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UNDERSTANDING ENGINEERING IDENTITY IN UNDERGRADUATE STUDENTS

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Abstract
The process of becoming an engineer is fundamentally an identity development process and students who identify as engineers are more likely both to graduate and to enter the field upon graduation. Therefore an opportunity in engineering education is providing undergraduates experiences that bolster their sense of identity as engineers. In particular, experiences that offer authentic engagement in engineering work should be expected to promote engineering identity.

This paper tests the relationship between collegiate experiences expected to promote engineering identity formation with change in engineering identity in a national sample of 918 engineering students using data from the 2013 College Senior Survey (CSS). The CSS is administered by the Higher Education Research Institute (HERI) at UCLA to college students at the end of their fourth year of college; data from the CSS are then matched to students' prior responses on the 2009 Freshman Survey (TFS) to create a longitudinal sample. Engineering identity is measured using a composite of items available in both surveys to assess change in engineering identity over four years, and intention to pursue an engineering career is also tested. Results show participation in undergraduate research appears to increase engineering identity, while participation in an internship increases likelihood of pursuing an engineering career.

Keywords
Engineering identity, engineering education.

Introduction
National reports have called for increasing the numbers of engineers graduating from American colleges and universities to fill anticipated job openings and help sustain the nation's economically competitive position globally. As a result, colleges and universities have worked to identify opportunities and interventions that will improve their institutions' engineering degree productivity. These opportunities have included expanded access to undergraduate research programs, internship opportunities, and increasing the support for engineering related student organizations to facilitate progress toward degree attainment. Further, colleges and universities have focused recruitment and retention efforts on groups historically underrepresented in engineering as these groups tend to represent some of the fastest growing demographic groups in the United States.

That said, improving degree productivity will only partially address this problem as only about half of seniors in engineering are fairly certain of their plans to pursue engineering as a career (Hughes & Hurtado, 2013; Sheppard et al., 2010). In other words, while a bachelor's degree is generally required to enter the field of engineering, completion of a bachelor's degree alone does not ensure entry into the field. Fundamentally, the engineering formation process is an identity development process, and scholars have turned to engineering identity as a possible explanatory factor motivating students' decisions regarding persistence in their degree programs and ultimate entry into practice (Meyers, Ohland, & Silliman, 2012; Pierrakos, Beam, Constantz, Johri, & Anderson, 2009).

The purpose of this paper is to explore the relationship between undergraduate experiences and the development of engineering identity. This paper uses a national, longitudinal dataset to test the effect of experiences intended to promote persistence to degree completion and development of an engineering identity on change in engineering identity over four years of college. While previous research has pointed to indicators to help measure engineering identity and experiences that promote engineering identity, that work has been limited in terms of sampling procedures, instrumentation, and cross-sectional design. This work begins to address that gap.

Literature Review

The process of becoming an engineer involves more than mastery of the skills and technical knowledge required to perform engineering work. Identity is central to the learning process—engaging in a practice and becoming a member of a community of practice lead to a transformed sense of self relative to that practice (Lave & Wenger, 1991). Learning a practice is thus a social process situated within the context of the community of practice, facilitated by legitimate peripheral participation in the community through the performance of productive activities that contribute to practice. This model has been applied to understand the role of undergraduate engineering programs in the engineering formation process because of the applied, professional nature of these programs (Johri & Olds, 2011). In addition, the community of practice model describes both how the engineering community defines its culture and how it promotes its image, within the context of its own organizational identity (Hatch & Schultz, 2002).

Wenger (1998) further elaborated on the relationship between learning, identity, and participation in a community of practice. Legitimate peripheral participation is a starting point for novices to engage in a practice and represents the first steps for newcomers to situate themselves and understand the rules of the community of practice. Learning then, and the underlying transformation of identity, happens along an inbound trajectory from peripheral to more central forms of participation. Said differently, identity is built as potential members of the community move from the periphery toward more integrated membership. Novices should thus be provided opportunities for participation that help them understand how to engage with the practice they plan to enter through introduction to the shared enterprise and repertoire of a community of practice. These opportunities can be provided through experiences that provide authentic engagement with practice.

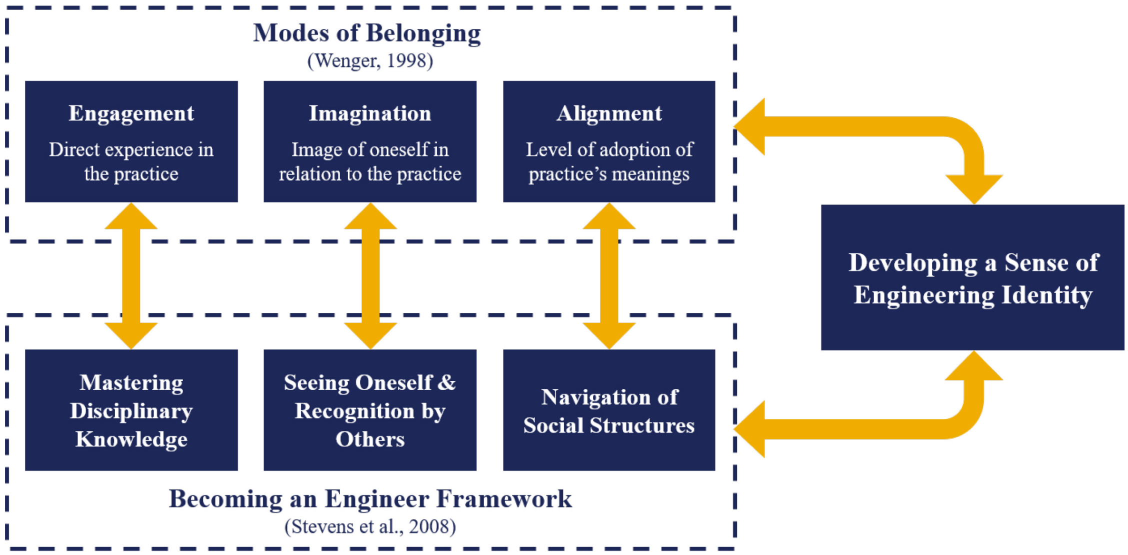
Ultimately, then, legitimate peripheral participation within a community of practice should result in a transformed sense of identity relative to that practice (Lave & Wenger, 1991; Wenger, 1998). Identification with a practice is best observed through the modes of belonging one may experience as part of a community of practice (Wenger, 1998). These modes are engagement, imagination, and alignment; engagement reflects one's direct experience participating in a given practice, imagination represents how one sees one's location relative to proximal and distal context for practice, and alignment captures the extent to which one has adopted shared meanings within practice. With respect to engineering practice, engagement would reflect a novice's ability to perform engineering work, imagination their individual identification with the practice of engineering through seeing themselves as engineers, and alignment their socialization into the practice of engineering and resulting identification as an engineer by others.

These three modes of belonging—engagement, imagination, and alignment—map onto the process of becoming an engineer as outlined by Stevens, O'Connor, Garrison, Jocuns, and Amos (2008). These activities include navigating complex social networks and structures into the profession (alignment), mastering engineering disciplinary knowledge (engagement), and identification by oneself and others as an engineer (imagination). These factors are observed across one branch of the engineering identity literature (Eliot & Turns, 2011; Godwin, Potvin, Hazari, & Lock, 2016; Knight et al., 2013; Kyriakidou, 2011; Morelock, 2017), and parallel those used to study science identity in terms of competence in scientific knowledge, recognition by others as a scientist, and performance of scientific practice (Carlone & Johnson, 2007). Exhibit 1 summarizes these theoretical experiences and the theoretical relationships between them. These relationships provide the foundation for the elements of experience investigated in this work.

Therefore, the provision of experiences that offer undergraduates authentic engagement with engineering practice should be expected to foster a sense of engineering identity. Pierrakos et al. (2009) determined that co-curricular experiences (e.g. engineering clubs) enhance engineering identity (see also Matusovich, Barry, Meyers, & Louis, 2011), and Mann, Howard, Nouwens, and Martin (2009) specifically pointed to internships and cooperative experiences as authentic experiences that develop engineering identity. However, Meyers and colleagues did not find significant relationships between engineering identity and co-curricular experiences (Meyers, Ohland, Pawley, & Christopherson, 2010; Meyers, Silliman, Ohland, Pawley, & Smith, 2012), determining students' evaluations of these experiences relative to their participation in engineering may be mixed. Using a similar, but older, dataset as this study, Hughes and Hurtado (2013) found receipt of mentoring and support from faculty increased engineering identity, while participating in internships or engineering-related student organizations increased the likelihood of choosing engineering as a career.

Other factors affect engineering identity as well, most prominently prior exposure to the field of engineering before college and classroom experiences in engineering programs (Mann et al., 2009; Pierrakos et al., 2009). Taken together, co-curricular and curricular experiences where students interact with their peers, faculty, and industry mentors help provide the aforementioned recognition requisite to the formation of an engineering identity (Godwin et al., 2016). Of course, this recognition that helps legitimize a student as an engineer in the community of practice, is not distributed evenly, especially along gender lines and differences in race and ethnicity (Dryburgh, 1999; Tonso, 2006).

Exhibit 1. Belonging, Becoming an Engineer, and Engineering Identity



Methods

Informed by the literature on engineering identity and the sometimes conflicting findings, the purpose of this study is to test the relationship between experiences that are intended to promote engineering identity with change in engineering identity over four years of college. The data for this study were taken from the 2009 Freshman Survey (TFS), and subsequent 2013 College Senior Survey (CSS) follow-up, both administered by the Cooperative Institutional Research Program (CIRP) at the Higher Education Research Institute (HERI) at UCLA. The TFS is a national, representative survey of incoming college students administered at hundreds of colleges and universities to students at the very beginning of their first year of college, typically during orientation programming. The CSS is a national survey of college students administered to students at the end of their fourth year of college, and student responses to the CSS are matched to their responses to the TFS to produce a longitudinal dataset. The 2013 CSS dataset includes student responses from 94 colleges and universities, totaling 17,667 students, of whom 918indicated an engineering major at the end of their fourth year of college. These 918 engineering students comprise the sample utilized for this work.

Two variables provided on both the TFS and CSS were used as measures of engineering identity, which were used to assess change in engineering identity over four years of college. The first is a factor adapted from a measure for STEM identity used in previous studies by researchers at HERI (Chang, Eagan, Lin, & Hurtado, 2011; Hurtado, Eagan, & Hughes, 2012), including a previous analysis of engineering identity (Hughes & Hurtado, 2013). The survey items used to develop this factor, and associated engineering identity components, are: 1) the extent to which students valued becoming an authority in their field (competence or imagination); 2) the extent to which students felt being recognized for contributions to their field were important (recognition or alignment); and 3) the extent to which students intended to make a theoretical contribution to science (performance or engagement). Exploratory factor analysis with varimax rotation was used to determine factor loadings, and factor loadings were used to compute factor scores. This process was repeated for both the TFS and CSS in order to provide engineering identity factor scores for both time points. Factor loadings and reliabilities for this sample are provided in Exhibit 2.

The second variable was whether or not students indicated engineering as their future career plan. One item on both surveys prompted students to select their planned career or occupation from an extensive list of occupations; this variable was recoded to reflect whether students selected "engineer" or not. This second variable was selected for this study to reflect students' commitment to engineering as a career as a secondary indicator of engineering identity.

Exhibit 2. Factor loadings and reliabilities for engineering identity

Element of Identity	First Year Engineering identity (TFS) (α=0.6674)	Fourth Year Engineering identity (CSS) (α=0.6697)
Becoming an authority in my field	0.624	0.662
Being recognized by others for contributions to my field	0.6893	0.6903
Making a theoretical contribution to science	0.4838	0.468

The primary independent variables of interest were four variables taken from the CSS. Three of these variables are dichotomous variables prompting students to indicate whether they had participated in a particular experience at some point during college. These experiences were an internship or cooperative education program, an undergraduate research program, and student clubs or organizations. The fourth variable is a construct score measuring student-faculty interactions (see Sharkness, DeAngelo, & Pryor, 2010 for technical information). Due to the prominence of gender in the literature on engineering identity (e.g., Du, 2006; Faulkner, 2007; Tonso, 2006), gender was also tested and used to determine possible interaction effects between experiences and outcomes.

Descriptive and inferential techniques were employed to test the bivariate relationships between the independent and dependent variables using STATA R15 (STATA Software, 2018). First, a dependent-samples t-test was used to determine if the change in engineering identity over four years of college was significant, and a cross-tabulation with chi-squared test was used to determine if engineering career plans changed significantly. Analyses of covariance were used to test the relationship between the dichotomous independent variables (gender, college experiences) with engineering identity at the fourth year, using engineering identity at the first year as a covariate. Simple ordinary least squares regression models were used to test the relationship between student-faculty interactions and engineering identity, including only first-year engineering identity as a control variable. Simple logistic regressions were used to test the relationship between each independent variable and engineering career plans at the fourth year, using only engineering career plans at the first year as a control variable.

Results

Investigation of the data began with exploring the summary descriptive statistics shown in Exhibit 3. Overall, average scores on the engineering identity construct increased, albeit slightly (0.168). However, the proportion that indicated engineering career plans decreased slightly from first to fourth year (-2.43%). More than 70% of engineers indicated having participated in an internship, and nearly 85% reported participating in student clubs and organizations. A much smaller proportion indicated having participated in undergraduate research, just under 40%. Exhibit 4 illustrates differences in college experiences by gender; internship and student organization participation significantly differed between men and women. Most notably, women participated in internships at a rate nearly 10 percentage points higher than men, a difference significant at $p < .01$.

Exhibit 3. Descriptive statistics for key variables

Continuous Variables	Mean	Std. Dev.	Min	Max
First Year Engineering Identity (TFS)	4.597	1.155	1.797	7.188
Engineering Identity (CSS)	4.765	1.225	1.820	7.281
Student-faculty interaction construct score	49.713	8.231	27.33	66.99

Dichotomous Variables	Proportion Yes
Engineering career plans, TFS	76.61%
Engineering career plans, CSS	74.18%
Female	27.34%

Exhibit 4. College Experiences by Gender

Student Activity	Participation	Male	Female	sig
Participated in an internship program	71.35%	68.67%	78.49%	**
Participated in student clubs/groups	84.83%	82.71%	90.44%	**
Participated in undergraduate research program	39.69%	38.89%	41.83%	
Student-faculty interaction, by gender		49.403	50.560	

** - $p < .01$

Exploring Differences in Engineering Identity

A dependent-samples *t*-test found a significant change in engineering identity from first to fourth year ($t(825) = 3.9046$, $p < .001$, $r = 0.13$). A cross-tabulation with chi-squared test of independence determined the change in engineering career plans from first to fourth year, while small, was also significant ($\chi^2(1) = 69.0866$, $p < .001$). At the same time that engineering students' sense of engineering identity ticked up slightly, their likelihood of entering an engineering career decreased slightly.

ANCOVA analyses using fourth year identity as the outcome and first year identity as the co-variate were utilized to determine if participation in internships, clubs and groups, and undergraduate research contributed to an increase in engineering identity. The covariate was significant in the model for each activity, $p < .001$, while only participation in undergraduate research was a significant experience ($F(1) = 20.12$, $p < .001$). Stated more directly, students who participated in undergraduate research experienced an increase in engineering identity, but participation in internships or cooperative education, or student clubs and groups, did not relate to an increase in engineering identity in the covariate model.

An ordinary least squares regression was then run to determine if student-faculty interactions contributed to engineering identity. Regression was utilized instead of ANCOVA as student-faculty interactions were measured as a continuous variable, rather than categorical. This analysis found student-faculty interactions did significantly predict engineering identity, net of first-year engineering identity ($b = 0.039$; $p < .001$).

Understanding Intention to Engage in an Engineering Career

Logistic regression models were run to determine if the four college experiences predicted fourth-year engineering career plans, using the variable indicating first-year engineering career plans as a control variable in the model. Similar to the outcome of engineering identity, first-year engineering career plans were significant across all four models, $p < .001$. In this case however, participation in an internship or cooperative education experience was the only significant predictor of the three experiences investigated ($b = 0.827$, odds ratio = 2.286, $p < .001$). This means that participating in an internship or cooperative education experience related to a higher likelihood of deciding to enter engineering as a career while participating in student clubs or organizations, undergraduate research, and student-faculty interactions did not.

Exploring the Effect of Gender on Engineering Identity and Career Plans

The relationship between gender and engineering identity was tested through factorial ANCOVAs to determine if college experiences operate differently by gender. First, an ANCOVA testing the relationship between gender and fourth-year engineering identity was run, controlling for first-year engineering identity (the co-variate); women tend to have higher engineering identity at the end of college ($p < .05$). Gender did not interact significantly with any of the four college experiences in predicting engineering identity.

The relationship between gender and engineering career plans was tested through logistic regression. Gender did not significantly relate to engineering career plans, and gender did not interact with three of the four college experiences significantly in predicting engineering career plans. However, gender did interact significantly with internship participation in predicting engineering career plans ($b = 0.793$, $p < .05$)—participating in an internship has a stronger effect for women than men on fourth-year engineering career plans. This finding is encouraging toward broadening participation in engineering given the descriptive finding earlier that women participate in internships at higher rates as well.

Limitations

This study is limited in ways that should be taken into account when making inferences from these results. First, although the sample is national in scope, representativeness of all engineering undergraduates cannot be completely assured in terms of generalizability, as the dataset only includes schools that opted to participate in the CSS. Second, in spite of the longitudinal nature of the sample, the independent variables were measured with the same instrument as the second measurement of the dependent variables, meaning causality is not completely assured. That said, the literature does offer support for interpreting significant results like these as causal. Third, only a limited number of control variables were used in the regression models as the scope of this study focused on the bivariate relationship between the independent variables and change in engineering identity. Future research will build from these findings to test more complex multivariate models to assess the potential unique influence of various factors on engineering identity. Finally, this analysis is a secondary analysis of an existing dataset. The size of the sample and breadth of the variables available lent this dataset to being used for the purposes of this study, but the instrument did not comprise all possible factors pertaining to engineering identity that might be investigated.

Discussion

The study explored the potential effect of college experiences on students' change in engineering identity over four years of college. Based on the analysis, engineering identity increases over four years of college in a statistically significant way, but plans to enter engineering as a career decrease at a statistically significant level. While these movements are statistically significant, it is not clear that the movement is of practical significance, a question for investigate in future qualitative phases of this work. Internship participation seems to affect students' plans to enter engineering as a career, especially for women, who participate in internships and student organizations at higher rates.

This study replicated findings by Hughes and Hurtado (2013) showing that student-faculty interactions contribute to engineering identity and internship participation contributes to engineering career plans with a more recent iteration of the CSS. While this study also found that undergraduate research participation affects engineering identity, Hughes and Hurtado used hierarchical linear modeling; so the effect of undergraduate research seen here may be explained by other control variables which were not examined in this study. Therefore this finding warrants additional examination to determine the breadth of its applicability. The relationship between co-curricular experiences and engineering identity here also aligns with findings by Pierrakos et al. (2009) and Matusovich et al. (2011), and disputes the conclusion of Meyers et al. (2010) that co-curricular experiences do not significantly contribute to engineering identity due to differences in individual experiences. This study adds nuance to the general conclusion that all co-curricular experiences, and internships specifically (see Mann et al., 2009), have a uniform effect on engineering identity. By separating out a measure of engineering identity that is more aspirational in affect from actual plans to enter engineering as a career, this study demonstrates that co-curricular experiences do affect engineering identity in different ways. Perhaps the complexity of students' reasons for selecting engineering as a course of study needs to be better understood as a component of studying engineering identity.

The literature demonstrates that gender can complicate the development of engineering identity in undergraduates (Dryburgh, 1999), especially when being legitimized through recognition by others as an engineer is not equally afforded to women and men (Tonso, 2006). The results of this analysis showed that women had a higher sense of engineering identity than men at the end of their fourth-year of college, and that participating in an internship had an even stronger effect on their engineering career plans than such participation did for men. This interaction was encouraging as women participated in internships at higher rates than men. Women likely seek out these formal opportunities to combat the pernicious effect of the climate in engineering for women (Faulkner, 2000, 2007), knowing they might be insuring their chances of success through these interactions.

The most significant implication from this work is that the formation of engineers takes place across the curriculum and the co-curriculum, especially within opportunities for legitimate peripheral participation in engineering practice through internships (Lave & Wenger, 1991). The classroom is where fundamental technical concepts necessary for engineering practice are taught, but the co-curriculum may better simulate actual engineering practice. Significant to broadening participation in engineering, this study shows the co-curriculum is a location where opportunity exists to encourage women engineering students to remain committed to their professional career plans. This finding is especially important since one might assume that internship participation may discourage, rather than encourage, women to pursue engineering as a career if one accepts the assumption that industry provides a less "safe" environment than academia. That said, internship participation had a specifically profound effect on women's commitment to an engineering career. Although industry may not offer a traditionally or generally friendly climate for women, this finding suggests industry-academia partnerships hold great potential for increasing the proportion of practicing engineers who are women.

If colleges and universities are expected to graduate greater numbers of engineers to fill an anticipated need in industry, undergraduate engineering programs need to consider the holistic experience of the engineering formation process beyond completing required programs of study. The engineering formation process requires consideration of the curricular and co-curricular experience, and, in particular, partnerships between industry and academia to provide students authentic experiences with practice to provide access for legitimate participation. By allowing the boundary between education and practice to become more permeable, higher education can contribute more effectively to both meeting the national need for engineers and broadening the participation of people currently underrepresented in engineering.

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