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Exploring the Use of the Competing Values Framework in Engineering Education

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Abstract

This study investigates the adaption of the Competing Values Framework (CVF) for use in studying behavioral complexity and leadership in engineering students working in project teams. Based on a foundation of other studies that leverage the CVF in an engineering education context, the CVF survey was slightly modified to be appropriate. Data were collected from students working on projects both in curricular and co-curricular settings. The data demonstrates levels of complexity among example student profiles and draws comparisons between curricular and co-curricular settings as well as between genders. Results show that while there are gender differences in the curricular setting, there are no significant differences in leadership roles between genders in the co-curricular setting.

Introduction

Engineers are faced with decisions that affect society on a daily basis. As engineering educators, we have the responsibility to educate engineering students in a way that prepares them for the challenges our society will face in the coming years in the areas of infrastructure, public safety, environment, and community building[1]. The National Academy of Engineering (NAE) sees engineers as servant leaders – leaders who have a primary focus to serve society[2]. Engineers who have business and management experience are the professionals who are given leadership positions[2].

While engineering leadership development programs have been added in the last 10 years to many U.S. universities, such as Iowa State, MIT, Penn State[3-5] among others, some argue that the discipline has not been fully embraced by the engineering academic community. Rottman et al. argue that "legitimacy of the field depends on engineers recognizing themselves as members of a leadership profession.".[1] They further elaborate to summarize some reasons why engineers do not consider themselves as part of a leadership profession: it takes over five years before engineers reach a management level and technical people tend to think of people problems as non-engineering, the traditional view of leadership goes against an engineering culture of equality, leadership is a vague term which does not align with technical thinking and analysis, and because leadership curriculum is often optional, it is perceived as less important.[1]

Despite barriers, engineering leadership education is continuing to expand. The most recent (as of writing) proposed ABET Criterion 3 Student Outcome 7 includes the ability to be an effective leader and part of a team[6]. Professional engineering societies agree that leadership is important for engineers[7-11]. As these programs grow and multiply, there is a limited body of research on what parts of an engineering leadership development program make the most impact. This study explores the use of the Competing Values Framework[12] from industry and organization literature, to study leadership development among college students in both curricular and co-curricular settings.

Background

Previous engineering leadership development literature focuses on a few key aspects to engineering leadership education such as its student perceptions[13], faculty perceptions[14], professional expressions of leadership in the workplace[15], and industry expectations of entry-level employees[16]. Various publications and the conference proceedings from the American Society for Engineering Education (ASEE) provide explanatory examples of the best practices of existing programs[17-20] and smaller-scale formative assessments of individual courses or experiences[21-24].

This study explores the use of the Competing Values Framework (CVF) to identify the leadership roles of engineering students and explore the level of behavioral complexity among them in an engineering team project setting. Behavioral complexity is a combination of behavioral repertoire and behavioral differentiation. Behavioral repertoire is the capacity to carry out various leadership roles[25] while behavioral differentiation is the ability to implement the most effective leadership role based on a given situation[25]. The CVF, as shown in Figure 1, describes roles and behaviors in four quadrants: Collaborate, Create, Control, and Compete. The resulting information, however, is not dichotomous, but rather acknowledges that an individual can express strong behaviors in multiple quadrants leading to behavioral complexity, a correlate to higher leadership effectiveness[26]. The CVF theory highlights that effectiveness stems from blending the use of various, seemingly "competing" leadership roles[12]. Research participants are not defined by a given leadership identity in one quadrant or another, but are rather identified by how well they report utilizing skills from each quadrant independently. The CVF has been used in a handful of engineering education related studies thus far[27,28], but it is more prevalent in industrial and organizational behavior research[12].

The Managerial Behavior Instrument (MBI) is the empirically tested instrument used to measure behavioral complexity. Lawrence et al. [12] demonstrated the reliability of the instrument using Cronbach's alpha and performed confirmatory and exploratory factor analyses to demonstrate discriminant validity on a group of mid- and senior-level managers from a professional organization, with an n of 1610. They also surveyed the direct reports of these managers to get an outside perspective to corroborate self-reported answers.

Though it has a stronger history of use in industrial and organizational behavior research, the CVF has also been used in engineering education research. Zafft et al.[27] used the CVF to explore the effectiveness of self-managed student teams in a class of construction management and architecture juniors and seniors. She compared the level of behavioral complexity, as defined by a team collectively, highlighting team members who excelled in at least 3 of the CVF quadrants. They found behavioral complexity to be correlated to higher grades ($p<.001$). Using an older version of the CVF, they also found that of the CVF quadrants, *managing processes* and *leading change* all related to a higher team grades. In the newer version of the CVF used in this study, the results showed higher grades are related to the Control and Create quadrants, respectively. *Producing results* was statistically significant when compared to grades at $p<.05$. *Relating to people* was not related to improved grades.

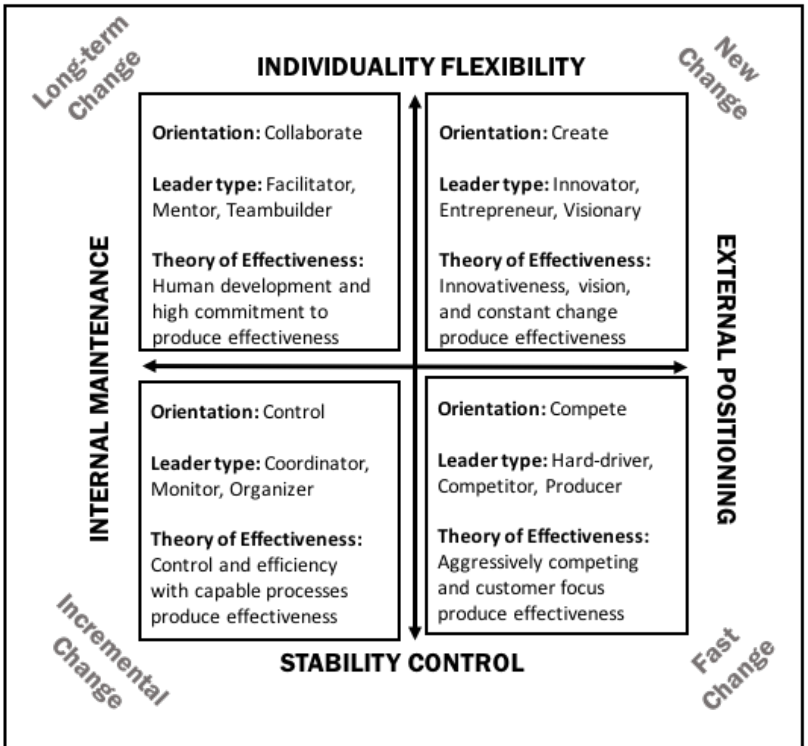

Figure 1. Competing Values Framework leadership orientation quadrants[26]

Oplinger and Lande[28] used the CVF in studying "makers" at a Maker Faire. They define makers as "hackers, tinkerers, or DIYers" who are part of the growing maker community. The researchers visited four high-profile Maker Faires and interviewed the individuals showcasing their work. Those individuals they spoke to fit the required criteria of being 18 years or older and self-identification as a maker. The researchers determined that many of the makers exhibited traits aligning with various CVF quadrants. Based on this level of complexity, they determined that makers are well-situated to relate to people, lead change, produce results, and manage processes[27], ideals which align with the ABET outcomes for engineering education. They determined that makers exhibited many of the outcomes that are expected of engineering students via the ABET a-k outcomes, such as designing within constraints, formulating ideas to solve problems, and possessing the ability to engage in lifelong learning.

These are two examples of instances of using a framework from industrial and organizational literature to inform engineering education. The sources of data in the two studies is different, with Zafft's study[27] looking at students in a curricular setting and Oplinger and Lande's study[28] looking at the leadership characteristics of individuals in an out-of-class, self-driven setting. The course-based setting in Zafft[27] is a required class taking students from one genre of majors, potentially leading to a perception of equality among students because they are peers. In Oplinger and Lande[28], they explore leadership among individuals in the activity of making, a voluntary activity, which exemplifies a strong level of motivation.

Educators use engineering project capstone courses as a way to teach professionalism skills, including leadership, to students as they near the end of their undergraduate career (Knight & Novoselich, 2017). Co-curricular experiences such as EWB, are shown to improve leadership skills in active members. It has been shown that men report leadership as a benefit more than do women (Litchfield & Javernick-Will, 2014). With the call for engineers to be aware of some basic business concepts, industrial and organizational literature is directly relevant to students working in engineering teams[29].

This research used the CVF to study the behavioral complexity and leadership orientations of engineering students in curricular and co-curricular settings leading to these research questions:

RQ1: How does the CVF and corresponding instrument, the MBI, work to determine behavioral complexity in mechanical engineering students taking a capstone course and EWB students working on a project?

RQ2: What differences in leadership orientation and behavioral complexity are observed (based on gender and context) among engineering students working in project teams in a mechanical engineering capstone course and on a co-curricular Engineers Without Borders project?

Methods

For this exploratory pilot study, the curricular setting is a mechanical engineering capstone design course and the co-curricular setting is Engineers Without Borders (EWB). Both sets of students attended a large public, research intensive university and were chosen based on convenience. Both settings provide the students the opportunity to work on a substantial engineering project, to work with a team, and to work with an independent client or user. The research was IRB approved.

The capstone design course spans two semesters and provides students the opportunity to work with an industry client. The corporate clients define a problem for a team of students to solve through a regimented process of design, fabrication, and testing. The students have various checkpoints throughout the two semesters when they must submit reports such as the preliminary design review, comprehensive design review, and testing plan. If needed, the students give an oral manufacturing plan report in which they get detailed feedback on how to make their designs more easily manufactured. The course culminates in a design expo, a day when all of the teams show off their finished products or prototypes in a poster session that is judged by local industry professionals. The student teams submit a final report and hand their finished product over to their client. During the duration of the class, the students receive a substantial amount of professionalism guidance and training. The course is run as a bridge between typical academic courses and a professional setting. Instead of having a syllabus, there is an employee manual. Instead of having lecture, the course has morning meetings. The class is intentional in preparing seniors for the workplace. The class under investigation consists of 237 students, predominately mechanical engineering seniors. Less than a dozen students are electrical engineering seniors who chose to take the mechanical engineering capstone course. These students are divided into 30 teams of 7-8 members each and work within a specified budget. The class is required for graduation for mechanical engineering students.

Alternatively, the Engineers Without Borders student group is a co-curricular opportunity open to students from all majors and from all academic levels. They design and implement engineering solutions for people in developing countries. One of the key tenants of the organization is that teams are working to design solutions *with* their international partners rather than imposing ideas onto them. Much of the work is self-driven, with some requirements provided by the EWB national organization. In order to travel to implement a project, teams must submit documentation of the thorough design and implementation plan through the regional and national organization. EWB teams work closely with the community in which they are working via email, telephone, and Skype calls. They raise money through grants and fundraising to send a team of students to help implement a project. The projects can consist of building bridges to latrines to designing water distribution systems and more, all defined by the community partner's needs. A portion of the group took our survey leaving the co-curricular sample size at n = 21 with 11 men and 10 women. Their disciplines of study were varied with 5 chemical and biological engineering students, three studying environmental engineering, two students each from aerospace, electrical, and mechanical engineering, and one student each from computer science, architecture, and business majors. One student did not report field of study. The students were predominately in their second or third year (16 of 21 respondents) with one first year student and four seniors. Thirteen of the 21 co-curricular students have been working on their project for more than a year. Five have been working on the project for over two years.

Both of these groups of students took an initial pretest survey distributed electronically in fall of 2016. The capstone students took the survey as a requirement for their course, so there were 237 responses, for close to a 100 percent response rate. The researchers were only able to determine gender of 233 of the respondents. The gender analyses used only 233 responses. The students took the survey in the fourth week of the semester. Students had been assigned design groups but had not had significant time to work with them yet. With the EWB group, two researchers attended meetings of two separate project teams to introduce the research and received 28 responses, though only 21 were complete. While an exact response rate is unavailable because of how the survey was shared, the researchers approximate it was around 50 percent, based on total number of students in each design group. The survey was administered during week 12 of the semester.

The survey was adapted from that used in the Lawrence, Lenk, & Quinn's study of behavioral complexity[12]. The original study focused on managers in a corporate setting, so some of the wording of the questions was inappropriate for an academic setting. Small changes were made (such as changing a word from "customers" to "clients" or "users") in the same manner as used by Zafft et al[27]. Survey questions can be seen in Table 1. One limitation of only using a pre-survey is that student opinions of their abilities, before doing the work of a substantial project, may be artificially inflated.

Initial data was used to explore construct validity and internal consistency reliability of the adapted survey instrument. As shown in Table 1, the survey has participants complete the statement "I would describe myself as being skilled in the following …" with a 5-point Likert scale of strongly disagree, disagree, neither agree/disagree, agree, or strongly agree. For the curricular setting, the MBI questions were added to a larger survey which explored desired student learning outcomes for the class. For the co-curricular survey, the same learning outcome questions from the curricular survey were included along with the MBI items. For the co-curricular survey, demographic questions were added at the end to avoid stereotype threat.

Twenty of 21 survey respondents answered all demographic questions such as gender, year in school, and field of study.

Results

The results of the is exploratory study first investigate the validity and reliability of using the CVF instrument (the MBI) in an engineering educational setting. The second portion of the results explores the differences in the student self-ratings on the MBI, based on the context in which they are working and their gender.

Validity and reliability exploration of the adapted instrument

To begin to address the first research question, evidence of validity based on confirmatory factor analysis was examined through structural equation modeling (SEM). SEM was used to describe underlying characteristics, or latent variables, which are assumed to be measured by the observed variables. For this study, SEM was used to examine how items related to the underlying latent variables, namely, the four dimensions of the CVF. SEM was conducted in IBM AMOS 24 to examine the existence of four separate leadership dimensions and that the Likert items in fact measured those. Attempts to use a second-order CFA identical to that in Lawrence and Quinn were unsuccessful, due to an insufficient number of responses relative to the number of variables in the model. Therefore, for the initial model, all 36 response items were mapped to the four predetermined scales of the CVF, based on the data set comprised of all of the complete curricular and co-curricular responses (n=188). The generalized least squares (GLS) method was used for the analysis because the sample size was insufficient for modeling using the asymptotically distribution-free (ADF) analysis. Then each of the four dimensions were analyzed to determine if the nine items within the dimensions clustered into the three sub-scales in each dimension. The number of responses included in the model for each dimension varied, because students' missed responses were often only in one dimension, allowing their responses to be included in the analysis. Here both the ADF and GLS analysis types were tried, and gave similar results. The ADF results are reported given its presumably superior results for ordinal data that need not be normally distributed[32].

Results of goodness of fit for the models are summarized in Table 2. The chi-square test statistics were all significant at 0.01, which suggests reasonable model fitting. Two other commonly reported metrics for fit quality[33] met general guidelines[34]: root-mean-square error of approximation (RMSEA) is less than 0.06 (good) for the overall model of the four dimensions and 0.06 to 0.08 (adequate) for each of the individual dimension models; goodness of fit index (GFI) is greater than 0.9 for the sub-models, but was weak for the overall model. In the previous work by Lawrence with a second-order CFA, RMSEA was 0.046 and GFI was 0.909 showing much better model fit indicators; this superior model fit is not surprising given their much larger data set of over 2000 responses.

Table 1. Adapted MBI instrument for engineering students including correlation and confirmatory factor analysis data

I would describe myself as being skilled in the following…

5-pt Likert scale (strongly disagree, disagree, neither agree/disagree, agree, strongly agree)

Collaborate (α=.765)	**Create (α=.828)**
1 *Encouraging participation (α=.501)*	4 *Anticipating customer needs (α=.603)*
1a. Making it legitimate to contribute opinions [.363*]{.343}*	>4a. Meeting with the client to discuss their needs [.575**]{.769**}
1b. Employing participative decision making [.451*]{.622**}	>4b. Identifying the changing needs of the client [.436**]{.544**}
1c. Maintaining an open climate for discussion [.496*]{.661**}	>4c. Anticipating what the client will want next [.270*]{.521**}
2 *Developing people (α=.543)*	5 *Initiating significant change (α=.763)*
>2a. Encouraging skill development [290*]{.420*}	5a. Initiating bold projects [.947**]{.863**}
>2b. Seeing that everyone has a project plan [.606*]{.436**}	>5b. Starting ambitious projects [.922**]{.738**}
>2c. Coaching people on team issues [.726**]{.809**}	>5c. Launching important new initiatives [.631**]{.777**}
3 *Acknowledging personal needs (α=.602)*	6 *Inspiring people to exceed expectations (α=.644)*
3a. Being aware of when people are burning out [.553*]{.753**}	>6a. Inspiring teammates to be creative [.501**]{.700**}
3b. Encouraging people to have work/life balance [.526*]{.614**}	>6b. Encouraging teammates to try new things [.527**]{.681**}
3c. Recognizing feelings [.580*]{.676**}	>6c. Getting teammates to exceed traditional performance patterns [.568**]{.696**}
Control (α=.775)	**Compete (α=.814)**
7 Clarifying policies (α=.638)	10 *Focusing on competition (α=.827)*
>7a. Seeing that course procedures are understood [.915**]{.665**}	10a. Emphasizing the need to compete [.558**]{.757**}
>7b. Insuring that course policies are known [.652**]{.647**}	10b. Developing a competitive focus [.557**]{.873**}
7c. Making sure formal guidelines are clear to people [.572**]{.657**}	10c. Insisting on beating outside competitors [.594**]{.742**}
8 Expecting accurate work (α=.456)	11 *Showing a hard work ethic (α=.735)*
8a. Emphasizing the need for accuracy in work efforts [.596**]{.777**}	11a Showing an appetite for hard work [.533**]{.714**}
8b. Expecting people to get the details of their work right [.220*]{.412**}	11b Modeling an intense work effort [.671**]{.767**}
8c. Emphasizing accuracy in work efforts [.530**]{.670**}	>11c Demonstrating full exertion on project work [.620**]{.780**}
9 Controlling projects (α=.740)	12 *Emphasizing speed (α=.613)*
9a. Providing tight project management [.731**]{.799**}	>12a. Getting work done quicker in a team [.682**]{.464**}
9b. Keeping projects under control [.575**]{.643**}	>12b. Producing faster team outcomes [.766**]{.824**}
9c. Closely managing projects [.816**]{.776**}	12c. Providing fast responses to emerging issues [.428**]{.652**}

> indicates that the item was changed from original MBI (Lawrence et al., 2009) with changed words underlined

α values indicate Cronbach's alpha

values in brackets [] indicate CFA standardized loadings; values in braces {} indicate loadings for sub-models

* p<.05, ** p<.001

As seen in Table 1, some of the standardized regression weights, which indicate the item loadings to the factors, are less than desirable. In the overall model, the “collaborate” construct was the weakest, with four of the nine items having loadings of 0.50 or less and an average factor loading of 0.510. The create dimension was somewhat better; two items loaded over 0.9 and only two items loaded under 0.5; the average factor loading was 0.597. For each of the control and compete dimensions, only one of the nine items had a loading under 0.5; the average loadings were 0.623 and 0.601, respectively. The ADF models of each individual dimension performed better in terms of greater loading of the items to the sub-elements within the dimension (average item loadings were 0.59, 0.70, 0.67, 0.73 for collaborate, create, control, and compete dimensions, respectively), but many are still below conventions of acceptable item loading. The original instrument average item loadings for all nine items in each dimension were 0.60, 0.73, 0.631, and 0.71 for the collaborate, create, control, and compete quadrants, respectively[12]. These values are reasonably similar to those found in this study of engineering students.

Table 2. SEM default model fit results

Model	n	Chi-square	Degrees of freedom	Probability Level	RMSEA	GFI
CVF with 4 dimensions, 36 items	188	871.0	588	0	0.051	0.741
CVF collaborate dimension, 9 items	218	45.65	24	0.005	0.064	0.931
CVF create dimension, 9 items	224	49.75	24	0.002	0.0069	0.934
CVF control dimension, 9 items	239	50.76	24	0.001	0.068	0.943
CVF compete dimension, 9 items	226	47.13	24	0.003	0.065	0.942

Table 3 shows the covariance estimates among the four dimensions within the CFA model and the three sub-domains within each dimension. While all of the covariance values were statistically significant, many are reasonably small; all were much lower than previously found by Lawrence where covariance values ranged from 0.09 to 0.71. Covariance is not unexpected, given that all of the elements relate generally to leadership. Using the results from the engineering students, covariance was the lowest between compete and collaborate, not surprisingly since these appear on their face to be somewhat opposing tendencies. However, in Lawrence work lowest covariance was collaborate vs. control (0.09 cov), also dimensions that may seem in opposition to one another. This study showed create and control to have the highest covariance. The create dimension had the highest covariance among its three sub-domains. Covariance within sub-domains was not explored in Lawrence. The goal of the CVF is to identify individuals who report higher complexity – those who have high scores in three or more quadrants. It can be assumed that the sample with which the MBI was validated has higher levels of complexity than undergraduate engineering students, given that the original data was taken from mid- and senior-level managers at an international organization[12].

Table 3. Covariance estimates of the dimensions within the CVF from the CFA models

		Covariance	p
Overall Model			
Create	Control	0.019	**
Compete	Control	0.187	**
Collaborate	Control	0.144	*
Collaborate	Create	0.040	*
Compete	Collaborate	0.033	*
Compete	Create	0.066	*

**p<001, *p<.05

Internal consistency reliability for the adapted survey questions was determined by taking the Cronbach's alpha of the curricular data (n=237). Cronbach's alpha values, as calculated in SPSS, are shown in parentheses in Table 1. Each quadrant shows a good level of reliability, ranging from .765 to .828. Acceptable values of Cronbach's alpha range from 0.70 to 0.95[35] with 0.70 being acceptable for social science research[36]. Most often, individual areas of focus (such as category [1] *encouraging participation* or category [8] *expecting accurate work*) showed lower levels of reliability than did the quadrant as a whole.

Initial construct validity was determined for the curricular data through analyzing both for convergent validity and discriminant validity using Pearson's correlation data from SPSS. Ninety-four percent of intra-instrument expected correlations were statistically significant at p< .05. Expected correlations stemmed from items that were similar on the MBI and on a series of professionalism questions asked on the curricular survey. For example, the answers for "Managing projects to completion" was correlated to MBI question 9c "closely managing projects."

Reported leadership orientations

To address the second research question, results from the survey were analyzed using descriptive statistics such as mean and standard deviations to focus on curricular, co-curricular, and gender differences among scores. Incomplete answers showed in the data as blanks and were averaged over. Each quadrant (or dimension) receives a score based on the average of the nine items in Table 1. Basic inferential t-tests were used to check compare groups and determine which quadrants or leadership profiles were more prevalent in one setting or the other, and with one gender or the other.

In reporting the results of this study, it is important to give a detailed description of the basic results of the MBI instrument. The focus of the study is to acknowledge the level of behavioral complexity of individuals, with high complexity shown by a high score (four or greater) in three or four of the CVF quadrants, medium complexity shown by having two quadrants with a score of four or more, and low complexity shown by having scores of four or greater in one or zero quadrants. Example plots of high and low complexity student profiles are shown in Figures 2 and 3. A summary of the fraction of students who reported themselves at the various levels of complexity is shown in Table 4.

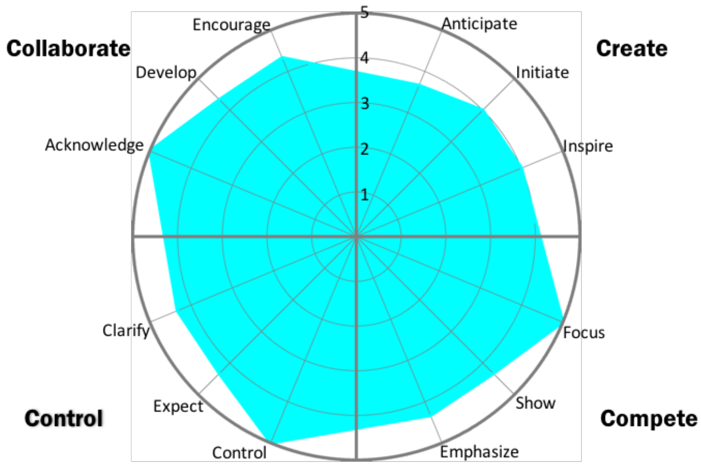

Figure 2. An example plot showing reported high behavioral complexity in an engineering student.

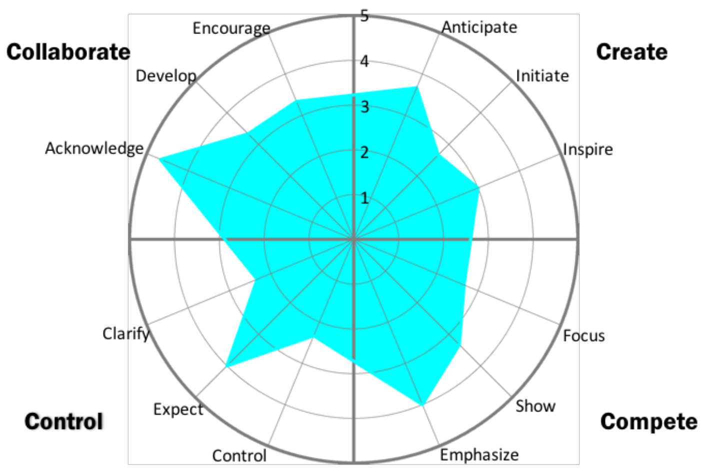

Figure 3. An example plot showing reported low behavioral complexity in an engineering student.

Table 4. Fraction of curricular and co-curricular students that reported high, medium, and low levels of complexity.

	Level of Complexity		
	High	Medium	Low
Curricular (n=233)	0.44	0.19	0.37
Co-curricular (n=21)	0.29	0.24	0.48

The researchers did some basic statistical analysis to compare various groups including gender and curricular and co-curricular. Unpaired t -tests were used to determine significant difference among groups. These tests were run as unpaired, two-tailed with an equal variance. In the curricular group of students, there were some significant differences between the genders in the Create, Control, and Compete quadrants. As shown in Table 5 with the asterisks, women rated themselves significantly lower in *initiating change* and *inspiring people*, leading to being significantly ($p<.001$) lower in the Create quadrant as a whole. Women ranked themselves significantly lower on the subgroup of *expecting accurate work*, but the Control quadrant was not affected. Women ranked themselves significantly lower on the subgroup *focus on competition*, contributing to scoring significantly lower in the Compete quadrant.

Table 5. Comparison of mean values of MBI results for curricular men and women.

	Men n=189	Women n=38	p-value		Men n=189	Women n=38	p-value
COLLABORATE	4.07	4.06	0.8991	CREATE	3.85	3.68	0.0004**
Encouraging participation	4.22	4.27	0.5562	Anticipate needs	3.91	3.88	0.6918
Develop people	3.96	3.91	0.5001	Initiate change	3.77	3.49	0.0013*
Acknowledge needs	4.03	4.03	0.9977	Inspire people	3.88	3.66	0.0107*
CONTROL	3.98	3.98	0.9933	COMPETE	4.04	3.92	0.0134*
Clarify policies	3.93	4.03	0.1674	Focus on competition	3.88	3.57	0.0018*
Expect accurate work	4.21	4.04	0.0202*	Show work ethic	4.39	4.28	0.8645
Control projects	3.79	3.85	0.4959	Emphasize speed	3.95	3.89	0.5296

**p<.001, *p<.05

Table 6. Comparison of mean values of MBI results for co-curricular men and women.

	Men n=11	Women n=10	p-value		Men n=11	Women n=10	p-value
COLLABORATE	4.13	4.20	0.5633	CREATE	3.98	3.50	0.0965
Encouraging participation	4.31	4.52	0.1907	Anticipate needs	3.61	3.73	0.6428
Develop people	4.00	3.93	0.7621	Initiate change	4.53	3.26	0.1077
Acknowledge needs	4.08	4.15	0.7271	Inspire people	3.81	3.52	0.2693
CONTROL	4.13	3.75	0.0753	COMPETE	3.78	3.86	0.5626
Clarify policies	4.22	3.77	0..4334	Focus on competition	3.33	3.56	0.4392
Expect accurate work	4.11	3.74	0.0945	Show work ethic	3.94	4.22	0.2444

Control projects	4.06	3.74	0.1370	Emphasize speed	4.06	3.81	0.2803

**p<.001, *p<.05

As shown by Table 6, there were no significant differences in mean MBI results between men and women in the co-curricular setting. But that could be due to small n. In future studies, it is reasonable to expect a larger sample, given more ambitious recruitment processes for the co-curricular students.

From the data gathered, it was also possible to take the average of the larger curricular and co-curricular groups to compare how the experiences drive leadership development in each context. Figure 4 shows both the curricular and co-curricular average scores.

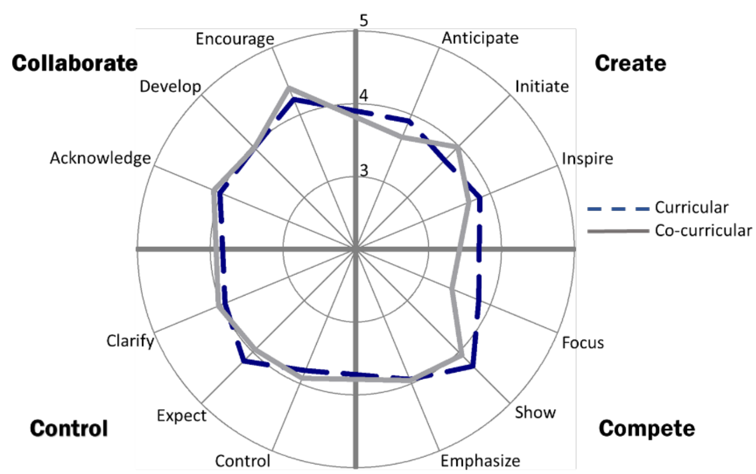

Figure 4. Plot showing reported average (mean) levels of complexity of curricular and co-curricular engineering students.

Table 7 highlights the factors that show differences between curricular and co-curricular averages that are statistically significant. These are shown in the shaded boxes. The first column includes all students, while the middle and right columns show the men and women, respectively. The largest differences are in the Control and Compete quadrants, as the entire quadrant was statistically different between curricular and co-curricular. For the Create quadrant, only individual subgroups of questions were significantly different. Results illustrated in Table 5 should be read with an understanding of the small co-curricular sample size.

Table 7. T-test results for comparison of curricular and co-curricular MBI scores, highlighting only statistically significant differences

	Curricular vs co-curricular	Higher	Men curricular vs. co-curricular	Higher	Women curricular vs co-curricular	Higher
4. Anticipate needs	0.0291*	curr	0.0350*	curr	0.4397	-
5. Initiate change	0.1099	-	0.0005**	co-curr	0.1189	-

7. Clarify policies	0.4918	-	0.0764	-	0.0183*	curr
8. Expect accurate work	0.0173*	curr	0.0764	-	0.0695	-
10. Focus on competition	0.0022*	curr	0.0011*	curr	0.9459	-
11. Show work ethic	0.0153*	curr	0.0045*	curr	0.7028	-
CONTROL quadrant	0.9028	-	0.0764	-	0.0208*	curr
COMPETE quadrant	0.0019*	curr	0.0021*	curr	0.6351	-
**p<.001, *p<.05						

Discussion

The confirmatory factor analysis showed that some of the sub-domains have especially low factor loadings, indicating that this instrument is only moderately successful at addressing leadership in an engineering student context[32]. This exploratory study resulted in full responses from around 200 individuals, significantly fewer that the over 2000 responses used by Lawrence et al. to validate their original model. However, in various areas, such as the average factor loadings per dimension, the values determined here (0.59, 0.70, 0.67, 0.73 for collaborate, create, control, and compete dimensions, respectively) were not that different from the values found in Lawrence et al.'s work (0.60, 0.73, 0.631, and 0.71 for the collaborate, create, control, and compete quadrants, respectively)[12].

Based on the data, there are some differences between reported student leadership orientations given their context (curricular or co-curricular) and given gender. The first notable insight, as shown in Table 4, is that 44 percent of the curricular students reported themselves as highly talented in at least 3 of the CVF quadrants (highly complex). In contrast, 29 percent of co-curricular students reported themselves as highly complex. Forty-eight percent of co-curricular reported themselves as low on the scale along with 37 percent of the curricular students. This difference could be from a variety of factors, one being that the curricular students are all senior level students who have had more experience. The majority of co-curricular students (17 out of 21) were earlier in their academic careers. Another potential explanation is that the survey was given to the curricular students before they had engaged in the hard work of teamwork and leadership. The survey was administered at the very beginning of the academic year, before substantial progress had been made on projects. Because of the ongoing nature of the co-curricular (Engineers Without Borders) projects, many of the co-curricular students had been working on their projects for a longer period of time. Thirteen of the 21 co-curricular students have been working on their project for a year or more. The curricular students will be given the same survey in the midst of their second semester working on the same project. These data may be more appropriate to compare to the co-curricular students who are in the middle of their projects. Furthermore, co-curricular students are working with team members of different levels of experience, allowing less-experienced team members to learn from more experienced team members. In the co-curricular setting, students from various majors work together in a challenging, cross-cultural context. This adds a level of complexity to the projects, which may result in a more realistic understanding of their own personal abilities.

The analysis of gender showed interesting differences between the curricular and co-curricular data. As shown in Tables 5 and 6, there were various significant differences in scores in the Create, Control, and Compete quadrants for the curricular students while there were no significant differences in scores among the co-curricular group. The sample size for the co-curricular group was much lower than the curricular, but the group was approximately 50 percent women. Focusing on the curricular data, men reported higher levels on all of the questions where the difference was significant. The highest significance was in the Create quadrant with a t-test results of $p < .001$. The factors that affected the score the most were the items of *initiating change* and *inspiring people*. Women also reported lower levels of *expecting accurate work* in the Control quadrant, perhaps highlighting that they do not hold their peers to high expectations and/or are more likely to forgive their peers' mistakes. This difference however, did not relate to a significant difference in attitudes at the Control quadrant level. The Compete quadrant, however, was significantly different. Literature shows that often women value communication and collaboration more than do men[37]. However, there were no significant differences in the Collaborate quadrants or its items. The lower reported scores for women align with research that shows women in science, technology, engineering, and math (STEM) fields show the same level of leadership capacity as women in other disciplines but report lower leader efficacy[38].

The differences between curricular and co-curricular data are shown both in Figure 4 and in Table 7. The data in Table 7 shows only the significantly different values when comparing all curricular to all co-curricular, curricular men to co-curricular men, and curricular women to co-curricular women. While the women showed differences in the item *clarifying policies* and in the Control quadrant with curricular being higher in both, the men showed more inconsistencies between the groups. For the women's responses, it makes logical sense that a course would have more clear policies and the ability to anticipate issues than would a co-curricular experience which involves implementing an engineering project in a developing country in an unfamiliar environment. The significantly different scores for the men come from the Create and Compete quadrants. The items in the Create quadrant, *anticipating needs* and *initiating change,* were split between the two groups with the curricular men having more confidence in *anticipating needs* and the co-curricular men having more confidence in *initiating change*. Again, the ability of the co-curricular students to truly anticipate needs of their users in developing countries may pose a challenge and contribute to this difference in reported values. The co-curricular men feel empowered by their projects (or self-selected to work on projects in developing communities) because of an idea that they have the power to initiate change. This was the only area where the co-curricular men scored higher than the curricular. Finally, the entire curricular group scored significantly higher than the co-curricular group on the *expecting accurate work* item. Again, the curricular survey was given before substantial project work was undertaken, potentially affecting students' realistic expectations for their teammate's work.

Limitations and Future Work

To reiterate a few points of limitation for the study, the sample size was too small for proper validation of the instrument. Future data will be gathered to more thoroughly validate the instrument. The curricular and co-curricular samples varied in size and in proportion of men and women. The curricular group was 233 students of known gender, of which 40 are known women (18 percent). The co-curricular group was 21 students with 10 women (48 percent). A larger co-curricular group would allow for stronger inferences. The curricular survey was distributed at the beginning of the academic year, before substantial project work had been completed. The students will take the survey again in the midst of second semester. This may be a better point in time for comparison to a co-curricular group who has been working continually on a project for months or years and have already experienced challenges related to their team and their project. Another limitation of note was that the survey distributed to the co-curricular students had not been revised at the time of administration and included wording such as “anticipating what the client will want next” in the Create quadrant which may have been off-putting if the student did not consider their partners in developing communities as “clients.”

Conclusion

To summarize, the CVF was adapted and used to study engineering students working in project teams, using behavioral complexity as a correlate to leadership ability. Based on the survey responses from the curricular students, the survey has initial reliability and validity at the quadrant level for use in an engineering student context, measuring student behavioral complexity. Moving forward, more data will be gathered in both contexts to further explore these concepts. The study will expand beyond one university.

In comparing mechanical engineering senior design students in a curricular setting and students of all ages and a variety of majors in a co-curricular setting, the data showed that more curricular students rated themselves as having higher complexity. The data also showed some gender differences in the Create, Control, and Compete quadrants between the curricular students, but no significant differences in the co-curricular students. Researchers interpret the differences among groups to be attributed to a variety of factors such as context, students’ discipline of study, level of experience, general background, and timing of the survey. In the future, these interpretations will be explored further by doing follow-up interviews to survey takers to help determine what experiences students believe to have influenced their abilities.

References

1. Rottman, C., Sacks, R., & Reeve, D. (2015). Engineering leadership: Grounding leadership theory in engineers’ professional identities. *Leadership*, *11*(3), 351–373.
2. National Academy of Engineering. (2004). *The engineer of 2020: Visions of engineering in the new century*. The National Academies Press.
3. Iowa State University College of Engineering (2017). LEAD: Leadership through Engineering Academic Diversity. Retrieved from https://www.engineering.iastate.edu/lead/
4. Bernard M. Gordon MIT Engineering Leadership Program (2017). Developing tomorrow’s engineering leaders. Retrieved from http://web.mit.edu/gordonelp/
5. Engineering Design, Technology, and Professional Programs (2017) Engineering Leadership Development program. Retrieved from http://www.sedtapp.psu.edu/eld/
6. ABET (2016) Proposed EAC criteria changes released for public review and comment. Retrieved from http://www.abet.org/blog/news/proposed-eac-criteria-changes-released-for-public-review-and-comment/
7. American Academy of Environmental Engineers. (2009). *Environmental engineering body of knowledge 2009*.
8. American Institute of Chemical Engineers. (2015). *Body of Knowledge for Chemical Engineers*.
9. American Society of Civil Engineers. (2008). *Civil engineering body of knowledge for the 21st century: Preparing the civil engineer for the future, 2nd Ed.*

10. American Society of Mechanical Engineers. (2011). *Vision 2030: Creating the future of mechanical engineering education*.
11. National Society of Professional Engineers. (2013). *Professional engineering body of knowledge, First Edition*.
12. Lawrence, K. A., Lenk, P., & Quinn, R. E. (2009). Behavioral complexity in leadership: The psychometric properties of a new instrument to measure behavioral repertoire. *Leadership Quarterly*, *20*, 87–102.
13. Paul, R., & Falls, L. G. C. (2015). Student perspective on defining engineering leadership. Presented at the ASEE Annual Conference, Seattle, WA.
14. Schell, IV, W. J., & Kauffmann, P. J. (2016). Engineering leadership: Faculty perceptions and profiles. Presented at the ASEE Annual Conference and Exposition, New Orleans, LA.
15. Reeve, D., Rottmann, C., & Sacks, R. (2015). The ebb and flow of engineering leadership orientations. Presented at the ASEE Annual Conference & Exposition, Seattle, WA.
16. Hartmann, B. L., & Jahren, C. T. (2015). Leadership: Industry needs for entry-level engineering positions. *Journal of STEM Education*, *16*(3), 13–19.
17. Kotnour, T. G., & Reilly, C. H., & Selter, J. A. (2014, June), Integrating Leadership Education into the Undergraduate Engineering Experience Paper presented at 2014 ASEE Annual Conference & Exposition, Indianapolis, Indiana.
18. Graham, R., Crawley, E., & Mendelsohn, B. (2009). *Engineering leadership education: A snapshot review of international good practice*.
19. Mendoza, L. R., Orea-Amador, L., & Kendall, M. R. (2016). Mixed Method Study of the Evolution of Leadership Traits during a Leadership Experience.
20. Brockman, J. B., & Goodrich, V. E., & Gilot, G. A. (2015, June), *The Touchstone Engineering Leadership Development Program* Paper presented at 2015 ASEE Annual Conference & Exposition, Seattle, Washington.
21. Pitts, S., McGonagle, S., & Klosterman, S. W. (2013). Developing Engineering Leaders using Engineering Leadership Capabilities and Leadership Labs. Presented at the ASEE Annual Conference & Exposition, Atlanta, GA.
22. Bayless, D. (2015). Development of assessable leadership experiences outside of the engineering classroom. Presented at the ASEE Annual Conference & Exposition, Seattle, WA.
23. Warnick, G., Schmidt, J., & Bowden, A. (2014). An experiential learning approach to develop leadership competencies in engineering and technology students. Presented at the ASEE Annual Conference and Exposition, Indianapolis.
24. Ahn, B., & Cox, M. F., & Osagiede, A. (2014, June), *Lessons Learned: Teaching Engineering Leadership in an Undergraduate Class Using Case Studies* Paper presented at 2014 ASEE Annual Conference & Exposition, Indianapolis, IN
25. Carmeli, A., & Halevi, M. Y. (2009). How top management team behavioral integration and behavioral complexity enable organizational ambidexterity: The moderating role of contextual ambidexterity. *The Leadership Quarterly*, *20*, 207–218.
26. Cameron, K. S., Quinn, R. E., DeGraff, J., & Thakor, A. V. (2014). *Competing Values Leadership* (2nd ed.). Northampton, MA: Edward Elgar Publishing, Inc.
27. Zafft, C. R., Adams, S. G., & Matkin, G. S. (2009). Measuring leadership in self-managed teams using the competing values framework. *Journal of Engineering Education*, 273–282.
28. Oplinger, J. L., Lande, M., & Jordan, S. S. (2015). Leadership characteristics within the Making Community. In *ASEE Annual Conference and Exposition*. Seattle, WA.
29. Knight, D. B., & Novoselich, B. J. (2017). Curricular and co-curricular influences on undergraduate engineering student leadership. *Journal of Engineering Education*, *106*(1), 44–70.
30. Litchfield, K., & Javernick-Will, A. (2014). Investigating gains from EWB-USA involvement. *Journal of Professional Issues in Engineering Education and Practice*, *140*(1), 1–9.
31. Borrego, M., Karlin, J., McNair, L., & Beddoes, K. (2013). Team Effectiveness Theory Industrial and Organizational Psychology Applied to Engineering Student Project Teams: A Research Reviews. *Journal of Engineering Education*, *102*(4), 472–512.

32. Muthén, B., & Kaplan, D. (1985). A comparison of some methodologies for the factor analysis of non-normal Likert variables. *British Journal of Mathematical and Statistical Psychology*, *38*(2), 171–189. doi:10.1111/j.2044-8317.1985.tb00832.x
33. Jackson DL, JA Gillaspy, R. Purc-Stephenson, 2009, Reporting practices in confirmatory factor analysis: an overview and some recommendations. Psychological Methods, 14 (1), 6-23
34. Lei, P.-W., & Wu, Q. (2007). Introduction to structural equation modeling: Issues and practical considerations. *Educational Measurement: Issues and Practice*, *26*(3), 33–43. doi:10.1111/j.1745-3992.2007.00099.x
35. Tavakol, M., & Dennick, R. (2011). Making sense of Cronbach's alpha. *International Journal of Medical Education*, *2011*(2), 53–55.
36. Institute for Digital Research and Education. (2017). SPSS FAQ: What does Cronbach's alpha mean? Retrieved February 13, 2017, from http://www.ats.ucla.edu/stat/spss/faq/alpha.html
37. Knight, D. W., Sullivan, J. F., Poole, S. J., & Carlson, L. E. (2002). Skills assessment in hands-on learning and implications for gender differences in engineering education. In *American Society for Engineering Education Annual Conference & Exposition*. Montreal, Canada.
38. Dugan, J. P., Fath, K. Q., Howes, S. D., Lavelle, K. R., & Polanin, J. R. (2013). Developing the leadership capacity and leader efficacy of college women in science, technology, engineering and math fields. *Journal of Leadership Studies*, *7*(3), 6–23.