Understanding How Students' Value the Behaviors of Individuals in Engineering Teams

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Introduction

Our engineering program incorporates a strong focus on engineering design, which begins during the students' sophomore year with two sequential design courses—Engineering Design I taken in the fall semester and Engineering Design II taken during the spring semester. [1-3] During this year-long sophomore design course sequence, students work to design and construct prototypes of human-powered vehicles for a client with cerebral palsy who lives in the local community. A client with cerebral palsy provides not only a real, client-based design experience, but also an opportunity requiring that the students develop a new customer persona differing from the "myself-as-the-customer" model; this process has proved challenging for many of the students. Ideally, by the end of the academic year, students should learn the importance of disassociating themselves from the customer as well as understand the ethical obligations associated with being an engineer.

A critical component of this sophomore project is the development of identity and community among a cohort of students. The sophomore design course sequence project is meant to expose the students to an experience that transcends the classroom, and in the process, teach the students that they are part of a larger complex system. Through this very-real project students, as representatives of the University and the Department, see first hand how their decisions and actions as engineers can (and likely will) influence individuals as members of society (i.e., they are a member of a system of systems). For many students, this project is their first realization of social systems and their future role as a member of a social system as a practicing engineer.

This paper will provide the preliminary results of an NSF-sponsored research project to explore values-based methods for teaching sustainability in five contexts—individual, social, environmental, economic, and technical. ***This paper focuses on the individual and social contexts of sustainability related to working as a member of a team, and presents the results of a study on student values associated with behavior of individuals on a team.***

Background

Students participating in the study presented herein were asked to rate their own values toward the behaviors of individuals working in engineering teams. The survey instrument as well as the results from the values survey are presented in this paper. During the survey deployment, students completed the survey three times through the academic year, providing longitudinal data. The goal of the study presented in this paper was to gain insight on whether or not students' values with respect to team-based project work change through an academic year. ***Our hypothesis is that the students' values with respect to the behavior of individuals in a team will remain stable through the academic year.*** Literature on the values of societal groups seems to support the idea that values tend to remain quite stable.[4,5] It should be noted, however, that individual values can change over time due to external influences and personal growth (e.g., business ideology and socio-cultural influences [6,7]). For this study, we have adopted the definition of value change proposed by Bardi and Goodwin, "*value change* is a change in the importance of a value, evident in a change in the rating or ranking of a value on a questionnaire. This can be a short-term (temporary) change, such as in the response to an experimental manipulation, or a long-term change." [8]

The overarching premise for our research project is that ***students generally embrace admirable values related to sustainability, but often encounter a "cognitive dissonance" when asked to explain whether their actions accurately reflect their values.***[9] In short, students often do not act according to their values and beliefs. In this study, we investigate the values of students with respect toward working as a member of an engineering team. This falls under the category of social sustainability.

Knowing how students value individual behaviors on engineering teams will allow the course instructor to develop course activities that target team-based behavioral weaknesses. Differences in values and behaviors can be demonstrated to the students through instructor, self, and peer evaluation of demonstrated behaviors leading students to recognize this dissonance. Research by Pappas has demonstrated that students' recognition of this dissonance has been shown to influence students to align their values and behaviors to attain "individual sustainability." [10,11] Course activities will be developed around this concept of dissonance and will be used to foster positive team behaviors and build team cohesion among students with the overarching goal of teaching students to function as a member of a multidisciplinary team—i.e, allowing us to more effectively meet ABET Outcome D during design courses.[12]

When solving engineering problems, the engineer is confronted by a decision that must be made according to the values related to human well-being—in other words, "Engineers, in the fulfillment of their professional duties, shall … hold paramount the safety, health, and welfare of the public."–*NSPE Code of Ethics Fundamental Cannon 1.*[13] As an individual and as a member of society, a student of engineering must learn the value-related ramifications of actions on a host of factors, whether they be corporate, community, or individual.

Consequently, beyond knowledge retention, outcomes assessment should also focus on the values, attitudes, and behaviors of students.[14] Education in sustainability must engender the values and behaviors in students that allow them to make educated, sustainability informed decisions. To do this, ethical values must be a key part of any course in sustainability.[15] Mulder suggests that a "University education is about sharpening critical minds that are able to make balanced appraisals of their subjects of choice, and the norms and values to use in this appraisal." [16] Similarly, Barth stresses the importance of instilling ownership of learning so that students can not only generate and acquire new knowledge but also reflect on their own behavior and values.[17] Arbuthnott warns, however, that changed values and behaviors do not always result in an intentional change.[18] He further stresses the importance of providing an environment that fosters individual change, and that programs should "plan education aimed at helping people translate their intentions into action." [18] Our goal is to understand the values of our students so as to foster an environment where students can work toward alignment of behaviors and goals.

Values Survey

To identify a set of values related to the behaviors of individuals when working as a part of an engineering team, the research group utilized existing surveys and literature in the area of team roles. Key sources used during this process included the *Groups in Context: Leadership and Participation in Decision Making Groups* text which provides task roles, social/maintenance roles, and dysfunctional roles for members of the team,[19] the CATME Team-Maker Instrument [20] which uses a behavior-based rating system to assess the contributions of team members,[21] de Bono's *Six Thinking Hats* which provides idealistic team behaviors based on individual roles to drive success,[22] and Tuckman and Jensen's "Stages of Small-Group Development Revisited," [23] which is covered by the course text (Dym and Little's *Engineering Design: A Project-based Introduction* [24]). It should be noted that the CATME Team-Maker Instrument is used during the junior and senior capstone design courses for self and peer evaluation purposes. The list of behaviors was generated to capture the breadth of behaviors seen in the aforementioned literature. The resultant list of behaviors was then independently evaluated by faculty in the Psychology, Integrated Science and Technology, Engineering, and Education departments at James Madison University. This process resulted in 36 behavior statements which follow.

Behavior Statements

1. I attend group meetings.
2. I am willing to acquire the knowledge necessary to complete group tasks.
3. I always correct other people's positions.
4. I get bored easily.
5. I let the group know as soon as I know I can't keep a commitment.
6. I want to know what everyone else in my group is doing.
7. I pay attention when other people are talking.
8. I provide more information than is necessary to complete group tasks.
9. I would rather work alone.
10. I use my knowledge of group dynamics to help lead the group to success.
11. I prefer to get work done as quickly as possible.
12. I am one of the hardest workers in my group.
13. I am unable to restate other people's positions.
14. I complete group assignments for which I'm responsible on time.
15. I frequently ask questions to help clarify ideas.
16. I rely on others to provide the knowledge necessary to accomplish tasks.
17. I take the time to get to know others.
18. I rarely stand-up for my own opinions.
19. I don't like it when I am asked to clarify my positions or ideas.
20. I engage group members in my portion of the group work.
21. I am good at summarizing progress.
22. I interact with the group.
23. I don't like meeting with my small group.
24. I rarely complete my portion of the work.
25. I like to make others feel good about their contributions.
26. I respect other people's opinions.
27. I arrive prepared with the necessary materials for group meetings.

28. I do not help teammates when they are having difficulty.
29. I express myself well verbally.
30. I volunteer to take on tasks necessary to complete group work.
31. I do not verbally participate.
32. I produce high quality work.
33. I am able to suggest the next steps the group should take to complete our task.
34. I encourage the team towards success.
35. I like to solve problems in groups.
36. I listen to alternative points of view.

Behavior statements were sorted based on affinity by the research team. For each grouping of behaviors, a value was assigned. Again, the list of values was independently evaluated by faculty in the Psychology, Integrated Science and Technology, Engineering, and Education departments at James Madison University. The resultant 13 value statements follow.

Value Statements

1. It is important for every group member to complete a fair share of the work.
2. It is important for every group member to do quality work.
3. It is important for every group member to accept responsibility for tasks required to complete work.
4. It is important for every group member to keep commitments to the group.
5. It is important for every group member to assist members who are having difficulty.
6. It is important for every group member to respect feedback from other members.
7. It is important for every group member to provide constructive feedback to other members.
8. It is important for every group member to respect and listen to the ideas and viewpoints of other members.
9. It is important for every group member to participate in group meetings.
10. It is important for every group member to communicate with other group members outside of meetings.
11. It is important for every group member to monitor and be aware of the progress of the team.
12. It is important for every group member to believe that the group will be successful.
13. It is important for every group member to acquire the knowledge necessary for the group to be successful.

Survey Administration & Population Statistics

The survey was administered three times during the 2012-2013 academic year to sophomore engineering students. All students who participated in the survey were enrolled in Engineering Design I (Fall 2012) and/or Engineering Design II (Spring 2013) and were declared engineering majors. Details on the administration times and survey participants follow in Table 1. The survey was administered twice during Engineering Design I—once when students were placed on their course teams and a second time at the conclusion of the course. During Engineering Design II, the survey was administered only once—at the conclusion of the course. The second administration of the survey during Engineering Design I was intended as a mid-academic year data point.

Table 1: Details on administration and participants.

	Week during the semester	Course	Administration Method	Number of Participants
Time Point 1	Week 3, Fall	ENGR Design I	Paper in-class	74
Time Point 2	Week 16, Fall	ENGR Design I	Online out-of-class	53
Time Point 3	Week 16, Spring	ENGR Design II	Online out-of-class	28

Engineering Design I and Engineering Design II are the first two classes in the six-course engineering design sequence at James Madison University. The relatively new James Madison University (JMU) engineering program was designed to train the Engineer of 2020. [25,26] The program was developed from the ground up to not be an engineering discipline-specific program, but instead to provide students training with an emphasis on engineering design, systems thinking, and sustainability while also providing a strong foundation in engineering science. [27] The vision of the program is to produce cross-disciplinary engineer versatilists.

At the heart of the program is the aforementioned six-course engineering design sequence which provides instruction on design theory (thinking, process, methods, tools, etc.), sustainability, ethics, team management, and technical communication (both oral and written), while incorporating elements of engineering science and analysis.[2,28] Students apply design instruction in the context of two projects during the six-course sequence—the sophomore design project spanning both the fall and spring semesters of the sophomore year (which is where the values survey was administered) and the capstone project spanning the junior and senior academic years. Following the sophomore design experience, students have the opportunity to "specialize" their degree through the selection of their two-year capstone project and their technical electives. Some students choose a very specific path with the desire to enter a particular field of study in graduate school, while others choose to remain non-discipline specific.

It is during the sophomore design experience where student's paths are most common, and consequently, the sophomore experience is the ideal time in our students academic career to study their values related to individual behavior on teams. Students have two different team experiences during the sophomore design sequence.[2,3] During Engineering Design I, students work in teams of three and four, which tends to be most similar to prior team experiences (if the students report having prior team experiences). During Engineering Design II, however, students work in teams of eight or nine, which pushes the team to adopt project and team management tools to continue working toward a successful project. Those teams that fail to manage their team along with the project, tend to struggle to balance the two and have difficulty completing the course project.

SAS 9.3 was used to analyze all data collected from this study.

Results

Students responded to the value survey on a 7-point response scale. Table 2 contains the descriptive statistics for the 13 value items averaging across all three time points. In evaluating univariate normality, all items are notably negatively skewed and some item distributions were highly leptokurtic.

Table 2: Descriptive statistics for all value items.

	Mean	SD	Skewness	Kurtosis
Value 1	6.20	1.09	-3.01	13.06
Value 2	6.70	0.88	-6.10	42.95
Value 3	6.53	0.92	-4.96	32.10
Value 4	6.50	0.90	-5.06	33.68
Value 5	5.91	1.06	-2.61	11.75
Value 6	6.24	1.02	-3.34	16.83
Value 7	5.95	1.13	-2.43	9.40
Value 8	6.51	0.96	-4.52	26.58
Value 9	6.28	1.02	-3.46	17.65
Value 10	5.85	1.32	-2.66	8.91
Value 11	6.00	1.05	-2.89	13.04
Value 12	6.35	1.05	-3.41	16.65
Value 13	6.30	0.95	-3.94	23.29

An Analysis of Variance (ANOVA) was run on the mean value scores across the three time points (Fall 2012 – Week 4, Fall 2012 – Week 16, and Spring 2013 – Week 16) with the data from the 74 students who completed items at time point one, the 53 students at time point two, and the 28 students at time point three. From this analysis, it was found that the homogeneity of variances assumption was upheld ($F(152) = 1.41$, $p = 0.25$), and the mean value scores did not differ significantly across time ($F(152) = 1.44$, $p = 0.24$). Indicating that for this student population, students' values placed on the behavior of individuals in engineering teams likely remained stable through the academic year.

Once it was understood that the students' values did not change through the academic year, the research team explored the correlations between each of the value statements. Due to the nature in which the value scale used in the value survey was generated, there are no grounds to assume any number of factors underlie the observed variables. However, it is probable that the students conceptualize these items supposing to measure "team work value" as one or a few different dimensions rather than thirteen different dimensions arrived at by the research team.

First, the data were evaluated to determine the amenability of the items to a factor analysis. The Factor 8.1 program [29] was used to calculate Bartlett's test and the Kaiser-Meyer-Olkin (KMO). The null hypothesis of Bartlett's test states that the variables are unrelated in that no factor solution can reduce the data. This null was rejected ($\chi^2(78) = 917.9$, $p < .001$), supporting the notion that these data can be reduced. The KMO for these data was 0.915 which is considered to be "marvelous" according to Kaiser.[30] Both of these tests indicate that the data are amenable to factoring; the decision now is how many factors to extract.

A parallel analysis [31] and a scree plot evaluation were conducted to determine the number of factors to extract from the data. In a parallel analysis, the observed eigenvalues of the data are compared to randomly generated eigenvalues from several matrices of the same structure. If the observed eigenvalues are greater than those obtained randomly, then the number of factors for that eigenvalue should be extracted. The parallel analysis was conducted using the Factor 8.1 program.[29] The observed eigenvalue for one factor is greater than the mean eigenvalue in the randomly generated data and the 95th percentile of these randomly generated eigenvalues. However, the second eigenvalue is not different from a random series of eigenvalues which means that a one-factor solution is most tenable. The results from the parallel analysis are provided in Table 3.

Table 3: Parallel Analysis Results

Root	Observed Eigenvalues	Random Eigenvalues	
		Means	95th %ile
1	8.949	1.767	1.951
2	0.837	1.557	1.681
3	0.601	1.402	1.511
4	0.493	1.276	1.374
5	0.419	1.160	1.240
6	0.366	1.053	1.124
7	0.329	0.954	1.028
8	0.278	0.859	0.935
9	0.238	0.768	0.845
10	0.178	0.683	0.759
11	0.135	0.597	0.674
12	0.104	0.509	0.580
13	0.071	0.415	0.492

A scree plot of the observed eigenvalues is presented in Figure 1. When examining a scree plot, one looks to see where the points "level off" or where the remaining plotted values become a line at some point. The eigenvalue point before this line should be selected as the number of factors to extract. According to the scree plot for these data, the points level off at the second eigenvalue suggesting further that a one-factor solution (i.e, a single value related to individual behavior with respect to team work) is most tenable.

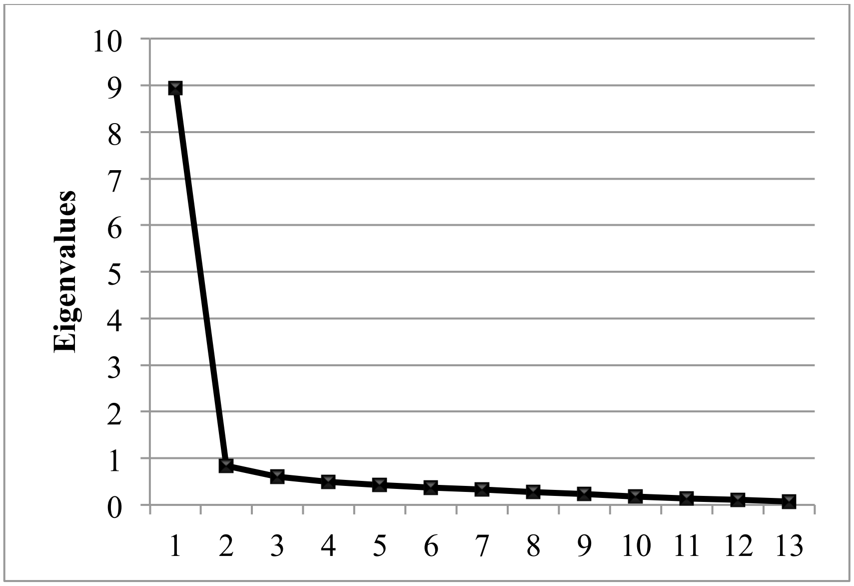

Figure 1. Scree plot for Value data

Discussion and Future Work

The results support our hypothesis that the students' values with respect to the behavior of individuals on a team will remain stable through the academic year. This is a positive finding, as we see that students seem to maintain their values even when their team environment changes. Additionally, it should be noted that students participating in the study were not provided feedback on their behavior during the Fall semester. Feedback was provided, in the form of a raw numerical percentage score during the Spring semester. This feedback, however, does not appear to have changed the values of the students as they were reported on the values survey.

We also can note that the students self report having strong values with respect to the values statements. The average score for all values, all students, all time steps is 6.25 with a high value of 6.7 and a low of 5.85. This seems to support the starting premise for our research: *Students generally embrace admirable values, but often encounter a "cognitive dissonance" when asked to explain whether their actions accurately reflect their value.* [9] The students in this study, however, were not placed in cognitive dissonance, as they were not asked to reflect on their values with respect to their behaviors. Future work will focus on making students aware of dissonance and encouraging them to balance more effectively the self-knowledge that informs decision making and problem solving. This is what we term as *Individual Sustainability* or a person's ability to live a lifestyle that includes creating harmony, interconnection, and relatively high levels of awareness in one's values, thoughts, and behaviors as well as maintaining an increasing control over one's physical, emotional, social, philosophical/spiritual, and intellectual life.[10,11]

Further, it is promising that based on the students ratings of the values, the value statements correlate to a single factor. During the two semesters when this study was being performed, students were also asked to self report on their behaviors based on the 36 aforementioned behavior statements. Future efforts of the research team will correlate behaviors to values as perceived by the students. This will provide insight into where there might be behavioral weaknesses, and consequently, which behaviors to target with course interventions.

As stated in the introduction, developing cohesion among the sophomore engineering cohort is a critical component of the sophomore design project. Our goal is to develop both identity and community among a cohort of students. We believe that if we can help students to work and function as a productive member of their engineering team, we can more fully achieve our goal of creating cohesion. The work reported in this paper is just the first step toward reaching this goal.

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Appendix

Name: ____

1. It is important for every group member to complete a fair share of the work.

strongly disagree	*disagree*	*slightly disagree*	*neutral*	*slightly agree*	*agree*	*strongly agree*

2. It is important for every group member to do quality work.

strongly disagree	*disagree*	*slightly disagree*	*neutral*	*slightly agree*	*agree*	*strongly agree*

3. It is important for every group member to accept responsibility for tasks required to complete work.

strongly disagree	*disagree*	*slightly disagree*	*neutral*	*slightly agree*	*agree*	*strongly agree*

4. It is important for every group member to keep commitments to the group.

strongly disagree	*disagree*	*slightly disagree*	*neutral*	*slightly agree*	*agree*	*strongly agree*

5. It is important for every group member to assist members who are having difficulty.

strongly disagree	*disagree*	*slightly disagree*	*neutral*	*slightly agree*	*agree*	*strongly agree*

6. It is important for every group member to respect feedback from other members.

strongly disagree	*disagree*	*slightly disagree*	*neutral*	*slightly agree*	*agree*	*strongly agree*

7. It is important for every group member to provide constructive feedback to other members.

strongly disagree	*disagree*	*slightly disagree*	*neutral*	*slightly agree*	*agree*	*strongly agree*

8. It is important for every group member to respect and listen to the ideas and viewpoints of other members.

strongly disagree	*disagree*	*slightly disagree*	*neutral*	*slightly agree*	*agree*	*strongly agree*

9. It is important for every group member to participate in group meetings.

strongly disagree	*disagree*	*slightly disagree*	*neutral*	*slightly agree*	*agree*	*strongly agree*

10. It is important for every group member to communicate with other group members outside of meetings.

strongly disagree	*disagree*	*slightly disagree*	*neutral*	*slightly agree*	*agree*	*strongly agree*

11. It is important for every group member to monitor and be aware of the progress of the team.

strongly disagree	*disagree*	*slightly disagree*	*neutral*	*slightly agree*	*agree*	*strongly agree*

12. It is important for every group member to believe that the group will be successful.

strongly disagree	*disagree*	*slightly disagree*	*neutral*	*slightly agree*	*agree*	*strongly agree*

13. It is important for every group member to acquire the knowledge necessary for the group to be successful.

strongly disagree	*disagree*	*slightly disagree*	*neutral*	*slightly agree*	*agree*	*strongly agree*