How Legitimate Peripheral Participation in Engineering during College affects Professional Identity

Purpose

Identity is central to learning; in the professions, development of professional identity is a core aspect of the education and training process (Lave & Wenger, 1991). For this reason, educators in professional fields should consider the formation of professional identity as they make decisions about how to best prepare graduates to enter their chosen fields. This issue is especially salient in engineering education where a majority of students graduating from engineering programs remain unsure about their plans to enter engineering as a profession (Lichtenstein et al., 2009; Sheppard et al., 2010). If the field of engineering is to respond to national concerns about diversification of the engineering workforce and addressing the projected shortfall in graduates relative to job openings (National Academy of Sciences, National Academy of Engineering, & Institute of Medicine, 2011; President's Council of Advisors on Science and Technology, 2012), a focus on engineering identity as a central aspect of the professional formation process is essential. Identification with engineering has been shown to assist in the recruitment of diverse students and improve student retention among all groups (Andriot, 2011; Carlone & Johnson, 2007; Matusovich, Streveler, & Miller, 2010).

The purpose of this paper is to identify which engineering students' college experiences promote or enhance engineering identity. The specific research questions guiding this paper are:

1. What opportunities for authentic engagement in engineering practice relate to an increase in engineering identity?
2. Do background characteristics, like gender, underrepresented racial/ethnic minority status, or first-generation status, moderate the effects of these experiences on engineering identity?

Theoretical Framework

The theoretical framework guiding this study, illustrated in Figure 1, is constructed from Astin's inputs-environments-outcomes (IEO) model for assessing the impact of college on student development (see Astin & antonio, 2012) and Lave and Wenger's (1991) communities of practice model. The IEO model was developed to approximate and isolate the impact of specific college experiences on some desired outcome of interest. The effect of college experiences are difficult to assess experimentally, so Astin (1977) proposed isolating the unique contributions of these experiences on development by accounting for students' background characteristics and pre-college experiences (inputs), the distal effects of the college environment, and the more proximal effects of other college experiences when assessing the impact of a specified college experience.

The communities of practice model is then used to explain the process of professional identity development in engineering students (Johri & Olds, 2011; Lave & Wenger, 1991). The professional formation of engineers is fundamentally an identity development process, and novice engineers are assumed to develop a sense of engineering identity through legitimate peripheral participation in engineering practice (Lave & Wenger, 1991). As these novice practitioners move from peripheral to more central participation, their identification with engineering is fostered through three modes of belonging—engagement, imagination, and alignment (Wenger, 1998). These modes of belonging, per Stevens, O'Connor, Garrison, Jocuns, and Amos (2008), are observed in engineering as developing mastery of disciplinary knowledge (engagement), identification with engineering (imagination), and navigation into the profession (alignment).

Methods

Data Source and Sample

The data for this study were taken from the 2013 College Senior Survey (CSS) and the 2009 Freshman Survey (TFS) administered by the Cooperative Institutional Research Program (CIRP) at the Higher Education Research Institute (HERI) at UCLA. The TFS is the longest-running annual survey of incoming college students in the United States (Higher Education Research Institute, 2016), and is administered to students at the very beginning of the academic year. The CSS follow-up survey is then administered to students at participating institutions at the end of their fourth year of college. The TFS surveys students about experiences prior to college, and the CSS surveys students about their experiences within college. Student responses to the CSS are then matched to their responses to the TFS to form a longitudinal sample as many items included on the TFS are provided again on the CSS. In this dataset, nearly 18,000 students from 94 colleges and universities completed the CSS, of which 918 indicated an engineering major by the end of the fourth year of college. These 918 engineering students form the analytic sample for this study, as it is most appropriate to assess change in engineering identity among students who appear most likely to graduate with an engineering degree.

The dependent variable used for this study is a factor composed of three items that, together, measure engineering identity. These items represent the three modes of belonging to a community of practice and are the importance of making a theoretical contribution to science (engagement), the importance of becoming an authority in one’s field (imagination), and the importance of being recognized for contributions to the field (alignment). Factors were extracted using varimax rotation, and factor scores were computed as a linear combination of the individual items, weighted by factor loading. Factor loadings and reliability are provided in Table 1.

The independent variables then include a pre-test for engineering identity available on the TFS, a set of college experiences intended to provide authentic engagement with engineering practice, and a host of control variables to account for potentially confounding background characteristics, precollege experiences, and college experiences. College experiences expected to contribute to engineering identity include plans to enter engineering as a career, participation in internships, participation in student clubs or organizations, support and mentoring from faculty, and participation in undergraduate research. See Table 2 for a complete list of variables included, including descriptive statistics for all variables used.

Analysis

The research questions were addressed using ordinary least squares (OLS) regression in Stata v15 (STATA Software, 2018), using the SVY commands to produce robust standard errors given the nested nature of the sampling design (students were sampled within institutions). Hierarchical linear modeling (HLM) may also have been appropriate, but would only have been required if level-2 (institutional) variables were included (Astin & Denson, 2009; Heck & Thomas, 2015). Before starting this analysis, all variables were examined with respect to assumption violations for OLS regression, then missingness was also assessed to determine whether imputation may be needed to preserve statistical power. Listwise deletion, one of the most robust methods for handling missing data (Allison, 2002), led to 344 cases (37.5%) being dropped. Due to this large loss of data, multiple imputation will be used for the final paper.

Research question 1 was addressed through a hierarchical OLS regression process. Variables were organized into blocks based on the theoretical framework, which were then entered into the model successively through a set of intermediate OLS models, noting how regression coefficients changed as additional blocks of variables were entered. The pretest for engineering identity was entered first, followed by the primary block of independent variables, then the control variables were entered. Research question 2 was addressed through testing interaction terms between background characteristics and college experiences; these were tested individually in the final model.

Limitations

This study is limited in important ways that should be taken into account when generalizing from the findings. First, though the analysis controls for engineering identity at college entry, the dependent variable and the primary independent variables were measured on the same instrument, meaning causality cannot be assured. That said, the theoretical framework and prior literature may support interpreting these relationships as casual. Second, although the TFS is constructed to be nationally representative, the CSS is only administered to institutions that elect to participate in the survey, which is a much smaller sample. The CSS is administered to a large number of students across the nation at a variety of institutions and may be approximately, but not guaranteed, nationally representative. Finally, as this analysis is a secondary analysis of an existing dataset, this study rigorously addressed an important research question without expending a great deal of research resources, but may not have had all factors important to the central problem available in the dataset (Thomas & Heck, 2001).

Results

Preliminary results are presented in Table 3. Four main effects remained significant in the final model, and one interaction term tested significant as well. The final model is significant, $F(34,1) = 414.25$, $p < 0.05$, and the model explains about 30% of the variance in the dependent variable. The strongest predictor, as determined by its t-statistic, is the pretest for engineering identity. This variable alone explained about 13.8% of the variance in the dependent variable, just under half of the overall R^2.

Only one college engineering experience was significant in the final model. Higher scores on faculty-student interaction predicted growth in engineering identity and was the strongest predictor after the pretest. This finding shows that faculty play an important role in the professional growth of engineering students and supports a wealth of research that demonstrates the developmental benefits of student-faculty interactions (see Mayhew et al., 2016 for a review of this literature). However, none of the other opportunities for engagement with engineering practice were significant, supporting the assertions of Meyers, Silliman, Ohland, Pawley, and Smith (2012) that these experiences are variable in their effect on students.

No background characteristics related significantly to change in engineering identity, but two precollege academic experiences did. Higher standardized test scores predicted a very small but significant decrease in engineering identity, while higher academic self-concept related to growth in engineering identity. These appear to suggest that performance alone is insufficient; a student's confidence in their own academic abilities may be a more influential factor.

Surprisingly, plans to enter an engineering career, at least at college entry, did not relate to engineering identity, and, encouragingly, no differences were observed among engineering fields. Only one interaction term was significant as well; the relationship between student-faculty interaction and engineering identity appears to be enhanced for URM students when compared to their peers. The implication for this finding is that faculty play a crucial role in diversifying the engineering workforce through their interactions with students—an encouraging avenue to promote the retention of underrepresented students in engineering, tempered by literature that has shown the need for White faculty to improve how they navigate cross-racial mentoring relationships with students (McCoy, Winkle-Wagner, & Luedke, 2015).

Significance

Previous research has identified college experiences that provide authentic engagement with engineering practice also contribute to engineering identity. Mann, Howard, Nouwens, and Martin (2009) determined that internships and cooperative experiences enhance engineering identity because they provide undergraduates direct experience in industry. Internships also offer access to professional networks, whereas co-curricular involvement with engineering organizations, like student chapters of professional associations, offers access to peer networks which may become future professional networks (Mann et al., 2009; Matusovich, Barry, Meyers, & Louis, 2011; Pierrakos, Beam, Constantz, Johri, & Anderson, 2009). Hughes and Hurtado (2013) also determined that participation in undergraduate research and receipt of faculty mentoring and support may contribute to engineering identity as well.

That said, Meyers and colleagues did not find significant relationships between co-curricular experiences and engineering identity (Meyers, Ohland, Pawley, & Christopherson, 2010; Meyers et al., 2012), concluding that students assess the impact of these experiences in different ways. This disagreement is further supported by studies that show how engineering identity development is racialized and gendered (Faulkner, 2007; Hatmaker, 2013; Knight et al., 2013; Tonso, 2007), centered on the experiences of White men and contributing to a chilly climate for women and minorities. However, much of this work has been limited by use of small samples, single-item measures of engineering identity, and cross-sectional analysis approximating longitudinal effects.

This study contributes by addressing these limitations. Most importantly, the longitudinal nature of the data used provide the opportunity to control for engineering identity at college entry, providing a better estimation of the contribution of college experiences to change in this measure. The larger sample offers more assurance for generalizing the findings, and use of multi-factor items to measure unobservable psychological constructs, such as engineering identity, increases the internal validity of the measure.

References

Allison, P. D. (2002). *Missing data series: Quantitative applications in the social sciences* (Kindle Edition ed.). Thousand Oaks, CA: Sage.

Andriot, A. L. (2011). *Gender and engineering identity development among undergraduate majors.* (Ph.D.), Purdue University, Ann Arbor. ProQuest Dissertations & Theses Global database.

Astin, A. W. (1977). *Four critical years : effects of college on beliefs, attitudes and knowledge*. San Francisco: Jossey-Bass.

Astin, A. W., & antonio, a. l. (2012). *Assessment for excellence: The philosophy and practice of assessment and evaluation in higher education* (2nd ed ed.). Lanham, Md: Rowman & Littlefield Publishers.

Astin, A. W., & Denson, N. (2009). Multi-Campus Studies of College Impact: Which Statistical Method is Appropriate? *Research in Higher Education, 50*(4), 354-367. doi:10.2307/29782927

Carlone, H. B., & Johnson, A. (2007). Understanding the science experiences of successful women of color: Science identity as an analytic lens. *Journal of Research in Science Teaching, 44*(8), 1187-1218. doi:10.1002/tea.20237

Faulkner, W. (2007). 'Nuts and bolts and people': Gender-troubled engineering identities. *Social Studies of Science, 37*(3), 331-356.

Hatmaker, D. M. (2013). Engineering identity: Gender and professional identity negotiation among women engineers. *Gender, Work & Organization, 20*(4), 382-396. doi:10.1111/j.1468-0432.2012.00589.x

Heck, R. H., & Thomas, S. L. (2015). *An introduction to multilevel modeling techniques : MLM and SEM approaches using Mplus* (3. ed.). New York u.a.: Routledge.

Higher Education Research Institute. (2016). TFS Overview. Retrieved from heri.ucla.edu

Hughes, B. E., & Hurtado, S. (2013). *Investing in the future: Testing the efficacy of socialization within undergraduate engineering degree programs*. Paper presented at the Association for the Study of Higher Education, St. Louis, MO. heri.ucla.edu/nih

Johri, A., & Olds, B. M. (2011). Situated Engineering Learning: Bridging Engineering Education Research and the Learning Sciences. *Journal of Engineering Education, 100*(1), 151-185. doi:10.1002/j.2168-9830.2011.tb00007.x

Knight, D., Sullivan, J. F., Kotys-Schwartz, D. A., Myers, B. A., Louie, B., Luftig, J., T., . . . Hornback, J. M. (2013, June). *The impact of inclusive excellence programs on the development of engineering identity among first-year underrepresented students.* Paper presented at the 120th ASEE Annual Conference and Exposition, Atlanta, GA.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge England ; New York: Cambridge University Press.

Lichtenstein, G., Loshbaugh, H. G., Claar, B., Chen, H. L., Jackson, K., & Sheppard, S. D. (2009). An engineering major does not (necessarily) an engineer make: Career decision making among undergraduate engineering majors. *Journal of Engineering Education, 98*(3), 227-234.

Mann, L., Howard, P., Nouwens, F., & Martin, F. (2009, 2009). *Influences on the development of students' professional identity as an engineer*.

Matusovich, H. M., Barry, B. E., Meyers, K. L., & Louis, R. A. (2011). *A multi-institution comparison of identity development as an engineer*. Paper presented at the Annual Conference of the American Society for Engineering Education, Vancouver, BC. Paper retrieved from

Matusovich, H. M., Streveler, R. A., & Miller, R. L. (2010). Why Do Students Choose Engineering? A Qualitative, Longitudinal Investigation of Students' Motivational Values. *Journal of Engineering Education, 99*(4), 289-303. doi:10.1002/j.2168-9830.2010.tb01064.x

Mayhew, M. J., Rockenbach, A. N., Bowman, N. A., Seifert, T. A. D., Wolniak, G. C., Pascarella, E. T., & Terenzini, P. T. (2016). *How college affects students, volume 3: 21st Century evidence that higher education works*. Newark, NJ: Wiley.

McCoy, D. L., Winkle-Wagner, R., & Luedke, C. L. (2015). Colorblind mentoring? Exploring white faculty mentoring of students of color. *Journal of Diversity in Higher Education, 8*(4), 225-242. doi:10.1037/a0038676

Meyers, K. L., Ohland, M. W., Pawley, A. L., & Christopherson, C. D. (2010). The importance of formative experiences for engineering student identity. *International Journal of Engineering Education, 26*(6), 1550-1560.

Meyers, K. L., Silliman, S. E., Ohland, M. W., Pawley, A. L., & Smith, K. A. (2012). Factors relating to engineering identity. *Global Journal of Engineering Education, 14*(1), 119-131.

National Academy of Sciences, National Academy of Engineering, & Institute of Medicine. (2011). *Expanding underrepresented minority participation: America's science and technology talent at the crossroads*. Washington, D.C.: The National Academies Press.

Pierrakos, O., Beam, T. K., Constantz, J., Johri, A., & Anderson, R. (2009). *On the development of a professional identity: Engineering persisters vs engineering switchers*. Paper presented at the Annual ASEE/IEEE Frontiers in Education Conference, San Antonio, TX. Paper retrieved from http://ieeexplore.ieee.org/lpdocs/epic03/wrapper.htm?arnumber=5350571

President's Council of Advisors on Science and Technology. (2012). *Engage to excel: Producing one million additional college graduates with degrees in science, technology, engineering, and mathematics*. Retrieved from Washington, D.C.: www.whitehouse.gov/ostp/pcast

Sheppard, S., Gilmartin, S., Chen, H. L., Donaldson, K., Lichtenstein, G., Eris, Ö., . . . Toye, G. (2010). *Exploring the engineering student experience: Findings from the Academic Pathways of People Learning Engineering Survey (APPLES) (TR-10-01)*. Seattle, WA: Center for the Advancement of Engineering Education.

STATA Software. (2018). STATA. Retrieved from https://www.stata.com/

Stevens, R., O'Connor, K., Garrison, L., Jocuns, A., & Amos, D. M. (2008). Becoming an engineer: Toward a three dimensional view of engineering learning. *Journal of Engineering Education, 97*(3), 355-368.

Thomas, S. L., & Heck, R. H. (2001). Analysis of large-scale secondary data in higher education research: Potential perils associated with complex sampling designs. *Research in Higher Education, 42*(5), 517-540. doi:10.2307/40196441

Tonso, K. L. (2007). *On the outskirts of engineering: Learning identity, gender, and power via engineering practice*. Rotterdam: Sense.

Wenger, E. (1998). *Communities of practice: Learning, meaning, and identity*. Cambridge, U.K.: Cambridge University.

Table 1

Factor loadings and reliabilities

	Engineering identity (TFS) (α=0.6674)	Engineering identity (CSS) (α=0.6697)
Becoming an authority in my field	0.6240	0.6620
Being recognized by others for contributions to my field	0.6893	0.6903
Making a theoretical contribution to science	0.4838	0.4680

Table 2

List of variables and descriptive statistics

	Mean	S.D.	Min	Max
Dependent variable (engineering identity, CSS)	4.765	1.225	1.820	7.281
Engineering identity, TFS	4.597	1.155	1.797	7.188
Experiences with engineering practice				
Internship	1.714	0.452	1	2
Student clubs/organizations	1.848	0.359	1	2
Undergraduate research	1.397	0.490	1	2
Studied with peers outside class	2.661	0.530	1	3
Worked on professor's research	1.628	0.748	1	3
Faculty-student interaction	4.971	0.823	2.733	6.699
Inputs: background characteristics				
Sex: female	1.273	0.446	1	2
URM status	0.132	0.339	0	1
Either parent employed in engineering	0.202	0.402	0	1
Low income (ref: middle)	0.063	0.243	0	1
Low-middle income (ref: middle)	0.091	0.288	0	1
Middle-high income (ref: middle)	0.346	0.476	0	1
High income (ref: middle)	0.190	0.393	0	1
First-generation student	0.165	0.371	0	1
Inputs: precollege experiences				
High school GPA	7.303	0.906	3	8
SAT score or ACT equiv (scaled by 100)	13.371	1.350	8.8	16
Academic self-concept (scaled by 10)	5.568	0.805	3.254	6.998
Social self-concept (scaled by 10)	5.028	0.854	2.425	7.043
Inputs: college entry				
Plan to change major in college	2.432	0.779	1	4
Plan to enter engineering as career	0.766	0.424	0	1
Aeronautical/astronautical engineering (ref: mechanical)	0.045	0.207	0	1
Civil	0.169	0.375	0	1
Chemical	0.158	0.365	0	1
Computer	0.090	0.287	0	1
Electrical	0.106	0.308	0	1
Industrial	0.015	0.123	0	1
Other	0.125	0.331	0	1
Aspire to less than bachelor's degree (ref: bachelors)	0.005	0.069	0	1
Master's degree	0.518	0.500	0	1
Doctorate	0.232	0.422	0	1
Medical	0.064	0.245	0	1
Law	0.014	0.119	0	1
Attending college to get better job	2.865	0.369	1	3

Table 3

Final regression model predicting fourth-year engineering identity

	B	S.E.	t	sig
Constant	2.608	0.687	3.80	**
Pretest				
Engineering identity, TFS	0.372	0.032	11.71	***
Experiences with engineering practice				
Internship	-0.020	0.084	-0.24	
Student clubs/organizations	-0.066	0.077	-0.85	
Undergraduate research	0.176	0.107	1.64	
Studied with peers outside class	0.038	0.071	0.54	
Worked on professor's research	0.067	0.069	0.96	
Faculty-student interaction	0.399	0.051	7.86	***
Inputs: background characteristics				
Sex: female	-0.115	0.089	-1.29	
URM status	-0.192	0.192	-1.00	
Either parent employed in engineering	0.136	0.083	1.65	
Low income (ref: middle)	0.339	0.209	1.62	
Low-middle income (ref: middle)	0.170	0.230	0.74	
Middle-high income (ref: middle)	-0.031	0.084	-0.37	
High income (ref: middle)	0.129	0.110	1.18	
First-generation student	0.155	0.102	1.51	
Inputs: precollege experiences				
High school GPA	-0.127	0.075	-1.69	
SAT score or ACT equiv (scaled by 100)	-0.090	0.031	-2.94	**
Academic self-concept (scaled by 10)	0.137	0.051	2.66	*
Social self-concept (scaled by 10)	-0.020	0.065	-0.31	
Inputs: college entry				
Plan to change major in college	-0.031	0.050	-0.62	
Plan to enter engineering as career	-0.086	0.130	-0.66	
Aeronautical/astronautical engineering (ref: mechanical)	0.165	0.100	1.65	
Civil	-0.009	0.169	-0.06	
Chemical	-0.017	0.117	-0.14	
Computer	-0.031	0.172	-0.18	
Electrical	0.091	0.132	0.69	
Industrial	-0.107	0.176	-0.61	
Other	-0.094	0.117	-0.80	
Aspire to less than bachelor's degree (ref: bachelors)	0.400	0.453	0.88	
Master's degree	0.037	0.094	0.39	
Doctorate	0.050	0.147	0.34	
Medical	0.147	0.176	0.83	
Law	-0.622	0.336	-1.85	

Attending college to get better job	-0.047	0.111	-0.43	
Significant interaction terms				
URM x Faculty-student interaction	0.412	0.181	2.28	*

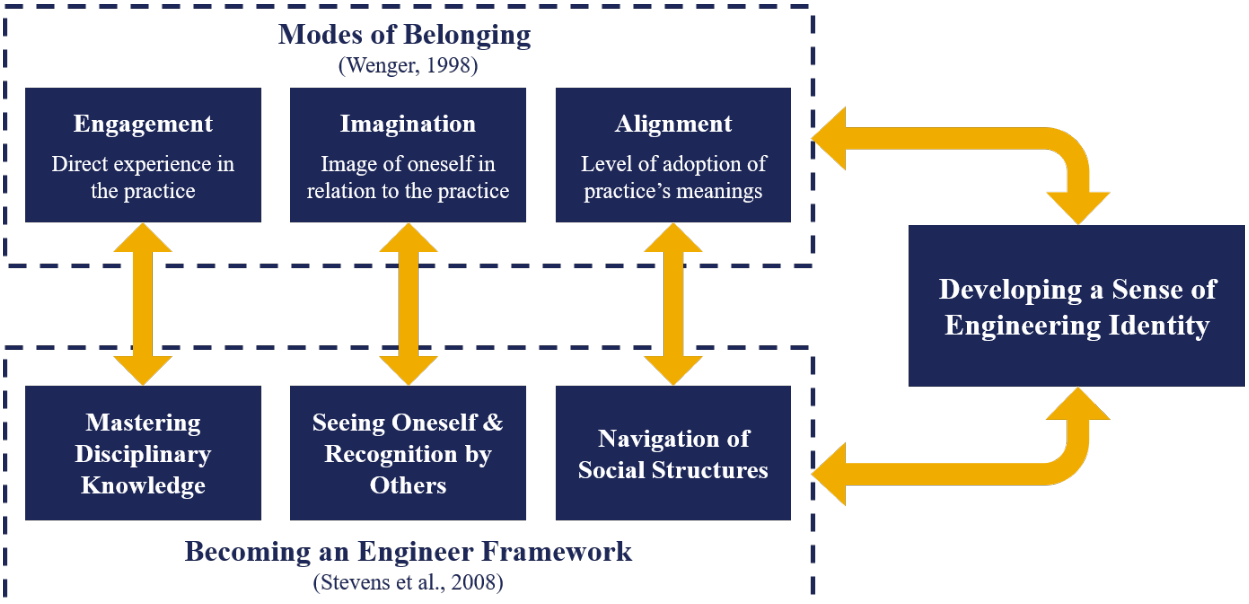

Figure 1. Theoretical framework for this study, illustrating the relationship between Wenger's (1998) modes of belonging from the communities of practice model with the three aspects of becoming an engineer per Stevens et al. (2008).