# How Relationships with Faculty and Peers Affect Value Development in Undergraduate Engineering Education: A National Survey Analysis

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**Abstract**

To prepare students for the serious ethical dilemmas encountered in STEM (science, technology, engineering, and mathematics), higher education educators strive to influence students' value development. Despite this goal, little is known about value development in undergraduate engineering education. Survey data from the 2008-2009 national administration of the revised College Student Experiences in STEM Questionnaire (CSESQ) was analyzed to examine the relationship between students' engagement with faculty and peers and their perceived value development. Findings from the present study offer insight into (a) engineering students' value development in college, and (b) the influence of relationships with peers and faculty members on such outcomes. Results from our analysis indicate that students who rate their relations with peers and faculty as positive, supportive, and welcoming also tend to report higher perceived gains in terms of value development. College classification and relationships with others such as faculty members were found to be statistically significant predictors of value development for undergraduate engineering students.

**Introduction**

Historically, higher education served major social functions like preparing citizens for active participation in democracy and socializing youth to cultural norms. Today, higher education tends to serve a more individualistic function, preparing students for their desired job or profession. Still, many agree that developing students' enduring values is a major goal of postsecondary education. Prior research suggests that value development is critical in fields that require individuals to make socially responsible decisions and ethical judgments regularly such as engineering.

On a daily basis, engineers design and build products that impact people's quality of life, from public health to safety. According to the National Society of Professional Engineer's (NSPE) Engineering Code of Ethics, "the services provided by engineers require honesty, impartiality, fairness, and equity, and must be dedicated to the protection of the public health, safety, and welfare." [1] However, students who aspire to work in engineering come to college with diverse beliefs, values, morals, and ethical backgrounds. Furthermore, ethics are not the same as morals. Ethics are learned and may be used in professional settings while morals are generally established externally and difficult to change over time. In engineering, the NSPE established a code of ethics that encourages professional engineers to:

1. Hold paramount the safety, health, and welfare of the public.
2. Perform services only in areas of their competence.
3. Issue public statements only in an objective and truthful manner.

4. Act for each employer or client as faithful agents or trustees.
5. Avoid deceptive acts.
6. Conduct themselves honorably, responsibly, ethically, and lawfully so as to enhance the honor, reputation, and usefulness of the profession." [1]

History has shown how important ethics are in engineering. For example, the U.S. has experienced numerous tragedies due to acts of deception and disregard for public safety. Recall the space shuttle Columbia tragedy in 2003 that resulted in the loss of seven lives.[2] Reports following the incident revealed that engineers suspected damage to the shuttle following launch, but National Aeronautics and Space Administration (NASA) managers failed to act on their warnings.[3] Similarly, in 1986, the Challenger space mission also resulted in a disastrous failure and loss of life due to suspected neglect on the part of engineers who allegedly disregarded a flaw in a vital mechanical part.[4] Even Minnesota's I-35 Bridge Collapse of 2007, which resulted in the loss of thirteen lives, was due to serious structural damage that went unaddressed or denied by engineers.[5] As these incidents demonstrate, nowhere is value development more important than in fields like engineering. Yet, little to no attention has been given to engineering students' value development in the research literature. This is the gap addressed by our study.

## Literature Review

To conduct this study, we drew upon literature about undergraduate engineering students' learning and development in college, skills and abilities needed for professional engineering practice, and factors that influence undergraduate engineering students' development outcomes. The following review is organized around these three groups of literature.

Quite a bit has been written about undergraduate engineering students' learning and development in college. For instance, The Accreditation Board for Engineering and Technology (ABET) identified several major learning outcomes in engineering such as one's ability to work on multidisciplinary teams, solve engineering problems, and understand ethical responsibilities.[6] Engineers are often called upon or expected to make socially responsible decisions or on-the-spot ethical judgments that are consistent with their personal or professional commitments. Though ABET stresses the importance of ethics and values in engineering practice, they provide little to no information about factors that promote such skills in engineering.

There are other reports that stress the importance of specific skills and abilities needed for professional engineering practice. In 2004, The National Academy of Engineering (NAE) released, *The Engineer of 2020: Visions of Engineering in the New Century*, that provided a plan for the future of engineering education in the United States.[7] While offering a comprehensive list of strategies to prepare future engineers, the NAE also recommended a series of key attributes, including (a) good communication and teamwork skills, (b) practical ingenuity to solve problems, and (c) high ethical standards, which provides additional justification for the focus of our study.[7]

In addition to creating *The Engineer of 2020* report, the NAE also established the *Grand Challenges for Engineering in the 21st Century*. The grand challenges report outlines human concerns which depend upon appropriate engineering solutions.[8] The list includes issues such as, providing access to clean water, creating better medicines, and revitalizing urban infrastructure, to name a few. To overcome such challenges, our country must rely on engineers who can solve complex real-world problems, as defined in our value development construct.

Although ABET and NAE have not conducted empirical research on factors that influence learning and development outcomes for undergraduate engineering students, some previous research exists. Several researchers have studied collaborative learning in STEM fields such as engineering. For instance, in 1999, Springer et al. reviewed over 39 studies on small group learning and its effect on student achievement, persistence, and attitudes in STEM.[9] They found that collaborative learning improved academic achievement, student attitudes toward learning and retention in STEM programs.[9] In addition, in 2001, Terenzini et al. compared undergraduate engineering courses which were taught using lecture/discussion with those taught with active/collaborative learning styles.[10] They found that collaborative teaching led to statistically significant gains in student learning and higher levels of communication and group skills.[10] Furthermore, in 2011, Stump et al. focused on the relationship between collaboration, self-efficacy, knowledge building behaviors, and course grade for engineering students. Their results suggest that collaborative learning increased student's self-efficacy and course grades.[11] Taken together, results from these previous studies highlight the importance of collaboration and teamwork in undergraduate engineering students' learning and development.

Some research focuses on the nature of ethical problems faced by engineering students and practitioners. Work by Jonasson et al. in 2006 describes the difference between typical engineering school problems and those conducted in the actual workplace, which tend to be less structured and more complex.[12] Jonasson and colleagues urged engineering educators to make school-based work more practical and intricate, stressing the importance of developing students' ability to solve complex real-world problems. In a later study, in 2009, Jonasson et al. conducted research on the use of problem solving in engineering ethics.[13] Results showed that students were better able to support their answers and create more counterclaims when working on realistic case studies in engineering ethics.[13] One conclusion from this line of research is that undergraduate engineering students' ethics and value development may be influenced in classroom and other learning contexts through teaching style and the kind of activities in which they're engaged. However, little is known about the role that relationships with faculty and peers play in engineering students' value development; there is a clear need for more research on these topics. The present study addresses that gap in our collective knowledge.

## Purpose

The purpose of the present study was to examine the relationship between engineering students' relationships with faculty and peers and their perceived value development in college. Specifically, we conducted multivariate analyses on multi-institutional survey data from 115 engineering students to answer the following research question: Is there a relationship between engineering students' perceived value development and the nature of their relationships with faculty and peers? The next section describes our methods, followed by a report of findings.

## Methods

This study is part of a larger, longitudinal study titled, *Investigating the Critical Junctures: Strategies that Broaden Minority Participation in STEM Fields* funded by the National Science Foundation (NSF). As such, the study focused on engineering students. While the larger study consists of both quantitative and qualitative components, this report is based on statistical analysis of the quantitative survey data only.

**Data Source.** Data was drawn from the 2008-2009 national administration of the revised *College Student Experiences in STEM Questionnaire* (CSESQ). The CSESQ consists of 191 items designed to measure the quality and quantity of students' involvement in college activities within STEM and related campus environments. For example, several items elicited information about STEM students' engagement in a series of college activities that have been shown to contribute positively to learning and psychosocial development.[14] The college activities section includes questions that ask how often students engaged in campus events and academic tasks (e.g., hours spent studying, attended a cultural event) during the school year. To date, more than 500 colleges and universities have used the national questionnaire. The revised CSESQ, and the original instrument, have been shown to be consistently reliable and valid in our previous studies.[15]

**Sample.** The analytic sample for this study was restricted to engineering majors only, given the focus of our paper. This yielded a sample of 115 participants. Of the students in this sample, the majority (70%) were male. White students comprised 89% of the sample, while 11% identified as students of color (i.e., Black, Asian/Pacific Islander, and Hispanic). The majority of students in the sample were seniors (61.7%) and 23 years old or younger (76.8%). In addition, 93% of the participants in the sample were full-time students. Academically, most of the students in the sample had an average grade of "B" or better (81.7%). Table 1 provides additional information about the sample.

**Table 1: Description of sample (N=115).**

| Variables | % |
|---|---|
| ***Academic*** | |
| **College classification** | |
| Freshman, first-year | 33.9 |
| Sophomore | 5.3 |
| Junior | 6.1 |
| Senior | 51.3 |
| Missing | 3.5 |
| **Enrollment status** | |
| Part-time | 7.0 |
| Full-time | 93.0 |
| **Enter college here or transfer** | |
| Started here | 72.2 |

| | |
|---|---|
| Transferred | 27.8 |
| **Grades at this college** | |
| C, C-, or lower | 4.3 |
| B-, C+ | 13.9 |
| B | 33.9 |
| A-, B+ | 30.4 |
| A | 17.4 |
| | |
| ***Demographic*** | |
| **Sex of student** | |
| Male | 70.4 |
| Female | 29.6 |
| **Ethnicity** | |
| African American/Black | 5.2 |
| Asian/Pacific Islander | 4.3 |
| Caucasian/White | 88.7 |
| Hispanic | 1.7 |
| **Age of student** | |
| 19 or younger | 34.8 |
| 20-23 | 40.0 |
| 24-29 | 15.7 |
| 30-39 | 7.0 |
| Missing | 2.6 |

**Measures.** As previously mentioned, the dependent variable used in this study—value development—is a construct assessing students' perceived gains in various learning domains related to ethics, beliefs, and values. Specifically, we operationalized value development, based on the extant literature, using items from the CSESQ that tapped various dimensions of this learning goal. Specifically, we computed a summated scale (*value development*) comprised of three (3) survey items; a sample item from this scale asked students to rate "To what extent has your experience at this institution contributed to your knowledge, skills, and personal development in developing a personal code of values and ethics?" Each original item was placed on a scale ranging from 1 to 4. Thus, the summated scale ranged from 3 (*very little*) to 12 (*very much*). Alpha reliability coefficient of the summated scale was adequate ($\alpha = 0.74$).
The independent variables of interest assessed the nature (i.e., frequency and quality) of student relationships with peers and faculty members respectively. Specifically, items asked students to rate the essence of their relationships with groups. Each item was placed on a scale ranging from 1 (*unfriendly, unsupportive, sense of alienation*) to 7 (*friendly, supportive, sense of belonging*). Both items were used in our analysis. Finally, we controlled for an array of potentially confounding factors including, age, gender, race/ethnicity, class level, enrollment status, transfer status and grades.

**Data Analysis.** Data analysis proceeded in three stages. First, descriptive statistics were calculated to describe the analytic sample and to determine any existing patterns among data points. Second, correlation analyses were conducted to estimate the magnitude and direction of statistical relationships among independent and dependent variables used in this analysis. Finally, hierarchical linear regression analysis was used to estimate the net effect of relationships with faculty and peers on engineering students' perceived value development in college. Hierarchical regression analysis is "a method of regression analysis in which independent variables are entered into the regression equation in a sequence specified by the researcher in advance." [16]

**Table 2: Descriptive statistics for value development and relationship variables**

| | M | SD |
|---|---|---|
| ***Gains*** | | |
| Value development | 8.32 | 2.36 |
| Working effectively with others | 3.07 | 0.91 |
| Solving complex real-world problems | 2.81 | 0.94 |
| Developing a personal code of values and ethics | 2.45 | 1.05 |
| ***Relationships*** | | |
| Relationships with other students | 5.67 | 1.20 |
| Relationships with faculty members | 4.90 | 1.58 |

## Limitations

Before presenting the results of this study, several limitations should be considered. First, the restricted analytic sample is relatively small. In particular, the sample was comprised of relatively few underrepresented racial minorities (i.e. 5.2 % Black, 1.7% Hispanic, and 0% Native American). Results should be understood with these considerations in mind.

Secondly, this analysis relied on student self-reported information about relations with faculty and peers, as well as students' perceptions of their own development. Despite a few challenges to their internal validity, self-reports are widely used in educational research and are generally considered valid if the information requested is known by the participant, if the questions are phrased clearly, and if the students deem the question worthy of a response.[17] Accordingly, items from the current analysis satisfy these conditions and, thus, were used in the analysis. The truth is, as Gonyea has insisted, "all questionnaire surveys, whether locally produced or nationally published, rely on some type of self-reported information." [18] Still, to the extent that self-reports alter the nature of statistical relationships; results may be limited in unknown ways.

Although important, these limitations do not reduce the study's usefulness in understanding the relationship between students' engagement with faculty and peers and their perceived value development.

## Results

The mean reported GPA for the sample was 5.55 (SD=1.65), which equates to a B and B+. The mean value development score for the engineering students in our sample was 8.32 (SD=2.36). Table 2 presents means and standard deviations for the central independent and dependent variables included in this analysis.

Correlation analyses revealed several statistically significant correlations among the dependent variables at both the $p<0.05$ and $p<0.01$ levels. These exploratory findings justified the use of multivariate regression techniques to estimate the net effect of engineering students' relationships with others on their perceived value development. Correlation results suggest that relationships with peers ($r=0.22$, $p<0.05$) and faculty members ($r=0.44$, $p<0.01$) are both positively and statistically significantly correlated with value development. There is also a moderate, positive and statistically significant correlation between relationships with faculty members and student grades ($r=0.34$, $p<0.01$). In other words, engineering students with better relationships with faculty members tended to report higher grades. Interestingly, no statistically significant correlations emerged along gender lines. Table 3 presents the correlations for all independent and dependent variables included in this analysis.

**Table 3: Correlations among variables in analysis**

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Value Development | 1 | | | | | | | | | |
| Age | -0.16 | 1 | | | | | | | | |
| College Classification | 0.02 | 0.74** | 1 | | | | | | | |
| Transfer Status | -0.21* | 0.61** | 0.34** | 1 | | | | | | |
| Gender | 0.04 | -0.13 | -0.03 | -0.04 | 1 | | | | | |
| Race/Ethnicity | -0.14 | -0.01 | -0.06 | -0.02 | -0.09 | 1 | | | | |
| Enrollment Status | 0.14 | -0.26** | -0.19* | -0.13 | -0.03 | -0.07 | 1 | | | |
| Grades | 0.14 | -0.08 | 0.02 | -0.03 | -0.04 | 0.27** | 0.01 | 1 | | |
| Relationships with other students | 0.22* | -0.22* | -0.13 | -0.22* | 0.09 | -0.09 | 0.23** | 0.07 | 1 | |
| Relationships with faculty members | 0.44** | -0.15 | -0.17* | -0.02 | 0.08 | -0.06 | -0.02 | 0.34** | 0.13 | 1 |

* indicates statistical significance at $p < 0.05$ ** indicates statistical significance at $p < 0.01$.

Hierarchical regression analysis was conducted to estimate the net effect of relationships with peers and faculty on value development for engineering students. To intensify the rigor of this analysis, a set of statistical controls were employed to account for potentially confounding influences such as background (e.g., sex, age) and academic factors (e.g., college classification, transfer status).  Several of these factors have been shown to be important when estimating the net effect of college on students,[14] therefore, the study was designed to account for such differences. In the final model, independent variables were statistically related to perceived value development for engineering students, $R^2 = 0.31$, $R^2_{adj}= 0.24$, $F_{9, 97}= 4.81$, $p <0.01$. The final model accounts for 31% of the variance in value development for engineering students. While background characteristics accounted for some of the variance in value development, ($\Delta R^2$= 0.13) the majority of the variance was explained by the relationship with peers and faculty variables ($\Delta R^2$= 0.18). Collinearity diagnostics, including tolerance statistics, eigenvalues and condition indices are all within acceptable limits suggesting that multicollinearity was not a problem for this analysis. Table 4 presents a summary of the regression results.

**Table 4: Predicting Value Development for Engineering Students from Relationships, Controlling for Confounding Factors**

| | *Step 1* | | *Step 2* | |
|---|---|---|---|---|
| *Variables* | *B* | *SE* | *B* | *SE* |
| Constant | 8.11 | 2.75 | 3.82 | 2.67 |
| Age | -0.48 | 0.48 | -0.44 | 0.43 |
| College Classification | 0.35 | 0.24 | 0.50 | 0.22* |
| Transfer Status | -0.84 | 0.65 | -0.93 | 0.59 |
| Gender | 0.05 | 0.50 | -0.16 | 0.45 |
| Race/Ethnicity | -0.55 | 0.32 | -0.28 | 0.29 |
| Enrollment Status | 1.02 | 1.00 | 1.13 | 0.92 |
| Grades | 0.24 | 0.15 | -0.03 | 0.14 |
| Relationships with other students | | | 0.18 | 0.18 |
| Relationships with faculty members | | | 0.69 | 0.14** |
| *R* | 0.36 | | 0.56 | |
| *R*2 | 0.13 | | 0.31 | |
| Adj. *R*2 | 0.07 | | 0.24 | |

* Indicates statistical significance at $p < 0.05$ ** indicates statistical significance at $p < 0.01$.

## Discussion

This study used survey data from 2008-2009 national administration of the revised College Student Experiences in STEM Questionnaire (CSESQ) to examine the link between students' relationships with faculty and peers and their perceived value development. The results of this investigation suggest a number of important conclusions and directions for future praxis and research.

First, results from this study suggest that undergraduate engineering students' perceived value development is a function of the nature of their relationships with peers and faculty members. Survey respondents who rated their relations with peers and faculty as positive, supportive, and welcoming also tended to report higher perceived gains in terms of value development. It may be the case that our results provide clues to the conditions in which engineering students' values can be developed. Working with faculty and peers in positive and meaningful ways may be the tools necessary for students to question unexamined assumptions, debate about their beliefs and moral thoughts, or clarify their commitments and values. Our study's results extend those of previous researchers who studied non-engineering students or those that stress the importance of

collaborative learning and other pedagogies.[9, 12] It's also true that engineering students' relationships with peers and faculty play a role in their values development.
Secondly, information from the present analysis can be used to enhance engineering students' value development, learning environments in engineering education, and forms of engagement in the curriculum. The only statistically significant predictors of value development for engineering students were college classification and relationships with others such as faculty members. More advanced engineering students (e.g. juniors and seniors) may be more likely to have higher value development scores for several reasons. It may reflect a maturation effect that's associated with continued enrollment in college and progress toward one's degree, which holds promise for the development of these students' skillsets. In other words, by staying in college and experiencing more of the college environment, engineering students' values are pushed, extended, and developed. Given that value development is a consummate goal of college, this finding underscores the importance of retention programs in undergraduate engineering.

Positive relationships with faculty influence engineering students' values development may hold a number of meaningful implications. For example, the results of this analysis suggest that the growth and development of values for engineering students depends a great deal on their relationships with faculty members. Faculty members from all disciplines should take this charge seriously and try to promote positive relationships with students that signal care for their well-being, support, and a sense that students belong in college.

Findings from this study also suggest important directions for future research. Since the responsible practice of engineering requires students to work together to ethically solve complex real-world problems, future studies should be conducted that attempt to estimate the impact of student relationships and other factors on value development for students at different kinds of institutions. For example, future studies could investigate the impact of relationships with administrators on value development for engineering students at community colleges, Black colleges, and even for-profit institutions. Investigating differences in engineering students' perceived value development along race, class and gender lines could also yield valuable information. It would also be useful to see how the development of values differs for engineering students across different programs of study (e.g., mechanical vs. environmental engineering). These investigations could prove useful for faculty, staff and administrators as they decide how to revise curriculum and allocate scarce resources to the training of future engineers and practitioners. These investigations could also aid students in knowing the type and kind of activities in which they should be engaged to develop the skills and abilities needed for successful practice in engineering.

## Conclusion

This study sought to examine the relationship between engineering students' relationships with faculty and peers and their perceived value development in college. Specifically, we conducted multivariate analyses on multi-institutional survey data from 115 engineering students to answer the following research question: Is there a relationship between engineering students' perceived value development and the nature of their relationships with faculty and peers?

Drawing upon the extant literature and using items from the CSESQ, we defined value development in undergraduate engineering programs (UEPs) as a student's perceived ability to work effectively with others, solve complex real-world problems, and develop a personal code of values and ethics after being in college.

As previously highlighted in the results section, our analysis indicated that students who rated their relations with peers and faculty as positive, supportive, and welcoming also tended to report higher perceived gains in terms of value development. The only statistically significant predictors of value development for engineering students were college classification and relationships with others such as faculty members.

Based on these findings, we offer the following recommendations. First, UEPs should focus on providing students with meaningful opportunities to collaborate with peers and faculty in positive, supportive, and welcoming environments. Collaboration with peers and faculty can occur through class assignments, extra-curricular activities, and social events. Such collaboration can also be encouraged through the use of formal programs such as student design teams and living learning communities. Secondly, more emphasis should be placed on other areas of value development (i.e. solving complex real-world problems and developing a personal code of values and ethics) to retain a higher number of students within UEPs. Targeted changes to curriculum and increased opportunities for students to gain work experience can help support this type of development. Based on the results of the current study, we believe the aforementioned strategies can improve students' overall perceived value development.

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