: Team Spirit Tank (6 Total Group Members)*

Table 7: Perception of team processes of communication/collaboration		
Excerpt #	GROUP MEMBER RESPONSE	Perceptive Rating
1	<i>Team work is difficult due to many different ideas and little time, but we still work well. We communicate often and we are looking forward to graduation.</i>	+
2	<i>When we began the project, we broke down the work into three subsystems and assigned a team to work on each one. This worked pretty well for the design part, but it didn't really continue through the build portion.</i>	-
3	<i>So far the teamwork aspect of the project has been one of the most challenging. We communicate often but not effectively about team goals and without a clear sense of how everything fits into the building process. This is evident by the fact that work has not been equal.</i>	-

Table 8: Attribution factors of communication and collaboration		
Excerpt #	GROUP MEMBER RESPONSE	Attribution Classification
1	<i>There &lt;was&gt; some disconnect that no one seems willing to work at the times I prompt them.</i>	External
2	<i>I think our weakness is a lack of cohesive effort. Two or three of us have been carrying the bulk of the workload. We need to get everyone focused if we're going to finish.</i>	External

Table 9: Transfer of “lessons learned” to leadership		
Excerpt #	GROUP MEMBER RESPONSE	Type of Leadership Transfer
1	<i>Our team is very close. Engineering is without a doubt the toughest part about West Point. Anyone can crawl through mud, not sleep for days, march for hours, and fire weapons. It takes a special character to fight through the CME demands as a cadet. We've come so far together, and have been through so much, nothing really disappoints or upsets us. We can complete any mission given the resources and mentors from CME.</i>	Follower
2	<i>I believe our project was a success, and as an Army Officer, I will use these experiences to try and work on how to work better with my team and how to manage my time more efficiently.</i>	Leader
3	<i>What will I take with me to the Army? I don't know---maybe lack of sleep and last-minute panic situations. I'll also use this experience to work on planning more so that there's less sitting around and more doing.</i>	Follower

*Interpretation of Findings for Case Study #3: Team Spirit Tank*

Once again, the excerpted data from Team Spirit Tank indicated differences in group members' shared experiences of the overall Capstone Design Project. In contrast to Case Study Team #1 and Case Study Team #2, excerpts from members of Team Spirit Tank suggested that negative perceptual experiences in Category 1 and Category 2 may be related to Category 3's Leadership focus. Examples of group members' frustration were evident in many of the excerpts:

- Two of the three excerpts indicated positive responses in the category of communication and collaboration while one excerpt (#3) expressed clearly negative perceptions about not only the group's communication process, but also noted the group's planning process in general;
- The data revealed only two applicable excerpts in the category of attribution, and both responses were external in nature. Both excerpts indicated other group members' failure to share group responsibility equally.
- In the category of Leadership, two of three excerpts identified the transfer of “lessons learned” to future leadership opportunities as follower-centric, while one excerpt (#1) was categorized as leader-centric.

Team Spirit Tank showed a higher degree of alignment than Team #2 and it was very well aligned at the beginning of the project. However, as the project progressed, the alignment of the team decreased as did their productivity. The attribution became increasingly external showing a drift toward the fundamental attribution error. However, there was a greater balance between leader and follower centric lessons. Given that, many of the comments were negative and,

especially in this group, the leadership seemed to influence the change in perceptions and attribution as the project progressed.

## Results

The outcomes of the team efforts closely mirrored the perceptual alignment of the teams. The team that exhibited the closest alignment had the greatest success. In terms of alignment, Team Baja had the greatest followed by Team Spirit Tank with Team Design Build Fly showing the lowest degree of alignment.

In case study #1 (Team Baja), the student team was able to construct a vehicle and go to their competition where the United States Military Academy team (composed of different students) the previous year was not able to even make it to the competition. While there, Team Baja placed 39th out of over 100 teams which was one of the better showings by a team from the Military Academy. They had some of their strongest comments from the technical inspectors who remarked that their car had many traits that they normally expect from an experienced and established team. In other universities, mini-baja teams spend several years working on their cars, a situation that the Military Academy's curriculum cannot support. Despite being at a disadvantage, Team Baja finished well above the 50 percentile of the teams that they competed against.

In contrast, Team Design-Build-Fly (DBF) had numerous delays in the construction and testing of their aircraft and ultimately crashed just a few weeks before their competition, making it impossible for the team to even compete. In the design build fly competition, the aircraft requirements are changed every year to force teams to build entirely new aircraft. Thus, unlike Team Baja, Team Design Build Fly had a level playing field and could reasonably be expected to perform as well as an average competitor but fell short of even making it to the competition.

Team Spirit Tank was in between these two teams in terms of performance. The Spirit Tank project was not part of an intercollegiate competition so the measurement of project success was more subjective. The team set as a goal:

*“To create a highly mobile, extremely realistic looking MIAI Spirit Tank that will be able to drive into athletic events and fire T-shirts out of the main gun in an attempt to raise Corps morale and overall unit pride.”*

The project was able to partially meet this goal. The tank was constructed and had an impressive performance at the projects day presentations. The vehicle functioned as designed and had the majority of the desired subsystems installed. However, the project lacked one primary subsystem, the ability to elevate and hold the gun, and had numerous refinements that had been identified which could not be implemented due to time constraints. Greater team alignment could have prevented this. However, it was an extremely ambitious project that many people felt would not be capable of achieving even rudimentary capabilities. Team Spirit Tank surpassed these expectations and was considered a huge success but there remained room for improvement.

Essentially, a rank ordering of perceptual alignment among team members showed a direct correlation to the effectiveness and overall success of the design team. Additionally, a balance of traits, in terms of internal and external attribution, as well as follower and leader roles seems to

be necessary. Teams 2 and 3 both exhibited mostly external attribution and both struggled with team alignment. The team with the worst alignment had the most leadership centric lessons learned. A clear definition of roles and skills in peer leadership were missing in this team.

## **Recommendations**

One key point underscored through this research is that student perceptions play a large role in determining group alignment and agreement. Attribution and leadership are two traits that must be balanced and both are socially dependent. Instructors need to be aware of these factors. It is important to note that attribution plays a key factor in the social processes related to perception. How students assign responsibility for errors and difficulties is important.

Team members should have a balanced attribution and to facilitate this instructors should have periodic reflective assignments that force students to evaluate their personal weaknesses and contributions to the group project. Additionally, instructors should force teams to periodically reevaluate their communication and work assignments, and give the individual team members an outlet to express perceptions. One of the key points discovered from this investigation is that the perceptions of team members are as important as reality to effective problem solving, if not more so. Given this, instructors should have a plan to measure, and when necessary adjust, this aspect of team dynamics.

Faculty should ensure that periodic assessments are included as the project matures and develops, as what worked in the beginning may be completely misinterpreted as the semester develops. This is facilitated when students are required to break their project into distinct phases and each phase is evaluated to determine work distribution and communication requirements. The design portion of the project will have distinct differences as compared to the build portion or the testing and refinement phases. Perceptions should be measured at each phase to see how well group alignment is being facilitated.

To facilitate correct perceptions, design project advisors need to ensure that groups plan a detailed communication strategy as early as possible and then either adhere to it or adjust it, as necessary, as a group. One method to ensure this is to make it a graded requirement and force the group to redo incomplete or illogical communication plans. This avoids miscommunication and the erroneous perceptions that generally result. Faculty can address the second characteristic by assigning individual grades and monitoring students' level of participation. These actions are important to ensure that students perceive that work is fairly and equally rewarded. A final design experience is a common facet in most engineering programs and it is incumbent on instructors to prepare students to enter the engineering profession as confidently as possible. Additionally, since the design experience is the usually the final step in an engineering curriculum, it will be the one that is remembered.

## **Conclusions**

While the results of this study represent a relatively small-scale methodology of examining three design teams through a case study format, it is possible that the findings could be generalizable to other design teams. Furthermore, the findings are significant because they help engineering

educators increase baseline knowledge about communication, problem solving, and leadership that takes place between team members over the course of a lengthy design project. In conclusion, we believe that individual team members' perceptions of their team's communication, problem solving, and leadership lessons are important, and the case study findings suggests links between the principles of Organizational Leadership applied to Capstone Design Team Projects. Specifically, teams with perceptual alignment and a balanced attribution were more successful. They were more successful because their perceptions were aligned. The old adage that perception is reality was never more true.

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