

## Investigating Team Roles Within Long-Term Project-Based Learning Experiences

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## Introduction

Experiential learning continues to increase in undergraduate engineering education in order to prepare students for their professional careers. Project-based learning is becoming more common throughout engineering programs, with the additions of first-year cornerstone design experiences and capstone senior design experiences. These experiences provide students with context for technical skills to be learned and applied as well as professional skills to be developed. While the first and final years of undergraduate engineering curricula have evolved significantly, the middle years are often lighter in project-based learning with more emphasis on engineering science courses and laboratories [1].

## Context

Vertically Integrated Projects (i.e., VIP Teams) provide another project-based curricular avenue for students to continue developing contextualized technical and professional skills, such as communication, teamwork, and leadership [2]. Vertically Integrated Projects are multi-semester, multi-disciplinary teams of students from across academic levels who work together to achieve long-term and large-scale project objectives. Students engage in VIP Teams by enrolling in the VIP courses which are one-credit, repeatable courses that are recognized as elective credit at New York University Tandon School of Engineering. NYU is one of over 40 institutions around the world with Vertically Integrated Projects programs, together known as the VIP Consortium. Each student generally participates (i.e., enrolls) on the same VIP Team for at least three semesters. Some students participate for up to three years. The long-term participation of students is essential to the peer-to-peer learning and mentorship that sustains VIP Teams over time. As students become more experienced on the VIP Team, they are expected to provide guidance to newer members, and have opportunities to hold different roles as well as a position of leadership within the VIP Team.

## Design Competition Teams

VIP Teams at NYU Tandon School of Engineering vary widely in their objectives (research, design, entrepreneurship, service, etc.) as well as their domains (e.g., transportation, robotics, etc.). One particular subset of VIP Teams at NYU Tandon School of Engineering are called Design Competition VIP Teams. Design Competition VIP Teams are those that participate in annual intercollegiate design competitions, generally hosted by professional organizations (e.g.,

SAE, ASCE, NASA, etc.). At other institutions, these projects are sometimes offered through capstone senior design experiences.

The Design Competition VIP Teams often garner significant student interest, and therefore become some of the largest VIP Teams with formal organizational structures. Generally, participation in a design competition team can offer a rich educational experience, although often a demanding one as well. Student participation in engineering design competition experiences has been investigated with respect to student demographics, and it was found that students' participation and engagement on a design competition team may be influenced by gender and race/ethnicity [3], [4].

The type of cooperative learning evident on VIP Teams over multiple semesters promotes "constructive socialization" [5]-[7] that helps students establish and develop their leadership roles within their project group. The establishment and development of leadership roles are facilitated by the criteria that Johnson and Johnson [5], [8]-[12] use to characterize cooperative learning: (1) Positive interdependence; (2) Individual accountability; (3) Heterogeneity; (4) Dispersed leadership; (5) Developing social skills; and (6) Reflection. The third criteria, Heterogeneity, has been highlighted as a significant deficiency in design competition teams with respect to underrepresented student participation, engagement, and retention [4]. This deficiency in membership, in turn, would exacerbate deficiency in leadership of members from these underrepresented groups.

### **Team Roles**

One of the most well-researched and commonly used team role models was developed by Meredith Belbin [13], [14]. Belbin defined a team role as a particular behavioral preference while performing tasks with other team members, and distinguished a team role from the concept of a functional role (the operational knowledge and technical skills relevant to performing a task) [13]. This distinction allows for the possibility that a group may be composed of several team members with the same functional role and different team role(s). The nine current Belbin Team Roles are described in Table 1. Each Team Role is defined by six factors: (1) personality; (2) mental ability; (3) current values and motivation; (4) field constraints; (5) experience; and (6) role learning [15]. Of particular relevance to the VIP Teams' structure are the connections that Belbin established between the following six stages of a team's development and the need for prevailing Team Roles at each stage: (1) identifying needs; (2) finding ideas; (3) formulating plans; (4) making ideas; (5) establishing team organization; and (6) following through [14].

The Belbin Team Roles have been operationalized through two instruments, the Team Role Self-Perception Inventory (TRSPI) and the Observer's Assessment Sheet (OAS). The TRSPI is comprised of 8 independent sections of 10 statements each. Each section contains one statement corresponding to each of the 9 Team Roles as well as one statement measuring social desirability. TRSPI respondents are asked to distribute 10 points total across any/all of the 10 statements in each of the 8 sections for a total of 80 points. To elaborate, a respondent could choose to assign all 10 points within one section to a single statement, or to distribute the 10 points across a subset of the statements, or to assign one point to each of the 10 statements in the

section. Since the score for each section sums to 10, the TRSPI is ipsative within a section, but not between any of the 8 sections.

Because Belbin recognized that the TRSPI should not be the only measure of a person's Team Role [17], Belbin also developed an Observers' Assessment Sheets (OAS) to make possible the corroboration or refutation of an individual's Team Role by at least four others who work with the team member (or who simply know the individual well). The 73-question OAS peer-rater checklist is divided into 2 sets of words or phrases that could describe the team member: 45 positive in part one, and 28 negative in part two. A peer-rater completes the OAS by ticking (or double ticking, if the peer-rater feels the word or phrase is particularly applicable) a subset of the words or phrases in each of the two parts. The OAS produces a ranking of the nine Belbin Team Roles, where the top ranked Team Role is regarded to be the dominant role.

*Table 1. Belbin Team Roles with summary descriptions [16]*

Team Role	Description of Positive Qualities	Description of Allowable Weaknesses
Completer-Finisher	A capacity for follow-through; perfectionism	A tendency to worry about small things; a reluctance to "let go"
Coordinator	A capacity for treating and welcoming all potential contributors on their merits and without prejudice	No more than ordinary in terms of intellect or creative ability
Implementer	Organizing ability, practical common sense, hard-working, self-discipline	Lack of flexibility; unresponsiveness to unproven ideas
Monitor-evaluator	Judgement, discretion, hard-headedness	Lacks inspiration or the ability to motivate others
Plant	Genius, imagination, intellect, knowledge	Up in the clouds, inclined to disregard practical details or protocol
Resource investigator	A capacity for contacting people and exploring anything new; an ability to respond to challenge	Liable to lose interest once the initial fascination has passed
Shaper	Drive and a readiness to challenge inertia, ineffectiveness, compliancy, or self-deception	Proneness to provocation, irritation, and impatience
Specialist	Single-minded, self-starting, dedicated	Contributes on a narrow front only
Team Worker	An ability to respond to people and to situations, and to promote team spirit	Indecisiveness at moments of crisis

Despite its prevalence, there are known concerns over weaknesses in the psychometric properties and predictive validity of the TRSPI. Often, these validity concerns are critical of the instrument

being used to make team selections or other high-stakes decisions [18]. Aritzeta, Swailes, & Senior reviewed 43 empirical studies regarding the construct validity of the Belbin TRSPI and concluded that the inventory has adequate convergent validity, although the discriminant validity among some scales was weak [15]. In other words, the Belbin team roles do show associations to cognitive and behavioral characteristics, although there is significant association between some of the team roles. This makes sense given that Belbin's theory states that each person on a team may naturally fit several team roles [14]. The construct validity of the OAS "as a whole is good" [16, pp. 345].

This study uses and compares both the TRSPI and the OAS over time, as both the comparison between self- and others' perceptions and over multiple timepoints represent a relative paucity in research on Belbin team roles [19]-[21].

## **Research Questions**

The goal of the research is to understand students' development of team roles and leadership over time, from both self and peer perceptions, and whether individual student characteristics may be relevant to such development in the engineering design competition team setting.

- To what extent does a student's self-perception of their Team Role, and interest in leadership, change over time?
- Do these perceptions of Team Roles vary when considering leadership title, URM status, or legal sex?  
To what extent does a VIP Team Leader's self-perception of their Team Role align or differ from their peers' perception?

## **Methods**

### **Data Collection**

The research study was reviewed and approved by the NYU Institutional Review Board prior to starting data collection. The survey was administered using Qualtrics software and sent via email to all students enrolled during a Spring semester in one of nine Design Competition VIP Teams at NYU, totaling 237 students. The student members of each Design Competition VIP Team were asked to complete the survey at two time points during the standard 16-week course semester (beginning and end). Due to publication timing, the data from the first round of collection are included in this study.

The Design Competition VIP Teams vary in size, from 8 to 55 students (mean team size: 26). There are as few as 4 and as many as 19 female students participating on any of the Design Competition VIP Teams (mean number of female students: 10). The Design Competition VIP Teams have as few as 2 and as many as 19 historically underrepresented students (mean number of underrepresented students: 7). In order to protect students' anonymity and for the purposes of grouping students into larger groups whenever possible, we define underrepresented minorities (URMs) as the composite group of Hispanic/Latinx, Black/African-American, American Indian or Alaska Native, Native Hawaiian or Other Pacific Islander, and students who identify with Two or More Races. Non-URMs, therefore, are those students who self-identified as White or

Asian. In addition, the specific Design Competition VIP Teams are not identified in order to ensure that students are not identifiable by association.

The survey begins by requesting a 3-tiered, IRB-required consent from potential research participants. Those students that provide full consent to participate in the research are given access to the study questions; otherwise, the survey is ended. In addition to data collected using the survey, participants also provided consent to integrate academic records (e.g., year in academic program, probationary status) and/or demographic records (e.g., gender) with the survey response data.

During the first round of data collection, at the beginning of the semester, the survey garnered 25 full-consent, self-perception responses using the TRSPI and 24 peer observations of 13 different team members using the OAS. Six students self-identified as VIP Team Leaders who completed the TRSPI and also were the subject of peers' OAS responses. Eleven of the responses represent members of the same VIP Team. Overall, students from 8 of the 9 targeted Design Competition VIP Teams responded. Together, there are 26 responses in this initial phase of this research study, representing 11% of all potential research participants enrolled in Design Competition VIP Teams. Twenty-five of 26 student participants fully completed the TRSPI, summarized in Table 2.

*Table 2. Participants disaggregated by URM status and legal sex, also with respect to leadership position.*

	Male	Female
non-URM	10	5
URM	5	5

	non-URM	URM	Male	Female
Team Leader	4	3	4	3
Member	11	7	11	7

The survey is composed of four major sections. First, students are asked to identify their personal information (academic major, race/ethnicity, and international student status, VIP Team affiliation, position). After the personal information is requested, students are asked several open-response questions regarding their interest in leadership positions on the VIP Team, and whether they have received any support or experienced any hindrances in pursuing such leadership positions. Third, students complete a self-evaluation using the TRSPI, and fourth, they respond to the OAS in evaluating at least one VIP Team Leader. Each Design Competition VIP Team has at least one designated VIP Team Leader, though most have more than one. For this reason, each study participant could choose to repeat the OAS portion of the survey multiple times for multiple VIP Team Leaders. Per IRB-guidelines, none of these responses were mandatory. The same survey was distributed again to the same group of potential research participants at the end of the same semester.

Although IRB regulations prohibit researchers' direct interactions with prospective study participants, the study team hopes that a similar peer-led phenomenon noticed during the initial phase of this study (where 11 of 19 members of a single VIP Design Competition Team appear

to have rallied each other to participate in the study) is repeated during future timepoints of this study, whereby increasing the number and validity of data and results.

### Data Analysis

Before beginning the data analysis, the individual survey responses were re-coded to be de-identified with respect to the research participants themselves as well as any student(s) that are referred to in the survey responses. All participant responses to the TRSPI are included for analysis. OAS responses are only included for those VIP Team Leaders that also completed the TRSPI, to ensure their consent and TRSPI responses for comparison.

After processing the data for de-identification, it was analyzed first at the individual-level. Each student’s responses to the TRSPI were used to produce a ranking of the degree to which they align with the various Belbin Team Roles. This was done by totaling the number of points allocated to the various statements associated with each Team Role across the 8 sections of the TRSPI. After the second round of data collection, the results will be used to generate and share individual reports with the participants for them to receive feedback regarding their responses. Since the statements in the TRSPI did not explicitly state which Belbin Team Role they were intended to reflect, the analysis of these began with assigning the most suitable Belbin Team Role to each of the statements in the Self Perception assessment. This assignment was done by using several existing, validated mapping reference tools, and after an independent consensus was reached by the research team on at least 72 (or 90%) of the statements with the category designated by the validated mapping resource. The distribution of the 9 team roles across the 80 TRSPI questions are given in Table 3.

*Table 3. Number of Belbin Team Role statements in Belbin<sup>®</sup> Team Role Self-Perception Inventory (TRSPI)*

Number of Statements in TRSPI for each Team Role			
Coordinator	7	Completer-Finisher	11
Implementer	9	Monitor Evaluator	9
Plant	11	Resource Investigator	7
Shaper	7	Specialist	9
Team Worker	10		

The values assigned by participants (1-10) to each TRSPI statement were summed within each Team Role; the total sum across all 9 Team Roles totaled 80 for each participant. To account for the different number of statements across the Team Roles, the sum of values across all statements related to a Team Role divided by the number of statements associated with that role. As a result, each participant has nine standardized scores, one for each Team Role, that were used to compare across Team Roles in the analysis.

Similar processes were followed to categorize and analyze peers’ OAS data. The OAS assessment tool, however, asked respondents to indicate which positive adjectives and phrases they believed the peer they were assessing reflected “More than Average” (analytical weight = 1)

or “In Abundance” (analytical weight = 2) and which negative or critical adjectives and phrases they believed were “Sometimes True” (analytical weight = 1) or were “Often True” (analytical weight = 2) about the peer they were assessing. The distribution of the 9 team roles across the 45 positive and 28 negative or critical adjectives and adjective phrases are given in Table 4.

*Table 4. Number of Belbin Team Role positive and negative or critical adjectives in Belbin<sup>®</sup> Observer Assessment Sheets (OAS)*

Number of Positive and Negative/ Critical Adjectives in OAS for each Team Role					
	<u>Pos</u>	<u>Neg</u>		<u>Pos</u>	<u>Neg</u>
Coordinator	4	2	Completer-Finisher	5	2
Implementer	6	3	Monitor Evaluator	4	4
Plant	9	3	Resource Investigator	4	2
Shaper	4	5	Specialist	5	3
Team Worker	4	4			

The OAS results were aggregated for analysis for those individuals who identified as a VIP Team Leader and received at least four OAS responses from peers on the same VIP Team. This was done by totaling the weighted tallies across the words and phrases which were associated with each Belbin Team Role. This sum was again standardized to account for the different number of adjectives and phrases by dividing the sum of each Team Role by the total number of adjectives and phrases associated with that particular Team Role. These OAS results were compared to the individual VIP Team Leaders’ TRSPI responses by rank. Because this analysis requires both a TRSPI response from the VIP Team Leader as well as OAS responses from at least four VIP Team peers, not all OAS responses are necessarily included in the analysis.

In addition to the analysis of the Belbin TRSPI and OAS, the open-responses were also open-coded to identify factors that are relevant to the respondents’ interests in and perceptions of leadership on the VIP Team. These summary data (grouped by Team Leader or Member, Gender, and Race/Ethnicity) are in Appendices A, B, and C.

## **Results**

### **Students’ Self-Perceptions of Team Role**

*RQ 1: To what extent does a student’s self-perception of their team role, and interest in leadership, change over time?*

These data represent students’ initial responses to the TRSPI, at the beginning of the semester. Each student’s responses resulted in nine standardized scores, one associated with each team role. The overall distributions of the TRSPI standardized scores from all complete responses are shown in Figure 1.



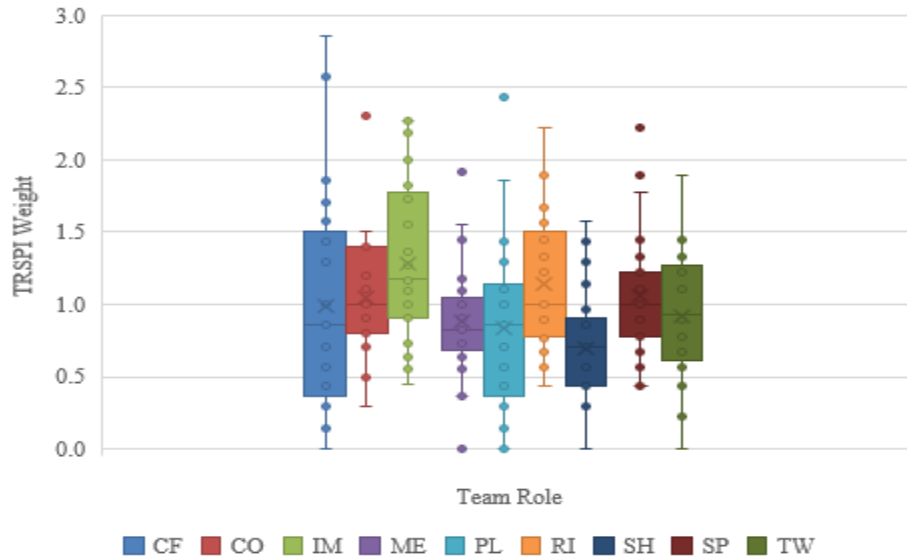


Figure 1. Distribution of students' TRSPI standardized scores with respect to each Belbin Team Role

The students' responses indicated the highest average TRSPI scores for the Implementer (IM; mean = 1.29; sd = 0.53) Team Role, followed by the Resource Investigator (RI; mean = 1.14, sd = 0.44) and Specialist (SP; mean = 1.06, sd = 0.42). The Shaper (SH) Team Role had the lowest average TRSPI score and a narrow distribution of scores (mean = 0.69; sd = 0.38). In other words, responding students' self-perceptions more closely aligned with the Implementer, Resource Investigator, and Specialist Team Role, while they less closely aligned with the Shaper, the Plant (PL; mean = 0.83, sd = 0.58), and the Monitor Evaluator (ME; mean = 0.88; sd = 0.38) Team Role. These standardized scores will be analyzed for change over time when additional data are included from the end of the same semester.

*RQ 2: To what extent do students' self-perceptions of their team roles vary when considering leadership role, legal sex, or ethnicity/race?*

The TRSPI scores with respect to each Team Role were compared when groups were disaggregated by several demographic identities (leadership role in the team, race/ethnicity, and legal sex), shown in Table 5. Since there is a limited sample size, the results focus on highest and lowest Team Role scores, and the largest differences between the scores.

Students' responses were grouped by title on the VIP Team, as either a Team Leader (or Sub-Team Leader) or Member. Overall, Team Leaders' responses were highest on average for the Implementer (IM), Resource Investigator (RI), and Plant (PL) Team Roles. Overall, Team members' responses were also highest on average for the Implementer (IM) and Resource Investigator (RI), as well as the Specialist (SP) Team Roles. The greatest difference between Team Leaders' and Members' reported Team Roles were evident when comparing the Specialist (SP) and Plant (PL) Team Roles, where Team Leaders identified more often as Plants (PL) than Team Members did, while Team Members identified more often as Specialists (SP) than Team

Leaders did. While both groups had low average TRSPI scores for the Shaper (SH) Team Role, the Team Leaders' still were much higher than Team Members' scores.

*Table 5. Average of standardized scores across the TRSPI Team Roles, disaggregated by demographic identities*

	<i>n</i>	CF	CO	IM	ME	PL	RI	SH	SP	TW
<i>by Title</i>										
Member	18	1.02	1.05	1.24	0.92	0.77	1.16	0.64	1.14	0.90
Team (or Sub-Team) Leader	7	0.90	1.04	1.40	0.81	0.99	1.09	0.83	0.85	0.97
<i>by Race/Ethnicity</i>										
non-URM	15	0.93	0.99	1.39	0.98	0.89	1.03	0.66	0.93	0.99
URM	10	1.06	1.14	1.13	0.74	0.74	1.31	0.73	1.26	0.81
<i>by Sex</i>										
Male	15	0.87	0.93	1.40	1.00	0.72	1.12	0.62	1.05	1.03
Female	10	1.16	1.22	1.11	0.71	1.00	1.18	0.80	1.08	0.76

Students who identified as a URM race/ethnicity indicated highest Team Role scores on average for the Resource Investigator (RI) and Specialist (SP) overall, which were also the highest relative to non-URM students. Non-URM students indicated the Implementer (IM) Team Role highest, also relatively high compared to non-URM students. Both groups of students' TRSPI responses ranked the Shaper (SH) Team Role lowest.

Male students' TRSPI responses were on average highest for the Implementer (IM) Team Role, which was also highest relative to female students' responses. Female students' TRSPI responses were on average highest for the Coordinator (CO) with Resource Investigators (RI) and Completer-Finisher (CF) Team Roles close and evenly behind, which were also highest relative to the male students' responses.

These relationships and rankings represent a small sample and initial timepoint. With additional data over more timepoints, statistical investigations will become more insightful.

### **TRSPI Comparison to OAS**

*RQ 3: To what extent does a VIP Team Leader's self-perception align or differ from their peers' perception?*

Seven team leaders completed the TRSPI, one of which received at least four OAS responses from peers on their VIP team. This set of data – one VIP Team Leader who completed the TRSPI who also received eight OAS evaluations from peers – will serve as a case study, summarized in Table 6. The scores of the TRSPI are not of the same scale as the OAS scores, and cannot be directly compared. Instead, the rank of scores is compared.

*Table 6. Peer and Self-Perceptions of a VIP Team Leader's Team Role*

Team Role	OAS Score		TRSPI Score	
	(Peer)	Rank	(Self)	Rank
Completer-Finisher	2.00	8	0.71	6
Coordinator	4.50	2	1.10	5
Implementer	3.00	4	1.27	4
Monitor Evaluator	2.38	6	0.55	8
Plant	2.08	7	1.43	3
Resource Investigator	3.00	4	1.56	2
Shaper	1.44	9	1.57	1
Specialist	3.25	3	0.56	7
Team Worker	4.63	1	0.44	9

The Shaper Team Role was ranked highest by the Team Leader's TRSPI responses, although it was ranked lowest by their peers' OAS responses. Conversely, the Team Leader's TRSPI responses ranked the Team Worker lowest while their peers' OAS responses ranked this as the highest Team Role for the Team Leader. Overall, there is very little relationship between the Team Leader's TRSPI and OAS responses.

Although not intended, this VIP Team Leader also chose to complete the OAS for themselves, which opened an interesting opportunity for comparison. The adjectives that were selected most by peers as characteristic of the Team Leader are shown in Table 7. Interestingly, there is good agreement between the adjectives selected by peers to describe the VIP Team Leader and the adjectives selected by the Team Leader to describe themselves.

*Table 7. Number of times peers selected OAS adjectives to describe Team Leader, compared to adjectives self-selected by the Team Leader.*

Adjective	Peer OAS			Self OAS		
	More Than Average	In Abundance	Total	More Than Average	In Abundance	Total
	(1)	(2)		(1)	(2)	
Helpful	2	5	12	0	1	2
Encouraging of others	3	4	11	1	0	1
Outgoing	2	4	10	1	0	1
Caring	3	3	9	0	1	2
Analytical	3	2	7	0	1	2
Diplomatic	3	2	7	0	0	0

### **Leadership Interest, Challenges, and Support**

Open-ended responses to questions regarding interest in starting (or continuing) leadership roles, challenges faced, and support received in pursuing leadership roles serve to elaborate, corroborate, and contextualize their quantitative responses. As can be seen in Appendices A, B,

and C, when these responses are viewed from the demographic intersections their respondents identify with, they provide further insight into salient factors that play roles in their views of how leadership may impact their selves, their teams, their projects, their future careers, and even the field of engineering overall.

When focused on the case study of the VIP Team Leader, the responses of the Team Leader and Team Members to the open-ended questions give more context to how the VIP Team Leader evidences their Team Roles. The VIP Team Leader scored highly as a Specialist Team Role on the TRSPI, as reflected by the following TRSPI statements (points out of 10 assigned to each TRSPI statement):

- I can provide information relating to my experience and expertise. (4)
- I can use what I have learned to help the team. (2)
- I am enthusiastic about applying my training and expertise. (1)

These statements highlight leveraging expertise to support the team, which the VIP Team Leader noted again through their response about support received for leadership: “[VIP Staff] has been extremley [sic] helpful as I learned how to be a lead for the team by always providing the resources and information I need. Along with alumni from the team have helped guide me on how to lead the team which has been extremley [sic] helpful as well.” As a VIP Team Leader, this student receives support from people with experience and expertise, and also provides their experience and expertise to others, akin to the Specialist Team Role.

When considering peers’ OAS and open-ended responses, the VIP Team Leader’s Team Worker Team Role becomes apparent as well. The VIP Team Leader described how “[b]eing in the leadership team has helped me strengthen my teamwork skills, public speaking, systems engineering and project managment [sic] skills. It’s taught me what it’s like to lead a team and helped me learn disipline [sic] with my studies as well.” This account from the VIP Team Leader aligns with peers’ OAS responses which described them as “Helpful” and “Encouraging of others” (teamwork skills), as well as “Analytical” and “Diplomatic” (project management skills). These adjectives were again salient in another peer’s open-response about support received to pursue leadership: “I have had significant support to become a leader in the future. My Team captain has established a mentorship program that will allow current members to get mentored so they could have an insider’s view of the program.” While the VIP Team Leader’s TRSPI scores did not closely align with the Team Worker Team Role, their peers’ OAS and open-ended responses both characterized how the VIP Team Leader aligned with the Team Worker Team Role.

## **Discussion and Conclusions**

Although the data are limited both in number and from a longitudinal lens, analyses of the data collected to date support several observations of note and worth tracking after additional data are analyzed in the near future.

The three Belbin Team Roles (Implementer, Resource Investigator, and Specialist) identified as most prominent from the TRSPI all have time-dependent qualities typically seen at the beginnings of a project. These Belbin Team Roles are associated with qualities including organizing, exploring anything new but having the possibility of losing interest once the initial

fascination has passed, and a self-starter, respectively. The prevalence of these Team Roles at timepoint 1 may imply that the passage of time could influence the qualities necessary and carried out, and therefore the Team Roles self-claimed on a subsequent TRSPI administration, as time passes.

It will also be of interest to future analyses if the Belbin Team Roles that were least evident at this time (i.e., Shaper, Plant, and Monitor Evaluator) supplant some of those Roles just highlighted as the most common at the beginning of this study. Furthermore, as the time passes, will interim-level Team Roles that were neither high nor low (i.e., Coordinator, Team Worker, Completer-Finisher) in this analysis move into one of these high or low categories as the work and needs of the team progresses over time (and as the roles' descriptions suggest)?

When students' self-perceptions were disaggregated by their leadership role on the team, the leaders ranked the Implementer Team Role highest on average. The Implementer (IM) Team Role is characterized by an organizing ability, practical common sense, being hard-working and self-disciplined. These skills and mindsets are important for a leader of a VIP Design Competition Team, which can be a demanding activity. VIP team members' self-perceptions of their Team Role were, on average, also highest for Implementer (IM) Team Role, and followed by an affiliation with the Resource Investigator (RI) and Specialist (SP) Team Roles which are characterized by connecting with new people and experiences, being able to respond to challenges, being dedicated, single-minded, and contributing on a narrow front. These qualities fit the goals of team members, who are usually responsible for pieces of the overall project associated with a particular sub-team.

Disagreement between the Team Roles identified highest in the TRSPI response from a Team Leader and their peers' OAS responses may have several explanations. This could be influenced by the survey's timing, the experience level of the Team Leader, or the length of time peers have been on the VIP team. Future data collections may evince patterns that speak to whether this agreement may align at different time points, or with students of varying experience. Although it was not an expected piece of data, it is noteworthy that the OAS response from the VIP Team Leader did align with the peers' OAS responses, leading to the consideration that the VIP Team Leader may perceive their own roles differently depending on their perspective.

### **Limitations & Future Work**

The data presented here represent an initial timepoint in a longitudinal study. The process in securing institutional permissions necessary to launch this study impacted the collection of multiple data points; a challenge that will not impact future data collection. The small number of responses could be due, in part, to the multiple required consent forms the students had to complete before even seeing the survey's content, the virtual communication saturation experienced by many during the COVID-19 move to remote instruction, and the absence of any prior data collection and public feedback to respondents that might have served as incentives to participate. The few responses collected in time to meet publication deadlines, therefore, temporarily limit any statistically significant analyses and/or conclusions that can be drawn at this time. In addition to some of the insight provided by the open-ended questions' responses, the research team has reason to believe this current data collection will be the timepoint with the fewest data given what was noted from a subset of this study's participants to date. One of the

eight VIP Design Competition Teams had outlier-level response rates that were many multiples higher than others', which the researchers believe (but cannot verify due to study guidelines on interacting with anonymous participants) may be due to direct encouragement from the VIP Team Leader – a phenomenon that researchers may wish to more actively encourage, and which in and of itself, may point to some of the goals of this study.

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**APPENDIX A:** Summary of Open-Ended Responses to “Why Continue in a Leadership Position”, by Leadership Role, Gender, and Race/Ethnicity

CONTINUING LEADERSHIP...	LEADER (or SUB-Leader)		MEMBER	
Ethnicity / Race	MALE	FEMALE	MALE	FEMALE
URM	<ul style="list-style-type: none"> <li>● Conveys Vision;</li> <li>● Makes choices;</li> <li>● Compares multiple purposes of leadership (competition vs. positive societal impact);</li> <li>● Inclusive ("we"; camaraderie);</li> <li>● Shared leadership (and stresses)</li> </ul>	<ul style="list-style-type: none"> <li>● Strengthens:</li> <li>● Teamwork Skills;</li> <li>● Public Speaking;</li> <li>● Systems Engineering;</li> <li>● Project Management Skills;</li> <li>● Learn discipline for my studies;</li> <li>● Participate more;</li> <li>● Take more responsibility</li> </ul>	<ul style="list-style-type: none"> <li>● Continuing a leadership role started while on a high school robotics team;</li> <li>● Wish to manage a large group of people at an entrepreneurial venture;</li> <li>● Benefit from as many leadership roles as possible;</li> <li>● Teaches much about working with a team;</li> <li>● Gratifying to be more in charge of scheduling and management;</li> <li>● strengthen my confidence as an engineer</li> </ul>	<ul style="list-style-type: none"> <li>● Leadership roles important to building a career in engineering; <ul style="list-style-type: none"> <li>○ Great way to learn how to:</li> <li>○ Communicate with others;</li> <li>○ Gain respect;</li> <li>○ Manage a project;</li> </ul> </li> <li>● Puts more responsibility on yourself;</li> <li>● An important experience;</li> <li>● Be able to contribute more to a team as a leader than as a member</li> </ul>
NON-URM	<ul style="list-style-type: none"> <li>● Wanting to see the finish of something (he) started;</li> <li>● Liked leadership role enough to continue for another year;</li> <li>● Enjoyed having some influence in the end product;</li> <li>● Weight of responsibility and the experiences gained were beneficial to professional career;</li> <li>● Gives responsibility to head a team</li> </ul>	<ul style="list-style-type: none"> <li>● Contribute to the growth of the team;</li> <li>● Mentoring new members as a junior after experiencing mentorship as a freshman;</li> <li>● As team evolves, emphasis on: <ul style="list-style-type: none"> <li>○ teaching;</li> <li>○ Collaboration;</li> </ul> </li> <li>● Striving for innovation</li> </ul>	<ul style="list-style-type: none"> <li>● Practical experience;</li> <li>● Learn to delegate tasks;</li> <li>● Manage deadlines;</li> <li>● Possibly work with people that have conflicting opinions;</li> <li>● Helps with career goals;</li> <li>● Being able to make a bigger impact in the team;</li> <li>● greater overview of the entire organization and project;</li> <li>● Would be a great test of my skills;</li> <li>● I could learn from the experience itself as well as from other members;</li> <li>● it's a wonderful place to contribute and grow</li> </ul>	<ul style="list-style-type: none"> <li>● Really enjoy being in/working on a team (environment)(x2);</li> <li>● One of the best ways to give back (x2);</li> <li>● Have learned a lot;</li> <li>● To be helpful;</li> <li>● Helps understand the responsibilities behind it</li> </ul>



**APPENDIX B:** Summary of Open-Ended Responses to “Challenges Faced as a Leader”, by Leadership Role, Gender, and Race/Ethnicity

CHALLENGES FACED AS A LEADER...	LEADER (or SUB-Leader)		MEMBER	
Ethnicity / Race	MALE	FEMALE	MALE	FEMALE
URM	<ul style="list-style-type: none"> <li>• Long-term Commitment by Team Members (and other sub-leaders);</li> <li>• Pressure to always make the right decisions;</li> <li>• Time (avoiding its waste, and completing tasks within given time constraints);</li> <li>• Onboarding (of new recruits and new sub-team leaders)</li> </ul>	<ul style="list-style-type: none"> <li>• N/A</li> </ul>	<ul style="list-style-type: none"> <li>• Self-questioning (x2): "Is it too early to pursue leadership roles in college?";</li> <li>• Technical background requirements;</li> </ul>	<ul style="list-style-type: none"> <li>• N/A</li> </ul>
NON-URM	<ul style="list-style-type: none"> <li>• Stagnancy ("Things are not happening"; "People are not doing work");</li> <li>• Insufficient Team Members</li> <li>• Team members doing "the bare minimum to scrap by";</li> <li>• Other (academic, personal) time commitments;</li> <li>• Finding candidates to succeed graduating Team Leaders (from an already scarce pool of interested/qualified candidates)</li> </ul>	<ul style="list-style-type: none"> <li>• Remote/Virtual Work;</li> <li>• Unable to experiment and produce results;</li> <li>• Giving members enough to do (Literature Reviews, etc.);</li> <li>• No bonding with teammates during lab times</li> </ul>	<ul style="list-style-type: none"> <li>• Balancing workload with responsibilities of the team;</li> <li>• Members unwilling to communicate;</li> <li>• Coordinating between all team members;</li> <li>• allocating tasks;</li> <li>• tracking individual progress;</li> <li>• resolving conflicts and settling differences</li> </ul>	<ul style="list-style-type: none"> <li>• Balancing workload with responsibilities of the team</li> </ul>

**APPENDIX C:** Summary of Open-Ended Responses to “Supporting People and Resources while Leading”, by Leadership Role, Gender, and Race/Ethnicity

SUPPORT AND RESOURCES WHILE LEADING...	LEADER (or SUB-Leader)		MEMBER	
	MALE	FEMALE	MALE	FEMALE
Ethnicity / Race				
URM	<ul style="list-style-type: none"> <li>• Faculty Advisor;</li> <li>• Fellow sophomores who step up as sub-leaders graduate</li> </ul>	<ul style="list-style-type: none"> <li>• Faculty Advisor;</li> <li>• Alumni from [Team];</li> <li>• Teammates;</li> <li>• Provided necessary resources and information;</li> <li>• Helped guide on how to lead the team</li> </ul>	<ul style="list-style-type: none"> <li>• N/A</li> </ul>	<ul style="list-style-type: none"> <li>• Applications and Approval process for leadership roles communicated to all team members equally</li> </ul>
NON-URM	<ul style="list-style-type: none"> <li>• Other Project Managers / Leaders;</li> <li>• Mentors</li> </ul>	<ul style="list-style-type: none"> <li>• Past and Present Team members;</li> <li>• Co-Team Leader;</li> <li>• Professor;</li> <li>• Program Director;</li> <li>• Collaborate with each other on tasks;</li> <li>• Constructive, illuminative criticism of work;</li> <li>• Administrative help;</li> <li>• Providing direction regarding deadlines, budgets, etc.</li> </ul>	<ul style="list-style-type: none"> <li>• Sub-team Leader;</li> <li>• Team Captain</li> <li>• Mentorship;</li> <li>• Shares insider's view of the program</li> </ul>	<ul style="list-style-type: none"> <li>• Leads acknowledged participation and interest by giving more opportunities for leadership;</li> <li>• invited to become a leader;</li> <li>• Many opportunities to step up and lead</li> </ul>