Investing in the future: Testing the Efficacy of Socialization within Undergraduate Engineering Degree Programs

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Introduction

The United States is in need of more than a few new engineers. Between projected job growth and anticipated retirements, by 2018 there will be over 500,000 job openings in engineering (President's Council of Advisors on Science and Technology [PCAST], 2012). Yet several national reports have indicated that the United States may not be producing enough engineering degrees to meet this need (Committee on Maximizing the Potential of Women in Academic Science and Engineering, National Academy of Sciences, National Academy of Engineering, & Institute of Medicine, 2007; National Academy of Sciences, Global Affairs, & Institute of Medicine, 2011). The National Academy of Engineering has pointed to this trend in particular as a "crisis," highlighting the relatively low bachelor's graduation rate in American engineering programs compared to other nations (Dutta, Patil, & Porter, 2012, p. ix). In response, PCAST has specifically stressed improving STEM degree productivity as part of the strategy to address this problem, calling for an additional one million STEM degrees over the next decade (PCAST, 2012). Engineering degrees will need to constitute a significant proportion of that increase.

Improving degree productivity may only partially address this problem. While more than half of college seniors in engineering in 2008 definitely planned to enter engineering careers after graduation, about one in five were either unsure or were likely pursuing work in another field (Sheppard et al., 2010), suggesting factors other than academic performance play a role in engineering students' decisions to enter engineering careers. One factor, the development of a professional engineering identity, has been associated with retention and persistence in degree programs (Pierrakos, Beam, Constantz, Johri, & Anderson, 2009), but most markedly with a commitment to pursue engineering as a career after college (Meyers, Ohland, & Silliman, 2012).

Yet developing engineering identity may be more difficult when a person is marginalized within that discipline. Women and students of color face a “chilly” or even hostile climate within engineering degree programs that may impede their identification with the field (Camacho & Lord, 2011; Goel, 2006; May & Chubin, 2003). Very few studies have examined the role climate may play in the development—or hindrance—of an engineering identity, however. Therefore, the purpose of this study is to examine both the effect of socializing experiences within engineering programs on engineering identity and whether campus climate affects students’ identification with and commitment to engineering.

This study stands to contribute to our understanding of the development of engineering identity, especially among diverse student populations. First, quantitative studies examining engineering identity often rely on single-item measures (Matusovich, Barry, Meyers, & Louis, 2011; Meyers, Ohland, Pawley, & Christopherson, 2010; Meyers, Ohland, et al., 2012), failing to account for the multiple dimensions of engineering identity that have emerged from exploratory qualitative studies into this phenomenon (Pierrakos et al., 2009; Tonso, 2006). Second, this study uses a longitudinal design with a national dataset; most prior studies have either examined only one or a small number of institutions (Du, 2006; Matusovich et al., 2011; Pierrakos et al., 2009; Tonso, 2006) or used cross-sectional data in pseudo-longitudinal designs (Meyers, Ohland, et al., 2012). Third, while there has been much more examination of gendered patterns in the construction of an engineering identity among men and women (Cech, Rubineau, Silbey, & Seron, 2011; Du, 2006; Faulkner, 2009; Heyman, Martyna, & Bhatia, 2002; Pierrakos, Beam, Watson, Thompson, & Anderson, 2010; Wolfe & Powell, 2009), much less research looks into the experiences of students of color, rather folding engineering students of color into broader studies across STEM fields (Carlone & Johnson, 2007; Chang, Eagan, Lin, & Hurtado, 2011;

Seymour & Hewitt, 1997). In addition, much of this work focuses on the experiences of underrepresented racial minority students, excluding Asian American students from analysis by grouping them with White students (Goel, 2006; Ma, 2010; Museus & Chang, 2009). By addressing some of these limitations in existing research, this study builds upon and extends theory on engineering identity.

Literature Review

In order to address the problem posed by an impending shortfall in the pool of qualified engineers relative to anticipated job growth, this study proposes to focus on how students develop an engineering identity while pursuing an engineering bachelor's degree, the first professional degree in engineering (Institute of Electrical and Electronics Engineers [IEEE], 2007). As opposed to a focus on engineering degree productivity, which provides insight into how students are retained and persist to graduation, understanding engineering identity development may also uncover why some students who complete engineering degrees choose not to pursue engineering as a career (Lichtenstein et al., 2009). The following section will review relevant literature on engineering identity, experiences found to enhance engineering identity, and the climate for women and students of color within engineering programs.

Engineering Identity

Weidman et al. (2001) argue in their framework for graduate and professional student socialization one goal of professional programs is the development of a professional identity. They indicate that prerequisite to assuming a profession, a person needs to identify—and be identified by others—as a member of that profession. Given an engineering degree is considered a professional degree (IEEE, 2007), it follows that one goal of engineering programs ought to be the development of a professional engineering identity in students. This argument has found support within the engineering education literature (Loui, 2005). While no singular framework has been articulated that outlines the essential dimensions of an engineering identity, the literature reveals a number of indicators associated with the successful development of engineering identity.

One indicator is competence in engineering knowledge, evidenced both in one's own engineering self-efficacy as well as through external markers like professional licensure or possession of an engineering degree (Allie et al., 2009; Loui, 2005). Related to external markers, legitimization and recognition as an engineer from others (e.g. faculty or fellow engineering students) is another important component of engineering identity (Tonso, 2006). Resulting from recognition and legitimization is the development of a sense of belonging within engineering as a community of practice (Allie et al., 2009), which is also associated with retention and persistence in engineering (Du, 2006; Pierrakos et al., 2009). Finally, engineering identity is marked by a deepening commitment to a career in engineering and consequently has been associated with the decision to enter the engineering workforce, pertinent to the problem of concern for this study (Meyers, Ohland, et al., 2012; Meyers, Silliman, Ohland, Pawley, & Smith, 2012). Engineering identity has also been described in terms of its relation to mathematics and science academic identities due to the high level of math and science requirements in the engineering curriculum (Carlone & Johnson, 2007; Cass, Hazari, Cribbs, Sadler, & Sonnert, 2011; Solomon, 2007).

Experiences that Enhance Engineering Identity

Engineering identity emerges from socializing experiences within both engineering degree programs and the engineering workforce (Loui, 2005), but several pre-college experiences and opportunities have also been identified as important as they influence students' initial decisions to enter an academic engineering program. Students' prior knowledge of the field and exposure to engineering, especially those who have a parent who works as an engineer, are more likely to pursue and commit to engineering as a career (Lichtenstein et al., 2009; Pierrakos et al., 2009). Academic preparation also matters, especially in math and science, and contributes to students' self-efficacy to succeed in an engineering program (Pierrakos et al., 2009).

At the point of college choice, institutional characteristics matter as students with a stronger commitment to engineering apply to colleges based on the reputation of the institution's engineering programs (Matusovich et al., 2011). Different types of institutions have differing levels of resources to support engineering students; for example, more selective universities have been found more likely to provide undergraduate research programs (Chang, Sharkness, Newman, & Hurtado, 2010). Institutional type also has an impact on engineering identity development as it plays a role in the major declaration process (Sheppard et al., 2010). Research universities often require students to apply to their majors after their first or second year whereas other colleges and universities allow students to declare upon matriculation. Having to endure a second admission process could reduce engineering students' confidence in feeling competent in their field and thus affect their identification with engineering. Institutional type has also been found to affect retention and persistence in engineering (Ohland et al., 2008; Zhang, Anderson, Ohland, & Thorndyke, 2004); this could be partially due to the effect of institutional type on engineering identity.

This study is primarily concerned with college experiences like engineering-related activities that provide students opportunities to "perform" engineering and demonstrate engineering "competence," to borrow terms from Carlone and Johnson's (2007) science identity framework. Studies have found internships, student engineering organizations, and undergraduate research experiences all relate to developing an engineering identity (Meyers et al., 2010; Meyers, Silliman, et al., 2012; Pierrakos et al., 2009). However, also relevant to Carlone and Johnson's framework, students who are more altruistically oriented are often dissuaded from committing to pursue a career in the field (Berndt & Paterson, 2010; Dukhan, Schumack, & Daniels, 2008). These researchers argue for inclusion of more service-related opportunities for engineering students (e.g. Engineers Without Borders) and especially the incorporation of service-learning into the engineering curriculum as a way to integrate a student's altruistic orientation with her or his developing engineering identity.

Campus Climate and Engineering Identity for Women and Students of Color

No studies have specifically tested the relationship between campus climate and engineering identity, but much research has examined the experiences of women and students of color within academic engineering programs. Patterns in enrollment as well as retention and persistence along the lines of gender and race/ethnicity endure (Lord et al., 2009; Lord, Camacho, Layton, & Ohland, 2010; Lord, Layton, & Ohland, 2011). As prior research has demonstrated little difference in terms of skills or ability between students who persist in engineering and students who leave (Ohland et al., 2008; Seymour & Hewitt, 1997), these discrepancies may be due to climate for diversity within engineering or on campus in general. A chilly or hostile climate for diversity interferes with a student's sense of belonging (Foor, Walden, & Trytten, 2007; Hurtado & Carter, 1997), although, as Foor, Walden, and Trytten (2007) demonstrated, individual determination can counteract feelings of isolation and exclusion. Thus while underrepresented students should not be cast as victims, students should be able to expect their institutions will provide a diverse learning environment in which all students can succeed (Hurtado, Alvarez, Guillermo-Wann, Cuellar, & Arellano, 2012).

The climate for women in engineering. A robust body of literature on the experiences of women within engineering has led scholars to label the field as "gendered." This conclusion refers to the conflation of engineering values and norms with those typically attributed to men (Faulkner, 2000, 2007). For instance, women's contributions and styles of communication are not afforded the same legitimacy within engineering as men's (Tonso, 2006; Wolfe & Powell, 2009).

The ways women form engineering identities are also undervalued (Du, 2006); in fact, "legitimate" engineering identities may prove inaccessible to women (Tonso, 2006). One study on engineering identity found the effects of engineering work experience, research experience, and involvement in student organizations on engineering identity lost significance when controlling for gender, suggesting not only were women less likely to see themselves as engineers, but gender possibly played a role in terms of access to other opportunities (Meyers et al., 2010). Du (2006) also found gendered patterns of access to engineering occurring even before college; namely, men were more likely than women to be encouraged as children to consider engineering as a career and thus encouraged to explore engineering activities at a young age.

These patterns lead to the exclusion of women from engineering and a subsequent isolation and tokenization of those few women who do pursue the field (Du, 2006; McKendall, 2000). Women also face explicit forms of gender discrimination, ranging from subtle microaggressions to outwardly sexist comments (Logel et al., 2009; McKendall, 2000; Richman, vanDellen, & Wood, 2011). Coupled with the fact that women only constitute 18.4% of engineering students (National Science Board, 2012; Yoder, 2011), the climate for women in engineering can only be described at best as "chilly" (Hall & Sandler, 1982). Camacho, Lord, Brawner, and Ohland (2010) have argued that improving the climate for women in engineering is critical to improving their recruitment and persistence rates.

The racial climate in engineering. African American, Latina/os, and American Indians remain underrepresented among students enrolled in engineering programs relative to their proportion of the overall U.S. population (National Academy of Sciences et al., 2011). For instance, African Americans constitute only 4%, and Latinas/os 8.5%, of engineering degree recipients (Yoder, 2011). This persistent underrepresentation is partly due to the unique barriers these students face such as inequitable academic preparation, the gradual dismantling of affirmative action policy in college admissions, and a lack of racial minority engineering role models in the popular media (May & Chubin, 2003). However scholars also point to the climate within engineering programs, especially at predominantly White institutions, as another important factor (Brown, Morning, & Watkins, 2005; Tate & Linn, 2005; Trenor, Yu, Sha, Zerda, & Waight, 2007).

At predominantly White institutions (PWIs), underrepresented racial minority (URM) students often report feeling isolated or alone, being the only or one of a few URM students in most of their engineering classes (Strayhorn, Long III, Kitchen, Williams, & Stentz, 2013). These feelings of isolation interfere with students’ ability to develop a sense of belonging within their engineering programs, which can interfere with their development of an engineering identity (Allie et al., 2009; Pierrakos et al., 2009). Tate and Linn (2005) attributed much of this, at least for women of color, to the fact that their academic peer groups tended to resemble the demographics of their engineering programs (predominantly White or Asian American) while their social peer groups tended to share their racial or ethnic background. However, far from being a barrier, Tate and Linn concluded that navigating these different spaces allowed women engineering students of color to construct multiple identities—as a student, as a woman of color, and as an engineer—as a mechanism to support their success. Litzler and Samuelson (2013) also identified support from faculty and peers as an important way URM engineering students develop a sense of belonging. Finally, Davis and Finelli (2007) detailed how undergraduate research programs, service-learning courses, and pedagogical approaches that connect academic work with real-world applications all hold promise for enhancing diversity and retention in engineering.

The relationship between a climate and URM student success in engineering is even more evident at minority-serving institutions (MSIs) such as historically Black colleges and universities (HBCUs) and Hispanic-serving institutions (HSIs). These institutions are committed to providing a uniquely supportive environment in which students of color feel culturally validated (Griffin & Hurtado, 2011), and as an example of their success, African American engineering students who attend HBCUs enjoy higher grade point averages than their peers attending PWIs (Brown et al., 2005). Fleming, Smith, Williams, and Bliss (2013) also observed a relationship between support from faculty and peers and students' development of engineering identity across HBCUs and HSIs. The supportive climate at minority-serving institutions has emerged as one reason why they play a critical role in diversifying the nation's engineering workforce (Newman, 2011).

The climate for Asian American students in engineering can be hostile as well; even though they are not considered underrepresented, Asian American students face a great deal of stereotyping, most especially the "model minority" myth (Do, Zhao, Trytten, & Lowe, 2006; Trytten, Lowe, & Walden, 2012). Finally, racial/ethnic microaggressions have been found to affect the experiences of all students of color in engineering (Camacho & Lord, 2011; Litzler, Mody-Pan, & Brainard, 2011). All of these experiences impact students' sense of belonging within engineering and may diminish engineering identity development; however, research has only begun to explore these connections.

This study then stands to contribute to the literature on engineering identity in several ways. First, much of the literature on engineering identity measures it as a single variable, whereas our study captures engineering identity as a multi-item construct. We also examine students' commitment to an engineering career. Second, our dataset is longitudinal and national, allowing us to study *change* in engineering identity or commitment over four years of college across many institutions. Finally, our study tests a broader range of variables within the same model, including background characteristics and predispositions, institutional characteristics, student experiences, and perceptions of the campus climate. Prior research has only examined smaller pieces of this larger picture.

Conceptual Framework

The framework guiding this study is primarily informed by Weidman et al's (2001) theory of socialization within graduate and professional programs. Although their theory is focused on graduate-level professional programs, theories of undergraduate socialization (Weidman, 1989) focus more broadly on the undergraduate experience, and this framework incorporates elements relevant to engineering programs, especially their connections to the engineering profession.

Weidman et al. (2001) indicate the primary outcome of graduate and professional school socialization is the development of a novice professional practitioner. In their model, this outcome is represented by what they posit are the two elements of successful socialization, professional identity and commitment to the field. However, while Weidman et al. may identify professional identity and commitment as the "outcomes" of the socialization process, they also argue that their model is dynamic and interactive. As a result, they conclude that the development of a professional identity and commitment to the field are interactive elements of the overall socialization process and thus affect and are affected by the other aspects of the model.

The model then details the core socialization experience within the graduate or professional program. Weidman et al. (2001) underscore that this component of their model is the part the academic program has the most influence over. First, institutional culture plays a role in socialization in that it guides the norms and practices of the institution. Included within institutional culture is the culture of the academic program as well as the peer climate. Second, several processes take place while a student is enrolled in the graduate or professional program and influence their overall socialization, including learning, interaction with faculty and peers, and integration into the academic program and its activities. Finally, the model articulates experiences that constitute the core elements of socialization, namely the acquisition of professional knowledge, investment in the professional field, and involvement in both the academic program and the broader professional community.

Surrounding the core socialization experience are four external components that influence a student's socialization. Two components are a student's background and predispositions and a student's developing professional identity and commitment, the "inputs" and "outputs" of the socialization process. The other two components are the professional community into which students are being socialized and the personal communities to which students belong, including family and friends. Finally, the model incorporates four stages of socialization that have been articulated in prior models—anticipatory, informal, formal, and personal—though this study is only concerned with the latter three stages. Although they represent them as stages, Weidman et al. (2001) indicate these stages are not necessarily sequential and a student can experience more than one simultaneously.

Even though Weidman et al. (2001) do include peer climate in their model and recognize that campus climate will affect the outcomes of socialization, campus climate remains undertheorized within their framework. Despite this, they indicate the applicability of the Hurtado, Milem, Clayton-Petersen, and Allen (1998) model of campus climate to graduate and professional programs. As a result, we incorporated two dimensions of the campus climate within the Multicontextual Model for Diverse Learning Environments (MMDLE; Hurtado, Alvarez, et al., 2012), the updated version of the 1998 campus climate model, into our framework. Specifically, the individual-level dimensions of campus climate—the behavioral and psychological—can represent the peer climate for diversity in Weidman et al.'s (2001) model. Also, given the vast research on the disparity in experiences and outcomes for women and students of color in comparison to their White, male counterparts, Weidman et al. acknowledge that the process of socialization likely unfolds differently for these students, especially when White, male norms and assumptions remain unchallenged in the academic program's culture.

Methods

Data Source and Sample

The data for this study come from the 2004 Freshman Survey (TFS) and the 2008 College Senior Survey (CSS) administered by the Cooperative Institutional Research Program (CIRP) at the Higher Education Research Institute (HERI) at UCLA. Students’ 2008 responses are matched to their 2004 responses to produce a longitudinal dataset. Administration of these surveys was augmented by grants from the National Institutes for Health (NIH) and the National

Science Foundation (NSF) in order to increase the representation of minority-serving institutions and institutions that produce large numbers of STEM graduates in the dataset. As a result, the overall longitudinal dataset contained 6224 students from 237 colleges and universities, and a weighting procedure was performed based on students' probability of participating in both surveys to produce a longitudinal sample more representative of the original 2004 sample. Surveys were disseminated over the internet and on paper.

The sample of interest to this study is students who aspired to an engineering degree at college entry, and so the dataset was filtered for students who indicated their major as any type of engineering on the 2004 TFS. The sample size after filtering for engineering students is 979, 22.74% of whom are female, representing 129 institutions. Due to a very small number of American Indian students in the sample, underrepresented racial minority students were analyzed as a group in our models to avoid excluding them from analysis. As a result, 53.64% of our sample were URM students, including multiracial students with one or more underrepresented identities, and 9.91% of the sample were Asian or Pacific Islander, also including multiracial Asian and Pacific Islander students who did not report a URM identity. Demographics for the sample are provided in Table 2.

Measures

Dependent variables. There are two dependent variables of interest to this study that represent the two elements of Weidman et al.'s (2001) socialization outcome, engineering identity and commitment to an engineering career. The first of these two variables, engineering identity, was modified from a STEM identity factor developed by researchers at the Higher Education Research Institute (HERI) at UCLA to operationalize Carlone and Johnson's (2007) framework for science identity using items from the Cooperative Institutional Research

Program’s (CIRP) annual surveys (Chang et al., 2011; Eagan, Hurtado, Garibay, & Herrera, 2012; Eagan & Sharkness, 2010). Although they have not yet validated this factor for engineering students specifically, the items constituting the factor correspond with indicators that have been identified in the literature as important to developing an engineering identity (Allie et al., 2009; Loui, 2005; Tonso, 2006). These items measure the importance of becoming an authority in my field, gaining recognition from colleagues for contributions to my field, making a theoretical contribution to science, and working to find a cure for health problems.

After imputing missing data (discussed below), exploratory factor analysis was used to determine how well the STEM identity items load onto a factor for engineering students. Factor loadings less than 0.40 and alpha reliabilities below 0.60 were used as cut-off points to create factors. Factors were extracted using principal axis factoring with promax rotation. All four items loaded at both time points with the exception of “finding a cure for health problems,” which did not reach the 0.40 threshold on the 2008 factor. We consequently excluded that item and measured engineering identity as a three-item factor. Factor loadings and reliabilities are provided in the Appendix.

The second dependent variable of interest to this study is commitment to an engineering career, another indicator of engineering identity (Meyers et al., 2010; Meyers, Ohland, et al., 2012). This variable measures whether a student aspired to an engineering career in their fourth year as a dichotomous variable indicating whether their planned career in 2008 was engineering or not.

Independent variables. The main independent variables of interest to this study are two sets of variables representing experiences intended to enhance engineering identity development and perceptions of a hostile campus climate. The first set of independent variables includes whether or not students participated in internships, major-related clubs, and undergraduate research programs as well as a construct measuring faculty mentoring and support (for more on CIRP constructs, see CIRP, 2011). In addition, given the possibility that students who are more altruistically oriented may feel pushed out of engineering for lack of an outlet to express their concern for social change (Berndt & Paterson, 2010; Dukhan et al., 2008), and the importance of an altruistic orientation in the science identity model undergirding our engineering identity factor (Carlone & Johnson, 2007), we included an item measuring to what degree students are concerned with finding a career where they can work for social change as a measure of an altruistic orientation.

Variables measuring perceptions of a hostile climate include a construct measuring frequency of negative cross-racial interactions (again, see CIRP, 2011) and items measuring being singled out on the basis of gender, race/ethnicity, or sexual orientation and hearing faculty express racial/ethnic stereotypes. These variables measure experiences that correspond with the behavioral and psychological dimensions of campus climate (Hurtado, Alvarez, et al., 2012). Interactions between these variables and gender and race/ethnicity were tested to determine whether these climate variables operate differently for these different groups of students.

Controls. Several independent variables were used to control for background characteristics and pre-college experiences that may have influenced students' engineering identity. These controls were determined by theory and research on engineering identity (Allie et al., 2009; Loui, 2005; Meyers, Silliman, et al., 2012; Pierrakos et al., 2009; Tonso, 2006).

First, pretests of the dependent variables were used to control for initial measures of engineering identity at college entry as the 2004 TFS contains items similar to those we used as our dependent variables, allowing us to study *change* from college entry to four years later. A second set of control variables includes demographic items like sex and race/ethnicity, first-generation college student status, students' mothers' level of education, and an item indicating whether either of a students' parents worked as engineers.

Race/ethnicity was dummy coded, using White students as the reference group. Students who belong to URM groups and multiracial students who marked one or more underrepresented race/ethnicity groups were classified as URM. Students who belong to Asian or Pacific Islander (API) groups and multiracial students who marked one or more API group but no URM groups were classified as Asian/Pacific Islander. The remainder were classified as White.

The third set of control variables includes items measuring students' pre-college academic preparation, such as years of study of math or science in high school, high school GPA, and SAT composite score (or ACT score converted into its equivalent SAT score). Goals, aspirations, and reasons students chose their particular institutions compose a fourth group of control variables, and then a set of variables measuring institutional characteristics compose the final set of control variables. A full list of variables, definitions, and coding is located in the Appendix.

Analysis

First, descriptive statistics were run in order to analyze the distribution of each of the variables (descriptive statistics are located in Table 1). Next, missing data was analyzed to identify any patterns that might preclude missing value imputation. As very little data was missing, expectation-maximization (EM) was used to impute missing values for all variables except the dependent variables and demographic items. EM is an iterative process that combines regression imputation with maximum likelihood estimation in order to converge to estimates for imputing missing values. EM is superior to simple regression imputation because EM is able to use all available predictors for estimation by using the full covariance matrix (Allison, 2002).

Hierarchical linear modeling (HLM) was used to predict the first dependent variable, engineering identity. Given the clustered nature of our data and continuous dependent variable, HLM was the most appropriate method for analysis with this first model. HLM partitions the variance between individuals (students) and groups (institutions), accounting for the unique clustering effect of our sample design and reducing the risk of making a Type 1 statistical error by erroneously concluding the significance of a parameter estimate (Raudenbush & Bryk, 2002). Commitment to an engineering career was also analyzed using multilevel techniques, but hierarchical generalized linear modeling (HGLM) was used to predict this dependent variable. HGLM is essentially multilevel logistic regression and is appropriate when the dependent variable, like commitment to an engineering career, is dichotomous (Raudenbush & Bryk, 2002).

As mentioned, interactions were tested to determine if the campus climate variables operated differently for students on the basis of gender or race/ethnicity. Interactions were tested individually by running separate models after analyzing each full model. Main effects are interpreted prior to testing interactions, however, as regression coefficients become uninterpretable after interactions are entered due to multicollinearity (Lewis-Beck, 1980). Thus, the regression tables display the effects of the variables in each model without the interaction terms, and the effects of each interaction term when it was entered.

Limitations

There are four significant limitations that need to be noted before exploring this study’s results. One important limitation is that several of the independent variables were measured on the same survey as the dependent variables. While the control variables were taken from a survey administered to this group of students four years prior to the measurement of the dependent variable, the relationship that our key independent variables of interest have with the outcomes is cross-sectional. Therefore, while claims for causation may be suggested by prior research and extant theory, the relationships between these variables are associative in nature and causation could actually proceed from the dependent variable to the independent variables. However, our design improves upon previous research since we are controlling for pretests of these variables and thus are testing the association is between college experiences and *change* in the dependent variable. Coupled with prior literature and theory, this also strengthens our ability to infer a causal relationship.

Second, this sample is not nationally representative. While the CIRP Freshman Survey is designed and administered to be nationally representative, this dataset was taken from a research project that augmented the 2004 CIRP Freshman Survey sample with data from additional minority-serving institutions and institutions that produce high proportions of STEM degrees. Therefore these institutions are oversampled in the dataset in order to examine institutions known for producing minority STEM baccalaureates, and this dataset is much more diverse than the general population of engineering students. The data are weighted so the longitudinal sample looks like the original sample of students who took the 2004 TFS at each institution. This sampling technique does help us to examine the experiences of engineering students of color and MSIs like HBCUs to a greater extent than much of the existing literature, however.

A third limitation arises from the fact that even though students of color are overrepresented in this dataset by design, the methods chosen to analyze the data fail to capture the diversity and variation within individual racial and ethnic groups. We are also limited by the fact that we are only analyzing a small subset of the overall dataset. For instance, in order to avoid excluding American Indian students due to very low representation in the dataset, we combined them with Latino/a and African American students to form a group of URM students. While prior research has found similar academic outcomes for these three groups in comparison to their White and Asian American peers (Hurtado, Eagan, & Hughes, 2012; Lord et al., 2009), a great deal of diversity exists within this group that is not being captured by this analysis. Also, researchers have indicated that failure to disaggregate Asian Americans by ethnic heritage also masks the variation among these students, especially those groups who face barriers to academic success similar to their URM peers (Goel, 2006; Ma, 2010; Museus & Chang, 2009).

A final limitation arises from the fact that this study analyzes secondary data. This analysis is limited to the variables available on these two surveys, and so several other items important to engineering identity development may not have been included in this analysis. Despite their limitations, secondary data sources, especially those like CIRP's which collect large amounts of data on an ongoing basis, provide a rich array of variables and large numbers of participants for scholars to examine important research questions without expending a great deal of additional resources for data collection (Rutkowski, Gonzalez, Joncas, & Davier, 2010; Thomas & Heck, 2001).

Results

Descriptive Statistics

A cross-tabulation comparing initial commitment to an engineering career at college entry to commitment to an engineering career during the fourth year of college is provided in Table 3. The chi-square for the cross-tabulation is significant, indicating that students' commitment to an engineering career changed from 2004 to 2008. The cross-tabulation shows that of those engineering aspirants who were not planning a career in engineering, about one-quarter changed their mind during college and indicated they were planning a career in engineering. In spite of this, given national concern over graduating students in engineering fields and facilitating their entry into related engineering careers, only slightly more than half of engineering aspirants who were planning a career in engineering at college entry indicated plans for an engineering career in their fourth year of college as well. Of those who initially aspired to an engineering career but later switched, over one-quarter aspired to a career in business while more than one-third were either undecided or had selected “other” (see Table 4 for a breakdown by career field), consisted with previous findings (Sheppard et al., 2010). As we are concerned with identifying experiences that enhance students' sense of engineering identity and commitment to an engineering career, the multilevel regression models helped us explore these experiences further.

Table 5 provides the results of both the hierarchical linear model predicting engineering identity in 2008 and the hierarchical generalized linear model predicting commitment to an engineering career in 2008. As we used the same predictors in both models, we are able to compare variables within each model as well as across both models to gain a more nuanced understanding of how students' sense of engineering identity is enhanced by these experiences. Since we control for a pretest for the dependent variable in each model, we interpret the findings as a relationship with *change* in either engineering identity or commitment to engineering, and we will discuss the findings for each model separately with a few observations across both models.

Engineering Identity

The strongest predictor in the engineering identity model is initial sense of engineering identity at college entry, the pretest. The only other pre-college variable significantly related to change in engineering identity is the degree to which students agree that the reason they plan to attend college is for training for a specific career. While this appears to be a surprising finding considering an engineering degree is considered a professional degree to prepare students for an engineering career, the initial correlation indicates this relationship is actually a suppressor effect and another variable is mediating the relationship between this predictor and the dependent variable.

Among college experiences, three experiences are significantly related to change in engineering identity. Students with greater concern for a career where they can work for social change, students who receive more mentoring and support from faculty, and students who experience more negative cross-racial interactions also indicate developing a stronger sense of engineering identity. The finding regarding faculty support and mentoring is encouraging: as Weidman et al. (2001) indicated that interactions with faculty, professionals, and other students are expected to facilitate the socialization process within a professional program, support and mentoring are interactions intentionally structured by faculty to help students reach their academic and professional goals.

The other two findings are more concerning, however. Although prior research has suggested students who are more concerned with social change find few outlets for their passion in engineering and are more likely to leave the field, these students also appear to be more likely to develop the dispositions that would make them more successful as professional engineers. Providing opportunities to demonstrate how students can pursue their passion for social change in an engineering career could be a critical opportunity for engineering programs to retain talented engineers and sustain their commitment to the field through employment as professional engineers.

Also, we find it very discouraging that students who experience an increase in their sense of engineering identity also report a greater frequency of negative cross-racial interactions, presumably due to the lower level of diversity in engineering majors. This finding suggests that negative cross-racial interactions remain common in the experiences of engineering students, and that if students do leave the field due to the racial climate, the field will continue to lose talented students who possess many of the values and qualities needed to be successful engineers.

Finally, one interaction term we tested was significant as well. The relationship between being singled out on the basis of race/ethnicity, gender, or sexual orientation and engineering identity development is more pronounced for women than men. Women with a stronger sense of engineering identity report a higher frequency of being singled out. This again is also extremely discouraging, but not very surprising given the low representation of women in engineering and the gendered nature of engineering culture (Cech et al., 2011; Faulkner, 2000; Lord et al., 2009). Much more remains to be done to improve the climate for women in engineering in addition to supporting and enhancing the critical work already taking place in higher education.

Commitment to an Engineering Career

Just like the model predicting engineering identity, the pretest predicting commitment to an engineering career at college entry is the strongest predictor of a commitment to an engineering career after four years in college. Unlike the other model, however, several pre-college and institutional variables are significantly related to a change in commitment to an engineering career. Students who aspire to both masters and doctoral degrees are more likely to commit to an engineering career by their fourth year in college, and students who plan to change their major are also more likely to change their mind about an engineering career. Students attending private colleges and universities are more likely to commit to an engineering career by their fourth year, and students attending institutions with higher proportions of STEM students are more likely to commit to an engineering career as well. Based on the *t* statistic, this latter finding is nearly as strong a predictor as the pretest, and most likely captures the effect attending a technical school has on career aspirations.

Finally, two college experiences also predict commitment to an engineering career by the fourth year. Students who participate in internship programs and in major-related clubs and organizations are more likely to commit to an engineering career. The strength of these predictors is also nearly equivalent to the pretest (based on the value of their *t* statistics) and again demonstrates how important interacting with peers, faculty, and professionals in the field has on a student's socialization, as per the Weidman et al. (2001) model. However, none of the climate variables are significant in this model, indicating that climate has no direct effect on plans for a career as an engineer.

Conclusions and Implications

First, our findings confirmed findings both from prior research as well as what we expected given the theoretical framework. Participation in internships and major-related clubs and organizations both relate to an increase in commitment to engineering as a career, and faculty support and mentoring relate to an increase in engineering identity. While we had also anticipated participation in undergraduate research to relate positively to one or both outcomes, given prior literature on the relationship between undergraduate research and retention in engineering (Zydney, Bennett, Shahid, & Bauer, 2002), this experience does not mirror the work that professional engineers do as closely and thus may only more broadly contribute to retention and persistence in engineering.

Second, even though we anticipated seeing a relationship between the campus climate and measures of engineering identity and commitment to an engineering career, very few of our climate variables were significant in either model. Only two variables were significantly related to engineering identity, and in the opposite direction of what we expected: negative cross-racial interactions and feelings of being singled out for women both related to higher measures of engineering identity after four years. What this signals is that these experiences are more common among students who report greater degrees of change in their engineering identity. If these students later leave engineering due to the unwelcoming climate, this attrition is a significant loss of talent for a profession trying to expand participation.

Another area where the field could be losing significant talent is among engineering students who are more altruistically oriented. While prior research suggests more altruistically-motivated engineering students are less likely to be retained in engineering (Berndt & Paterson, 2010; Dukhan et al., 2008), we found a positive relationship between change in engineering identity and a desire for a career and values to work for social change. Unless more intentional efforts are made to provide outlets for students to do engineering work that is aimed at social justice outcomes, many of these students will also be lost to other fields.

As a final note on campus climate, even though most of the climate variables were not significant, this analysis is only focused on change over four years. The decision to leave engineering may likely come later, rather than during an engineering program. Considering the positive relationship between graduate school aspirations and commitment to an engineering career, the decision to leave engineering may come at graduation, and if the student pursues graduate school, even later than that. Future research may want to consider the relationship between campus climate and the decision to enter or forego an engineering career (or graduate school in engineering) after graduation to more definitively test this relationship.

Weidman et al.'s (2001) model theorized about the relationship between peer climate more broadly than climate for diversity, and we found students at institutions with higher proportions of students majoring in STEM are more likely to commit to engineering as a career. Because schools that have higher proportions of students in STEM are most likely technical colleges, there are likely strong peer norms within the culture about entering STEM careers after graduation. In addition, there are relatively few options of majors to switch into at one of these colleges except into other STEM fields. These colleges may also have strong ties to industry and be involved in cutting-edge research, providing more opportunities for students to be involved in engineering-related activities. Our results showed these experiences are extremely influential in sustaining or increasing students' commitment to the engineering field.

Also, while Weidman et al. (2001) indicate their socialization model is open, iterative, and somewhat cyclical, the results suggest more nuance to the mechanisms that facilitate the development of an engineering identity and commitment to an engineering career. For instance, "performing" as an engineer, like in internships or clubs and organizations, are more related to plans to work in engineering while mentoring from faculty leads to a strengthened self-identity as an engineer. Mentoring also happens within internships and student organizations, and opportunities to "perform" engineering work occur within the academic environment as well. While the variables available to us do not allow us to tease this out further, future research should explore the multidimensionality of socialization within engineering more deeply. For instance, future studies could examine the relationship between mentoring from professional engineers or participation in a curricular engineering design project with the study outcomes, engineering identity and commitment to the engineering profession. Further analysis could then help faculty more intentionally tie experiences within engineering degree programs closer to these desired professional outcomes.

National reports call for an increase in the number of college graduates with engineering degrees in the near future to fill projected job openings in the field. One way to facilitate this process is to support the development of an engineering identity in students and to foster their commitment to pursuing a career in engineering. This study examined experiences that contributed to engineering identity development as well as commitment to an engineering career, and tested measures of campus climate to determine its possible influence. By examining these variables, engineering educators can use our findings to structure their programs more intentionally to help students reach desired professional outcomes.

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Appendix

List of variables definitions, scales, and factor loadings and reliabilities

Dependent Variables	*Coding*	*Loading/Reliability*
Engineering identity		α = 0.703
Indicate the importance to you personally of:		
Becoming an authority in my field	1=Not important 2=Somewhat important	0.783
Obtaining recognition from my colleagues for contributions to my special field	3=Very important 4=Essential	0.782
Making a theoretical contribution to science		0.461
Commitment to an engineering career		
Please mark your probable career or occupation	0=All others 1=Engineering	
Pretests		
Engineering identity		α = 0.710
Indicate the importance to you personally of:		
Becoming an authority in my field	1=Not important 2=Somewhat important	0.862
Obtaining recognition from my colleagues for contributions to my special field	3=Very important 4=Essential	0.695
Making a theoretical contribution to science		0.491
Commitment to an engineering career		
Please mark your probable career or occupation	0=All others 1=Engineering	
Background characteristics		
Sex	1=Male 2=Female	
URM student (including multiracial)	1=No 2=Yes	
Asian/Pacific Islander student (including multiracial	1=No 2=Yes	

Mother's level of education	1=Grammar school or less 2=Some high school 3=High school graduate 4=Postsecondary school other than college 5=Some college 6=College degree 7=Some graduate school 8=Graduate degree
Either parent is employed as an engineer	1=No 2=Yes
HS academic preparation	
What was your average grade in high school?	1=D 2=C 3=C+ 4=B- 5=B 6=B+ 7=A- 8=A/A+
SAT score (100)	4-16
During high school, how many years did you study each of the following subjects? Math, Physics	1=None 2=1/2 3=1 4=2 5=3 6=4 7=5 or more
Pre-college expectations and aspirations	
Highest academic degree planned (dummy coded): Master's degree aspiration (ref: bachelor's degree or lower) Doctoral degree aspiration Medical degree aspiration Law degree aspiration	1=No 2=Yes
In deciding to go to college, how important to you was each of the following reasons?	1=Not important 2=Somewhat important 3=Very important
How important was each reason in your decision to come here? My teacher advised me Graduates get good jobs	1=Not important 2=Somewhat important 3=Very important

Rankings in national magazines	
What is your best guess as to the chances that you will change major field?	1=No chance 2=Very little chance 3=Some chance 4=Very good chance
Institutional characteristics	
Institutional Control: Private	1=Public 2=Private
Institutional Type: Four-year college	1=Research university 2=Four-year college
HBCU	1=Other 2=HBCU
Percent of students majoring in STEM in 2006	0.00-1.00
Selectivity (average SAT score, scaled by 100)	4-16
College experiences	
When thinking about your career path after college, how important are the following considerations: Working for social change	1=Not important 2=Somewhat important 3=Very important 4=Essential
Since entering college have you: Participated in an internship program Participated in an undergraduate research program (e.g. MARC, MBRS, REU) Joined a club or organization related to your major	1=No 2=Yes
CSS Faculty Interaction Construct	see CIRP (2011)
Campus climate	
CSS Negative CRI Construct	see CIRP (2011)
Please indicate the extent to which you agree or disagree with the following statements: I have been singled out because of my race/ethnicity, gender, or sexual orientation I have heard faculty express stereotypes about racial/ethnic groups in class	1=Disagree strongly 2=Disagree somewhat 3=Agree somewhat 4=Agree strongly

Table 1

Descriptive statistics

n=979

	Mean	St. Dev.	Min	Max
Dependent variables				
Engineering identity factor in 2008	0.025	0.874	-1.880	1.816
Commitment to engineering career in 2008	0.432	0.496	0	1
Independent variables				
Engineering identity factor in 2004	0.039	0.915	-1.936	1.758
Commitment to engineering career in 2004	1.687	0.464	1	2
Participated in internship program	1.544	0.498	1	2
Undergraduate research program	1.159	0.366	1	2
Major-related club or organization	1.648	0.478	1	2
Singled out on the basis of gender, race/ethnicity, or sexual orientation	1.976	0.867	1	4
Overheard faculty express racial stereotypes in class	2.016	0.815	1	4
Career concern: opportunity to work for social change	2.189	0.955	1	4
Average high school GPA	6.688	1.369	1	8
Years of study in HS: Math	6.064	0.474	3	7
Years of study in HS: Physics	4.115	1.212	1	7
Mother's level of education	5.386	1.928	1	8
Reason for attending college: To get training for a specific career	2.725	0.524	1	3
Chose this college: Teacher advised me	1.387	0.563	1	3
Chose this college: Graduates get good jobs	2.537	0.634	1	3
Chose this college: Rankings in national magazines	1.904	0.788	1	3
Plan to change major	2.419	0.824	1	4
Institutional control: private	1.295	0.456	1	2
Institutional type: four-year college	1.396	0.492	1	3
HBCU	1.038	0.192	1	2
Percent of students majoring in STEM	0.276	0.194	0.000	0.890
Undergraduate FTE (1000)	13.735	8.557	0.875	36.731
Faculty support and mentoring	46.926	9.371	27.33	66.99
Negative cross-racial interactions	53.230	7.866	41.66	76.57
Selectivity (100)	11.669	1.299	8.5	14.67
Composite SAT score (100)	12.095	1.722	5	16
Either parent employed in engineering	1.157	0.364	1	2
Master's degree aspiration (ref: bachelor's or less)	1.501	0.500	1	2
Doctoral degree aspiration	1.280	0.449	1	2
Medical degree aspiration	1.045	0.208	1	2
Law degree aspiration	1.012	0.109	1	2

Table 2

Demographics
n=979

Female	22.74%
Underrepresented racial minority	53.64%
Asian/Pacific Islander (including multiracial)	9.91%
First generation	29.59%

Table 3

Crosstabulation, commitment to an engineering career in 2004 by commitment in 2008 *n*=979

	Commitment in 2004	
	No	Yes
Commitment in 2008		
No	74.68%	48.63%
Yes	25.32%	51.37%

Note: χ^2=60.039, *p*<0.001

Table 4

Planned careers of students who aspired to engineering at college entry, but not four years later *n*=366

Artist	3.35%
Business	26.22%
Business (clerical)	0.91%
Clergy	0.61%
College teacher	3.05%
Doctor (MD or DDS)	5.49%
Education (secondary)	2.44%
Education (elementary)	0.91%
Health professional	2.44%
Lawyer	5.49%
Military (career)	7.62%
Research scientist	4.88%
Social, welfare, or recreation worker	0.91%
Skilled worker	0.30%
Other choice	25.30%
Undecided	10.06%

Table 5

Multilevel regression models predicting engineering identity and commitment to an engineering career in the fourth year of college
n=979

	Engineering Identity						Commitment to an Engineering Career					
	r	sig	B	S.E.	*t*	sig	*r*	sig	B	S.E.	*t*	sig
Intercept			-0.155	0.559	-0.277				-8.341	2.084	-4.002	***
Pretest of dependent variable (2004)	0.373	***	0.296	0.033	9.029	***	0.243	***	1.022	0.209	4.885	***
Background characteristics												
Sex: female	-0.004		-0.024	0.058	-0.410		-0.036		-0.278	0.190	-1.461	
URM student (ref: White)	0.012		-0.097	0.066	-1.465		-0.075	*	-0.305	0.196	-1.560	
Asian/Pacific Islander student	0.032		0.036	0.105	0.339		0.000		-0.137	0.265	-0.517	
Mother's level of education	-0.034		-0.004	0.018	-0.207		0.009		-0.057	0.065	-0.884	
Either parent employed in engineering	0.004		-0.004	0.066	-0.057		0.068	*	0.263	0.170	1.548	
First generation student	0.065	*	0.121	0.080	1.511		-0.025		0.144	0.270	0.533	
Pre-college academic preparation												
Average high school GPA	0.044		0.021	0.027	0.778		0.141	***	0.080	0.088	0.907	
Composite SAT score (100)	-0.069	*	0.013	0.023	0.591		0.115	***	0.113	0.072	1.581	
Years of study in HS: Math	0.023		0.042	0.050	0.842		0.093	**	0.244	0.192	1.270	
Years of study in HS: Physics	-0.006		-0.008	0.027	-0.297		0.036		0.002	0.068	0.025	
Degree aspirations												
Master's degree aspiration (ref: bachelor's or less)	-0.081	*	-0.046	0.083	-0.549		0.063	*	0.513	0.230	2.227	*
Doctoral degree aspiration	0.127	***	0.062	0.091	0.684		0.055		0.596	0.245	2.438	*
Medical degree aspiration	0.065	*	0.032	0.136	0.239		-0.127	***	-0.772	0.675	-1.145	
Law degree aspiration	-0.015		-0.215	0.242	-0.886		0.004		1.150	0.681	1.690	
Pre-college expectations												
Reason for attending college: To get training for a specific career	0.020		-0.128	0.045	-2.816	**	0.044		0.032	0.177	0.178	
Chose this college: Teacher advised me	0.050		-0.050	0.049	-1.016		0.062	*	0.252	0.160	1.569	
Chose this college: Graduates get good jobs	0.096	**	0.048	0.049	0.966		0.078	*	0.066	0.134	0.491	
Chose this college: Rankings in national magazines	0.055		-0.004	0.044	-0.087		0.094	**	0.066	0.094	0.705	
Plan to change major	-0.056		-0.012	0.035	-0.340		-0.174	***	-0.357	0.118	-3.041	**

Institutional characteristics (level 2 variables)												
Institutional control: private	0.044		0.117	0.085	1.386		0.092	**	0.547	0.252	2.170	*
Institutional type: four-year college	0.027		-0.027	0.073	-0.363		0.072	*	0.115	0.264	0.437	
HBCU	0.106	***	0.190	0.203	0.935		0.076	*	1.174	0.799	1.469	
Percent of students majoring in STEM	-0.003		0.236	0.125	1.885		0.165	***	2.034	0.482	4.223	***
Undergraduate FTE (1000)	-0.032		0.003	0.005	0.695		0.005		0.025	0.014	1.749	
Selectivity (100)	-0.053		-0.029	0.028	-1.025		-0.025		-0.123	0.099	-1.241	
College experiences												
Career concern: opportunity to work for social change	0.270	***	0.126	0.032	3.957	***	-0.085	**	-0.222	0.118	-1.881	
Participated in internship program	0.045		-0.041	0.060	-0.693		0.249	***	0.774	0.164	4.719	***
Undergraduate research program	0.072	*	-0.013	0.073	-0.175		-0.003		-0.133	0.222	-0.599	
Major-related club or organization	0.095	**	0.058	0.068	0.855		0.243	***	0.896	0.186	4.816	***
Faculty support and mentoring	0.276	***	0.018	0.004	4.908	***	-0.007		-0.008	0.011	-0.699	
Climate for diversity												
Negative cross-racial interactions	0.225	***	0.016	0.004	4.572	***	-0.047		0.001	0.014	0.050	
Singled out on the basis of gender, race/ethnicity, or sexual orientation	0.028		-0.042	0.039	-1.069		-0.031		0.050	0.095	0.529	
Overheard faculty express racial stereotypes in class	0.095	**	0.014	0.043	0.317		-0.081	**	-0.192	0.136	-1.415	
Interactions												
Model 2: Sex X singled out			0.243	0.072	3.397	**			0.328	0.211	1.556	
Model 3: URM X negative cross-racial interactions			0.008	0.007	1.244				0.020	0.019	1.064	
Model 4: URM X singled out			0.042	0.061	0.694				0.077	0.197	0.388	
Model 5: URM X overheard stereotypes			0.038	0.067	0.572				0.246	0.222	1.109	
Model 6: API X negative cross-racial interactions			0.012	0.010	1.245				-0.047	0.041	-1.145	
Model 7: API X singled out			0.061	0.105	0.578				0.218	0.280	0.779	
Model 8: API X overheard stereotypes			-0.013	0.095	-0.136				-0.284	0.325	-0.873	

Note: * $p<0.05$, ** $p<0.01$, *** $p<0.001$