Professional Aspects of Engineering Improve Prediction of Undergraduates' Engineering Identity

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Abstract

Identity, or how people choose to define themselves, is a popular lens for studying undergraduate persistence in engineering. Quantitative studies of engineering identity build on prior work on math and science identity, emphasizing the academic aspects of engineering. However, professional practice is also central to the formation of an engineering identity. In this research paper, the authors present a series of regression models that demonstrate the increased ability to predict engineering identity when engineering practice is included. The authors administered a questionnaire survey in the 2016 fall and 2017 spring semesters to 1,536 undergraduates in civil, architectural, mechanical and biomedical engineering at two institutions. The authors conducted multiple sequential regression models to determine if engineering practice factors and engineering academic factors predicted engineering identity of undergraduate students. The engineering practice factors are tinkering, design, analysis, problem solving, collaboration and project management. This study shows that factors capturing affect towards elements of engineering practice are meaningful predictors of engineering identity in addition to the academic aspects of engineering identity that have been examined in prior research.

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Introduction

The goal of this study is to understand whether and how considering the professional aspects of engineering practice improve upon current ways of measuring the identity of undergraduates in civil, architectural, and other engineering majors. Identity, or how people choose to define themselves (Gee 2000), is emerging as an attractive explanation for who persists in engineering. Students who identify with engineering would be more likely to persist in engineering majors and pursue full-time employment as engineers. A shortage of engineers has drawn increasing attention within academia and industry in the U.S. (President's Council of Advisors on Science and Technology 2012), and several studies have investigated engineering students' persistence in engineering (French et al. 2005; Jones et al. 2010; Lee et al. 2017; Morello et al. 2018; Weinrach et al. 2001).

Much of the prior quantitative research on measuring the identity of engineering students has been based on adaptations of similar work in math and physics. Researchers have developed engineering identity survey instruments Godwin (2016); (Prybutok et al. 2016) by adapting similar survey instruments on science identity (Hazari et al. 2010). Based on a theory originally developed by Carlone and Johnson (2007), these instruments focus primarily on the academic aspects of engineering identity: performance/competence, engineering interest, and engineering recognition. These are described in Table 1. All three factors were positive predictors in regression models of engineering identity in undergraduates, and interest in particular was a significant factor predicting engineering student persistence (Patrick et al. 2018).

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However, there is one very important aspect of engineering that distinguishes it from math and science: engineering is a profession. Engineering as a profession is characterized by a common set of practices and career paths (Downey 2005) for which engineering students are trained. Though some prior studies have investigated the impact of engineering project and work experiences on career choice and persistence (e.g., Atman et al. 2010), the lack of studies directly measuring the professional aspects of engineering identity limits our ability to meaningfully link these experiences to the professional formation of engineers. While the literature does describe how interest in building things, taking things apart, programming, and playing computer games positively predicts engineering-related outcomes (Pierrakos et al. 2010), few studies directly link student attitudes toward building and figuring out how things work to engineering identity in undergraduates. Sheppard et al. (2010) linked professional experiences to motivation as a surrogate for identity. In investigating the engineering identity of school children, Capobianco et al. (2012) found that their theorized four components of identity reduced to academic and career aspects upon statistical analysis. Although the questions did not emphasize specific professional aspects of engineering, the finding supports the need to include both academic and professional aspects in studying engineering identity in students. In sum, there is good reason to include measures of the professional aspects of engineering in quantitative research on engineering identity, but few prior studies have done so.

Background

The theoretical framework for this study draws on identity theory from psychology and other social sciences. From this perspective, an individual's identity is constructed from multiple identities (or selves) based on situational factors, such as the social and cultural environment,

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assigned roles, or organizational affiliation (Gee 2000). As such, identity is dynamic, fluid, contextual and social. Individuals project different aspects of their identities at different times, as these identity aspects are more or less salient in different situations. Social identity theory focuses on an individual's self-conception based on membership in a collective social category or categories (Tafjel and Turner 1986), such as race/ethnicity or gender. Role identity describes an identity derived from the perceived expectations and performance of the role an individual takes on or is assigned (Stets and Burke 2000), such as engineer or engineering student. In organizational theory, "members assess the attractiveness of [work organization] images by how well the image preserves the continuity of their self-concept, provides distinctiveness, and enhances self-esteem" (Dutton et al. 1994), which is also relevant to engineering.

Based on the multiple identity work by Gee (2000), researchers from a variety of fields have utilized identity as a lens for STEM educational research (Capobianco et al. 2012; Cribbs et al. 2016; Fleming et al. 2013; Matusovich et al. 2011). Since much of this research began with a focus on math and science education (e.g., Hazari et al. 2010), researchers have focused on understanding student identification with a domain of interest, particularly academic aspects of the domain (Dutton et al. 1994). This study focuses on both the academic and professional aspects of identity.

The concept of professional identity pushes beyond technical knowledge to include elements of interpersonal skills, professional skills, values, and behavior patterns that are consistent with the expectations of the profession (Patterson et al. 2002). It builds on elements of role identity, such as professions, and often has a prescribed set of skills and behavior patterns, but differs from

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organizational identity, as it supersedes a single organization. In the literature (Trede et al. 2012), there are only a few studies focused on engineering professional identity development. For example, Hatmaker's interview study of 52 women engineers describes how they struggled to form professional engineering identities and implement a variety of coping mechanisms and impression management strategies to build a sense of belonging in engineering (Hatmaker 2013). In 2005, Loui explored the use of an engineering ethics course to teach students about the engineering profession and its ethical obligations to society. When asked how they would know when they became professional engineers, students reported three types of criteria: tangible markers (e.g., BS or MS degree, job title), external approval (e.g., engineering job assignment or responsibility), and internal qualities (e.g., technical competence)—these align with performance/competence and recognition in Table 1. Further, in attempting to understand the role that the development of a professional identity plays in persistence, Pierrakos et al. (2009) found that those students who persisted had higher levels of knowledge, exposure, and feeling of "fit" with the engineering degree. Thus, there is limited but promising evidence that professional identity development may lead to persistence in engineering.

For studying professional identity in other fields, accreditation standards have been utilized as a theoretical framework or a starting point for the development of professional identity scales in several fields including counseling education (Weinrach et al. 2001) and medical education (Hilton and Slotnick 2005). In engineering, ABET criteria serve this function for the development of scales related to professional identity development in the United States (ABET, 2012).

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In prior work (Patrick et al. 2017), the authors developed a scale of affect (i.e., liking or affinity) towards elements of engineering professional practice based on the ABET EC2000 criteria and student outcomes. Since changes to the ABET criteria had been proposed around the time of scale development, the proposed criteria changes were also consulted. To develop the affect scale, the authors consulted ABET's EC2000 criteria 3a-k as a theoretical base to define elements of engineering practice (ABET, 2012). These criteria were used as the theoretical base since the outcomes were developed collaboratively between industry and engineering stakeholders through an extended, multi-year process and represent the current minimum expectations of engineers' professional formation (Prados et al. 2005).

Using these criteria as the foundation, the research team used a combination of inductive and deductive processes for item generation. For the inductive process, the authors generated items based on in-depth qualitative interviews conducted by part of the research team with seven recent alumni who graduated with bachelor's or master's degrees in civil, mechanical, or biomedical engineering within the prior 2-5 years, and focus groups with 20 undergraduate and master's students in civil, mechanical and biomedical engineering. For the deductive process, members of the research team who were not involved in the interviews identified the content domain of the ABET criteria and used the existing literature to generate items to assess affect toward elements of engineering practice captured in each of the criteria. The items generated via both the inductive and deductive approaches were compared and discussed to arrive at the initial list of items. The authors circulated the items to experts in engineering and made modifications for clarity based on their suggestions on the items (Anderson and Gerbing 1991). Then, the authors conducted an exploratory factory analysis (EFA) on the initial set of items using a sub-set of

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survey responses (n=384). Since there was not a strong theoretical base for how the professional affect scale items might be organized (and in fact the ABET criteria were being reorganized during this time), the authors conducted EFA prior to confirmatory factor analysis (CFA). The EFA resulted in the extraction of a six-factor solution with total of 30 items. The six-factor solution was subjected to a CFA using the other sub-set of the data, which confirmed the six-factor structure of the new scale measuring affect toward elements of engineering practice. Details of the derivation of the six factors in the affect toward elements of engineering practice scale are described elsewhere (Patrick et al. 2017). The six factors comprising the scale are described in Table 2: Framing and Solving Problems, Design, Project management, Analysis, Collaboration, and Tinkering. Ethics was considered and included in initial set of survey questions but did not emerge as a salient factor.

In the current study, the authors first sought to assess how affect towards key elements of engineering professional practice predicts engineering identity of undergraduate engineering students. In addition, the authors examined the extent to which academic aspects of engineering identity predict engineering identity. Finally, the authors sought to bring the two together to determine the impact both academic and professional elements have on predicting engineering identity of undergraduate students.

Methods

Overview

The authors analyzed a total of 1,536 survey responses from undergraduate engineering students at two institutions. They used sequential multiple linear regression models to predict

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identification with engineering. That is, the first model established how much variance in engineering identity could be predicted using only student characteristics ("control variables" of gender, race/ethnicity, mother's education, division (upper vs. lower), institution, major, and whether the respondents were surveyed in the fall or the spring). The second model incorporates the affect toward elements of professional practice to understand how much additional variance in identity is explained by this new scale. The third and final model adds academic measures of engineering identity adapted from math and science to understand how well engineering identity can be predicted by considering both professional and academic aspects of engineering. The authors used STATA 14 software for all analyses.

Participants

The target population was undergraduate students majoring in civil engineering, architectural engineering, mechanical engineering, or biomedical engineering at two institutions from the same southwestern state. The two institutions can be characterized as a predominantly white institution (PWI) and a Hispanic serving institution (HSI) respectively. PWI is a large public institution in the U.S. with high-ranking engineering programs where the students are admitted directly into specific engineering majors. The participants at PWI are from civil, architectural, mechanical, or biomedical engineering majors. HSI is also a large public U.S. institution but with a predominantly Hispanic student population (80%). At HSI, participants were recruited from the mechanical engineering department. However, at the time of the study, HSI admitted students into a first-year pre-engineering program. Thus, the authors included pre-engineering students enrolled in first year mechanical engineering courses and mechanical engineering students in sophomore, junior, and senior years. At both institutions, all class years were surveyed.

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Data collection and cleaning

The survey, which took approximately fifteen minutes to complete, was administered in class electronically during the second week of the fall 2016 semester and the third week of the spring 2017 semester in a total of 32 engineering courses: eight civil and architectural engineering courses, 20 mechanical engineering courses, and four biomedical engineering courses. Of the 32 courses in which the survey was administered, 16 were designated by the institutions as lower-division (freshman and sophomore level) and 16 were upper-division (junior and senior level).

The authors matched survey responses with student records to include gender, race, major and first semester at the institution in the data set. Students with more than one major were retained in the analysis as long as one major was civil, architectural, mechanical, biomedical or pre engineering. Non-majors were removed from the data set. The response rate was approximately 70%. The authors removed the spring 2017 data of participants who completed surveys in both fall 2016 and 2017. The authors analyzed responses from a total of 1,536 students.

Instrument and Variables

This survey had total of 44 items. The dependent variable had two items. The factors of the independent variables were measured using 41 items. One demographic item was asked (others were obtained from student records).

1. Dependent variable: Engineering identity was measured using a two-item scale that utilizes one primarily visual and one verbal item to assess the extent to which an individual cognitively categorizes himself or herself as an engineer (Borrego et al. 2018). Using two items is an

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improvement (Diamantopoulos et al. 2012) over prior studies of engineering identity that relied on one item, (e.g., Meyers et al. 2012). The internal consistency of the engineering identity scale, assessed using Cronbach's alpha, is 0.84. This scale was adapted from scales widely used to measure identification with other professions (Bartel 2001; Bergami and Bagozzi 2000).

2. Independent variables: Two different scales were used in this study for independent variables.

a. Affect factors toward elements of engineering professional practice

Since engineering students are not yet practicing engineers, their "affect," liking, or affinity towards several aspects of professional practice must be measured. The authors used a total of 30 items to measure six factors of the affect toward elements of engineering professional practice scale (Patrick et al. 2017). The survey stem for the items was: "As you think about your future after you finish your education, to what extent would you enjoy a profession or career that usually requires each of the following?" All items used a 5-point Likert-type response scale where 5 is very much and 1 is not at all. Table 3 lists the factors, the number of survey items in each, their reliability as measured by Cronbach's alpha, and an example item. Constructs with two items originally included more items that were removed based on factor analysis. Our prior work developing this scale is detailed in the Background section above. CFA analysis (Patrick et al. 2017) supports validity of the underlying factor structure, including discriminant validity between constructs, their relation to a latent higher order construct of affect towards professional practice, and correlation to engineering performance/competence and engineering identity.

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b. Academic aspects of engineering identity factors

The authors used the academic aspects of engineering identity scale (Patrick et al. 2018), which has three factors with a total of 11 items using a Likert-type response scale where 1 is strongly disagree and 5 is strongly agree. Table 3 lists the factors, the number of survey items in each, their reliability as measured by Cronbach's alpha, and an example item. The *Engineering Competence/Performance* factor represents engineering students' perception of mastering challenging engineering knowledge and skills. The *Engineering Interest* factor is associated with engineering students' interest in learning and working in engineering. The *Engineering Recognition* factor assesses recognition as an engineer by parents, relatives, and friends of engineering students. Prior regression analyses demonstrate that these items predict engineering identity and persistence in engineering (Patrick et al. 2018), and CFA provides evidence that similar items indeed align according to this 3-factor structure Godwin (2016).

3. Respondent Characteristics

Most of the participant characteristics were obtained from university records; mother's education was asked in this survey. Respondent characteristics are summarized in Table 4.

Analysis Approach

Pearson correlation analyses were conducted to measure the relatedness of the dependent variable and independent variables. Each coefficient of the correlation provides the strength of a linear association between two variables. Testing the significance of the Pearson correlations between independent and dependent variables indicates significant linear relationship between

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two variables, and the significant relationship suggests which independent variables are likely to predict dependent variable in a regression model.

Several assumptions of multiple linear regression were tested prior to regression analysis. All assumption criteria including linearity, normality, equal variances, and multicollinearity were satisfied. Scatter plots were used to test linearity. Multiple linear regression assumes that dependent variable and independent variables have a linear relationship. Variance Inflation Factor (VIF) coefficients were calculated to test multicollinearity, or high correlation among independent variables. High multicollinearity negatively impacts regression model fit and increases the standard error of the estimate, making it difficult to test the coefficient of the regression (Stevens 2001). In this study, all VIF values were less than 4, which indicates that multicollinearity was not a concern (Slinker and Glantz 1985). The other two assumptions for multiple linear regression analysis are normally distributed residuals and equal variances. Due to the large sample size, the regression models are robust to violations of normality and equal variances assumptions (Keith 2014).

The authors ran a total of three regression models. The authors entered gender, race/ethnicity, major, mother's education, division (grade level—upper vs. lower division), institution, and surveyed in fall vs. spring, as control variables in the first model. Then, the authors added the six factors of the affect towards elements of engineering practice scale in the second model. Last, the authors added the three factors for academic aspects of engineering identity in the third model.

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Among demographic variables, the authors treated mother's education as a numerical variable [Graduated from high school or equivalent (GED) or less as 1, Degree or certificate from a vocational school, a junior college, a community college, or another type of 2-yr. school as 2, completed a college degree as 3, and completed a masters, doctoral or other advanced professional degree (JD, MD, PhD, etc.) as 4]. The authors dummy-coded other demographic variables to transform categorical variables into a series of dichotomous variables with a value of zero or one. For gender, the reference group was male. For race, White was the reference for comparison with Black, Hispanic, Asian, multi-race, international, and American Indian/Native Hawaiian. Major was dummy-coded with three categories, and mechanical engineering was the reference for comparison with civil and architectural engineering and biomedical engineering. For division, which represents grade level, upper division (junior and higher years) was the reference group for comparison with lower division (freshman and sophomore). For institution, Predominantly White Institution was the reference group for comparison with Hispanic Serving Institution. For semester, fall 2016 was the reference group for spring 2017.

Results

Pearson Correlation

Table 5 shows the Pearson correlations between the dependent variable (engineering identity) and independent variables (academic aspects of engineering identity and affect towards elements of engineering professional practice). All independent variables had significant positive correlation with the dependent variable ($p < .01$). The coefficient values ranged from 0.23 to 0.43. In social science, correlation coefficients around 0.10 are considered small, 0.30 considered medium, and 0.50 considered large (Cohen 1988). Most of the correlation coefficient values

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between the dependent variable and independent variables in this study are medium. Thus, the authors have a good justification to include all independent variables in the regression models.

Although all independent variables are significantly correlated to other independent variables, correlation coefficient values were less than or equal to .70, so there is less potential of multicollinearity in the main regression models, as was indicated by the VIF coefficients obtained.

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Sequential multiple linear regression models

Table 6 presents three regression models for the outcome engineering identity. Based on the R^2 value, model 1 shows that the student characteristics explain 6.9% of the variance in engineering identity. Two control variables significantly predicted engineering identity. These variables are female ($\beta = -.106$, $p < .001$) and institution ($\beta = .198$, $p < .001$). Model 2 introduces the six affect factors towards engineering professional practice. These factors explain 17.7% of the variance in their engineering identity after excluding the 6.9% of 24.6% explained by controls. Among the six factors, three factors were significant: *Tinkering* ($\beta = .200$, $p < .001$), *Design* ($\beta = .191$, $p < .001$), and *Analysis* ($\beta = .123$, $p < .001$). The two control variables that were significant in the first model remained at the same significance level in Model 2. In Model 3, the authors added the three factors for academic aspects of engineering identity. A total of 33.0% of variance was explained by Model 3. Academic aspects of engineering identity explained an additional 8.4% of variance in engineering identity. In this final model, among the nine independent variables, six variables significantly predicted engineering identity: *Tinkering* ($\beta = .149$, $p < .001$), *Design* ($\beta = .127$, $p < .01$), *Analysis* ($\beta = .090$, $p < .01$), *Engineering Performance/Competence* ($\beta = .102$, $p < .001$), *Engineering Interests* ($\beta = .192$, $p < .001$), and *Engineering Recognition* ($\beta = .170$, $p < .001$).

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Discussion

While previous studies of engineering identity have focused on academic aspects of engineering identity—e.g., engineering performance/competence, engineering interest, engineering recognition—this study shows that factors capturing affect towards elements of engineering professional practice explained a substantial amount of variance in students' engineering identities. This study provides additional evidence of the Anderson et al. (2010) finding of engineers' professional practices such as problem solving, design, analysis, and collaboration fostering positive engineering identities. While Anderson et al. (2010) focused on practicing engineers in U.S. companies to understand engineering identity development, this study provides evidence that engineers' affect toward engineering professional practices starts earlier, during undergraduate engineering programs.

Among the six factors capturing affect toward elements of engineering professional practice, three factors—tinkering, design and analysis—were significant predictors of engineering identity. In other words, engineering undergraduate students with more positive affect toward *Tinkering, Design,* and *Analysis* had stronger engineering identities. Affect toward *Problem Solving, Collaboration, and Project Management* were not significant positive or negative predictors of engineering identity. It is possible that engineering students' classroom experiences may have led them to emphasize the role of the professional engineering practices of tinkering, designing and analyzing in shaping their perceptions of themselves as engineers. These findings are similar to those of Pierrakos et al. (2010) who found that affinity for building things and taking them apart was related to identification with engineering. They are also consistent with those of Sheppard et al. (2010) who found relationships between engineering work experience

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and motivation to study engineering. This study provides a stronger link between professional aspects of engineering and engineering identity. In addition, internship or co-op opportunities are available to some students, but the short period of engineering experience enabled by internships or co-ops may not provide students enough of an opportunity to consider the importance of *Problem Solving, Collaboration,* and *Project Management* in professional engineering practice. In preliminary analysis we included co-op or internship experience as a control variable, but it was not significant in predicting engineering identity. However, it does not mean that these three factors are not influential in affecting engineering identity since these three factors were positively correlated with engineering identity in the univariate analysis.

Importantly, the set of factors of the affect towards elements of engineering practice scale that were significant predictors of engineering identity remained significant after the authors included the three factors of academic aspects of engineering identity, which have been found to be powerful predictors of engineering identity. This finding suggests that there is added value in examining the role played by professional aspects in understanding the formation of engineering identity and ultimately, attraction to and retention within the engineering profession. This study contributes evidence in this direction by demonstrating the significance of undergraduate students' affect toward elements of engineering practice, and in particular towards the *Tinkering*, *Design*, and *Analysis* elements, in predicting engineering identity. This added explanation for the formation of engineering identity, based in professional aspects of engineering, suggests the importance and utility of focusing on engineering as a profession in addition to engineering as an academic discipline, in understanding and shaping undergraduate students' development within engineering.

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In this regression analysis, female engineering students reported weaker engineering identities than male engineering students. This is important to explore in future studies. Further, HSI students perceived that they had a stronger engineering identity compared to PWI students. Institutional characteristics such as admissions selectivity and the typical career paths of graduates (which may or may not be related to institutional mission) may account for the differences. Ongoing work by the authors is examining this using qualitative methods at the two institutions and by expanding data collection to more HSI institutions.

Implications for Engineering Educators

This study reinforces prior findings that engaging in professional practice builds engineering identity and focuses on specific aspects of engineering practice that support engineering identity in undergraduates. Students' affinities for tinkering, design, and analysis were positively related to engineering identity. It follows that positive experiences tinkering, designing and analyzing may build engineering identity and ultimately impact persistence in engineering degree programs and careers. Other professional practices such as collaboration, project management and framing and solving problems have been important in studies of practicing engineers and were included in the current survey because practicing engineers mentioned them in interviews. However, these were not related to engineering identity in this study of undergraduates. There may still be a disconnect in students' understanding of the importance of these professional skills to being a successful engineer. This has important implications for diversity and inclusivity in engineering if students with these skills and preferences do not feel like they are doing "real" engineering or are discouraged from developing strong engineering identities. It is up to engineering educators

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to develop learning experiences and environments that value important professional—as well as technical and academic—contributions to engineering so that the profession does not lose talented engineers.

Limitations

There are a few limitations to note. The sample was drawn from two institutions and cannot be claimed to be generalizable to the broader engineering student population. Civil and architectural engineering students are underrepresented in the sample, as are students from several other engineering disciplines who were not surveyed at all. Although major was included as a control in the regression model and the model should have accounted for differences, it is still possible that mechanical engineering students dominated the results, perhaps by overemphasizing the design and tinkering aspects of engineering. The response rate was high (70%), but self-selection bias may still have played a role. Nonetheless, this study demonstrates the importance of considering professional aspects of engineering practice in future studies of engineering student identity and retention.

Conclusion and Future Work

This study demonstrated significant prediction of engineering identity with a measure of affect towards key elements of engineering professional practice. In future work, the authors will investigate significant differences in engineering students' engineering identity development within gender (male vs. female) since gender was significant in predicting engineering identity in this analysis. Future work should also seek to link these professional scale items to persistence

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and explore relationships between specific curricular and extracurricular activities to building these important aspects of a professional engineering identity.

In sum, this work illustrates that a new dimension of attitudes related to professional practices in engineering, rooted in the professional rather than only the academic aspects of engineering, was a significant contributor to undergraduate engineering students' engineering identity.

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Table 1. Academic factors for engineering identity.

Factor	Description
Performance/ competence	A student's belief in their ability to perform academically or when conducting engineering-related tasks, and their ability to understand engineering material
Interest	How motivated a student is toward the content and career they are pursuing, often encompassing the motives a student has for pursuing graduate study; encompasses not only affinity towards engineering tasks but also the ongoing reasons students identify for persisting in engineering
Recognition	How others such as parents, relatives, friends, colleagues and faculty see the student in the context of engineering

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Table 2. Professional factors for engineering identity.

Factor	Definition
Framing and Solving Problems	The propensity for individuals to embrace curiosity and problem-solving. Relates to an appreciation for continuous learning and finding ways to improve processes and methods. Describes an individual's interest in the application of math and science in solving engineering problems, particularly those related to addressing societal issues.
Design	The interest that an individual has in creative and generative processes. Describes an individual's push to search for ways to be innovative and test out new ideas, whether via experimentation or prototyping. Relates to an individual's ability to keep up with and apply technology to contemporary issues. The ability of an individual to accurately design all or a component of a system based on a set of constraints.
Project Management	The skill set individuals need to help them bring projects to life. Not only includes organization, planning, and decision-making skills needed to execute a design, but also the wherewithal to see the plan through to the end.
Analysis	Includes the ability to apply math and science and solve the relevant governing equations during design and evaluation. Includes the ability to identify what you need to know to solve a problem or complete a project.
Collaboration	Those skills necessary for working with other people. Includes the ability to communicate and present your ideas and the ability to be persuasive and convince other people as to the merits of an idea. Includes the ability to work on a team and to break down a project into smaller, manageable parts.
Tinkering	The propensity an individual has to understand how something works by taking it apart and to fix things.

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Table 3. Cronbach's Alpha, number of items, and sample items for scales measuring independent variables. Adapted from Patrick et al. (2017).

Variables	Alpha	# of Items	Example item
Affect toward elements of engineering professional practice			
Framing and solving problems	0.82	7	Solving problems that allow me to help a lot of people
Design	0.86	8	Designing and conducting experiments to test an idea
Project management	0.74	4	Planning a project and staying organized to complete it
Analysis	0.77	3	Applying my math knowledge and skills
Collaboration	0.79	6	Working with people with different skills and interests
Tinkering	0.76	2	Taking something apart to see how it works
Academic aspects of engineering identity			
Engineering performance/competence	0.88	6	I can understand concepts I have studied in engineering
Engineering recognition by others	0.81	3	My friends see me as an engineer
Engineering interest	0.81	2	I enjoy learning engineering

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Table 4. Respondent characteristics.

Parameter	*n*	Percentage of total
Gender		
Male	1061	69.1
Female	475	30.9
Major		
Mechanical engineering	957	62.3
Civil or architectural engineering	303	19.7
Biomedical engineering	276	18.0
Year		
Freshman	474	30.9
Sophomore	355	23.1
Junior	378	24.6
Senior	329	21.4
Institution		
PWI	1161	75.6
HSI	375	24.4
Ethnicity		
White	604	39.3
Black	19	1.2
Hispanic	498	32.4
Asian	290	18.9
Multi-race	41	2.7
International	81	5.3
American Indian and Native Hawaiian	3	0.2

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Table 5. Means, Standard Deviations, and Correlations Between Independent and Dependent Variables

	1	2	3	4	5	6	7	8	9	M	SD
1. Engineering identity	1									5.21	1.35
2. Project management	.27*	1								4.27	.59
3. Tinkering	.42*	.37*	1							4.09	.85
4. Collaboration	.23*	.64*	.34*	1						4.12	.62
5. Analysis	.35*	.57*	.45*	.54*	1					4.13	.73
6. Design	.42*	.61*	.60*	.56*	.63*	1				4.21	.63
7. Framing and solving problems	.31*	.62*	.46*	.63*	.54*	.70*	1			4.48	.50
8. Engineering perform/comp.	.37*	.35*	.30*	.33*	.36*	.41*	.38*	1		3.95	.68
9. Engineering interest	.43*	.36*	.40*	.30*	.39*	.45*	.45*	.58*	1	4.37	.78
10. Engineering recognition	.31*	.25*	.23*	.24*	.22*	.26*	.25*	.29*	.27*	4.06	.83

Note. *$p < .01$.

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Table 6. Results of Multiple Linear Regressions with Nine Independent Variables– Engineering Identity

	Model 1		Model 2		Model 3	
Variables	*β*	*p*	*β*	*p*	*β*	*p*
(Constant)	-	.000	-	.000	-	.000
Control variables						
Female	-.106**	.000	-.091**	.000	-.076*	.001
Civil or Architectural	-.134	.655	-.004	.858	-.032	.213
Biomedical	-.011	.708	.002	.948	-.012	.640
Lower division	.002	.943	-.025	.270	-.033	.135
Spring semester	-.029	.294	-.025	.313	-.043	.073
HSI	.198**	.000	.137**	.000	.126**	.000
Black	-.030	.234	-.010	.659	.008	.696
Hispanic	.021	.562	-.027	.413	-.012	.707
Asian	-.001	.975	-.011	.650	.035	.146
Multi-race	-.007	.768	-.015	.504	-.008	.696
International	-.014	.602	-.011	.627	.008	.731
AINH[a]	.028	.263	.002	.939	.003	.900
Mother education	-.041	.129	-.005	.841	-.011	.627
Affect toward elements of engineering practice variables						
Project management			.017	.605	-.010	.743
Tinkering			.200**	.000	.149**	.000
Collaboration			-.048	.137	-.056	.069
Analysis			.123**	.000	.090*	.002
Design			.191**	.000	.127*	.001
Framing and solving[b]			.035	.322	-.024	.478
Academic aspects of engineering identity variables						
Engineering perf/comp[c]					.102**	.000
Engineering interest					.192**	.000
Engineering recogn[d]					.170**	.000
R^2	.069**		.246**		.330**	
Delta R^2	.069**		.177**		.084**	

Note: *$p< .01$ and **$p< .001$. (two-tailed tests)
[a]American Indian and Native Hawaiian; [b]Framing and solving problems; [c]Engineering performance/competence; [d]Engineering recognition

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