

## ORIGINAL ARTICLE

# Master's and doctoral engineering students' interest in industry, academia, and government careers

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## Abstract

**Background:** Graduate education literature tends to focus on faculty careers with little attention to industry careers. However, more than one-third of U.S. engineering doctorates enter industry.

**Purpose:** Our purpose is to understand engineering graduate students' interest in industry, academia, and government careers as it relates to their graduate engineering identities.

**Design/Method:** A total of 249 engineering thesis master's and doctoral students completed a survey about their graduate engineering identities and career preferences. We created regression models to predict students' likelihood of pursuing careers in industry, academia, and government. Then, we used cluster analysis to understand the extent to which students are considering multiple options and used chi-squared and ANOVA tests to compare the clusters.

**Results:** In the regression model predicting an academic career, research recognition and research performance/competence were positive predictors and engineering performance/competence was a negative predictor. Regression models of industry and government described less than 10% of the variance. Four clusters emerged, which collectively demonstrate that engineering graduate students are considering careers in multiple sectors. Students with internships during graduate study were more likely to pursue industry careers. Master's students were underrepresented in the cluster with highest likelihood of an academic career. International students were keeping more options open than some domestic students. There were also differences by engineering discipline.

**Conclusions:** Engineering graduate students are considering multiple career sectors. Advisors and education researchers should focus not only on academic career preparation but also on industry and government career preparation, particularly on preparing for multiple options simultaneously.

## KEYWORDS

career choice, master's students, PhD students, regression, survey

## 1 | INTRODUCTION

Graduate education research on career trajectories tends to focus on PhD students' paths to faculty careers, including increasing competition for tenure-track positions (e.g., Austin, 2010; Roach & Sauermann, 2010; Thiry, Laursen, & Liston, 2007). For example, the Survey of Earned Doctorates (SED) data show that among U.S. engineering PhD recipients, commitments to academic positions declined from 16% in 2004 to 12% in 2009 (Fiegener, 2010; National Center for Science and Engineering Statistics, n.d.). Across all engineering disciplines in the United States, Larson, Ghaffarzadegan, and Xue (2014) estimate that at steady state, only 12.8% of new PhDs will be able to find tenure-track faculty positions and that for 50% of new PhDs to find tenure-track positions, "the whole field would need to grow at an improbable rate of 14% every year" (p. 4). It has taken nearly 10 years, from 2009 to 2017, to achieve a growth rate in engineering tenure-track positions of 12% (2009:  $n = 24,369$ ; 2017:  $n = 27,372$ ; ASEE, 2010, 2018). Even so, a culture persists in engineering and science doctoral education that privileges tenure-track faculty career paths, limits discussion of other options, and shames students who do not land coveted faculty positions at research institutions (Thiry et al., 2007). Clair et al. (2017) found that biomedical science doctoral students received less support for nonacademic career development from their advisors and other faculty members. Although many advisors may not intend to privilege academic career paths, their greater familiarity with academia may cause students to perceive less support for industry, government (e.g., national labs), nonprofit and other career paths. The recent National Academies (2018) report on STEM graduate education calls for programs to more systematically provide advising and career preparation for industry and government as well as academic career paths.

In engineering, industry and government are popular employment options for master's and doctoral recipients. In recent decades, U.S. engineering doctoral recipients have entered industry positions at rates (38%) nearly as high as academia (45%, including faculty and postdoctoral research positions; Fiegener, 2010). Among 2017 U.S. PhD engineering graduates, 8% reported initial employment in government and 59% in private, for-profit industry (National Science Foundation & National Center for Science and Engineering Statistics, 2017). Although data by employment sector are not as readily available for master's recipients, even stronger representation in industry is expected. In 2012, there were more than 4 times as many engineering master's recipients as engineering doctoral recipients (43,150 master's and 8,427 PhD recipients, National Science Foundation & National Center for Science and Engineering Statistics, 2015). In sum, due to the substantial proportion of engineering master's and PhD recipients in private industry and government, it is important to understand career options other than academia and how engineering graduate students consider their career preferences.

A potentially productive perspective for understanding how engineering doctoral and master's students view different career preferences is engineering identity, or the degree to which an individual identifies with engineering (Eliot & Turns, 2011). At the undergraduate level, research has linked engineering, science and math identity to engineering persistence and career intentions (Godwin, 2016; Hazari, Sonnert, Sadler, & Shanahan, 2010; Patrick, Borrego, & Prybutok, 2018; Tendhar, Singh, & Jones, 2018). Other studies have demonstrated relationships between aspects of science or engineering identity and decisions to pursue graduate study (Borrego, Knight, Gibbs, & Crede, 2018; Estrada, Woodcock, Hernandez, & Schultz, 2011; Ro, Lattuca, & Alcott, 2017). Among graduate students, stronger science and engineering identity has been linked to persistence in science and engineering career preferences (Burt, 2014; Chemers, Zurbriggen, Syed, Goza, & Bearman, 2011). Extending this work to study graduate students' preferences for three different career sectors (i.e., academia, industry, and government) adds new dimensions to persistence outcome variables, which have previously been treated as binary (i.e., persisting or not persisting in science or engineering).

A relatively new direction for identity at the graduate level is extricating different aspects of engineering identity. Prior work has suggested that graduate students form separate disciplinary and research identities (Park & Schallert, 2019; Syvante & McNair, 2015), and research at the undergraduate level has modeled engineering identity as having both disciplinary and professional components (Choe, Martins, Borrego, & Kendall, 2019). In this article, we refer to these aspects—including professional, disciplinary, and research identity—collectively as *graduate engineering identity*. The purpose of this study was to understand what student characteristics and components of thesis master's and doctoral students' engineering identity predict career preferences toward industry, academia, and government. The research questions that guided the study are:

1. What student characteristics and components of graduate engineering identity predict engineering graduate students' career preferences toward industry, academia, and government?
2. What are the characteristic profiles of the extent to which engineering graduate students are considering careers in industry, academia, and government?

3. What are the statistically significant differences between profiles of career preferences in terms of student characteristics and graduate engineering identity variables?

We focused on industry, academia, and government because our own analysis of Survey of Earned Doctorates data (National Center for Science and Engineering Statistics, n.d.) indicates that among engineering PhDs completing between 2006 and 2017, only 3.2% took employment in other sectors such as nonprofit or started their own businesses. This study extends prior work in multiple ways. First, it considers industry, academia and government career preferences as equally desirable outcomes. Second, it extends engineering identity frameworks to the graduate level and develops quantitative measures of several aspects of graduate engineering identity. Finally, it adds cluster analysis to create profiles of the extent to which graduate students are considering multiple career preferences simultaneously.

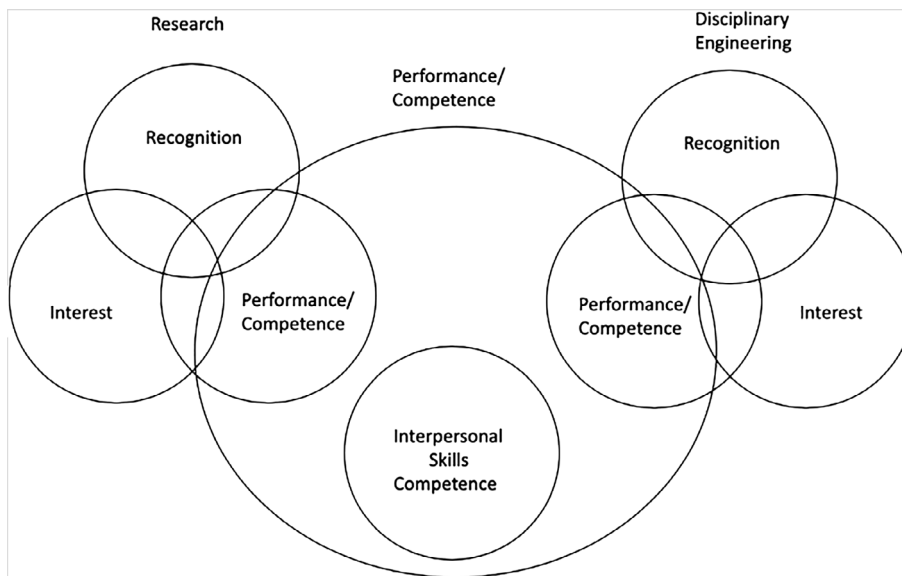
## 2 | THEORETICAL FRAMEWORK

According to Gee's (2000) multiple identity theory, an individual holds or develops their multiple types of identities that connect to their performances in society. Multiple identity theory includes aspects of identity, which are salient in educational, work, and personal situations, including personal and social identity in addition to science or engineering identity (Carlone & Johnson, 2007). Of these identities, disciplinary engineering identity has been studied most extensively among engineering students. Studies of undergraduate engineering identity have demonstrated relationships between engineering identity and retention in engineering (Patrick et al., 2017; Pierrakos, Beam, Constantz, Johri, & Anderson, 2009; Tendhar et al., 2018) and science and math identity and pursuit of an engineering major (Godwin, Potvin, Hazari, & Lock, 2016). Other studies are also beginning to link identity to persistence among engineering doctoral students (Miller et al., 2017).

We argue that Gee's multiple identity theory may be particularly useful for understanding how graduate students navigate their many roles and responsibilities and how these roles and responsibilities relate to preferences for a career in industry, academia, or government. Although prior studies on graduate engineering identity inform this work and are cited here (e.g., Burt, 2014; Svyantek, Kajfez, & McNair, 2015), a relatively new direction for graduate identity is extricating different aspects of graduate engineering identity such as research and disciplinary engineering. The focus on different employment sectors (i.e., academia, industry and government) is an additional new direction for engineering identity research. While prior studies of high school and first-year undergraduate students indicate that identity constructs predict interest in an engineering career (Cass, Hazari, Cribbs, Sadler, & Sonnert, 2011; Cech, Rubineau, Silbey, & Seron, 2011; Cribbs, Cass, Hazari, Sadler, & Sonnert, 2016), the outcome variable is typically treated as binary (i.e., engineering or not engineering) instead of as a variety of possible outcomes, all of which would be considered as persistence in engineering (i.e., engineer in academia, industry or government). Our framework, as depicted in Figure 1 and described below, is informed by the literature, interviews with graduate students and alumni, and factor analysis of pilot survey data.

One of the most widely used models for quantitative studies of undergraduate engineering identity posits that engineering identity comprises three constructs: engineering performance/competence, engineering interest, and recognition as an engineer by others (Godwin, 2016; Prybutok, Patrick, Borrego, Seepersad, & Kirisits, 2016). These studies used models adapted from research on science identity (Carlone & Johnson, 2007) and physics identity (Hazari et al., 2010). Performance/competence refers to belief in one's ability to perform engineering tasks and understand engineering concepts. It is closely related to self-efficacy beliefs (Godwin et al., 2016). Interest reflects one's desire to learn more about engineering, participate in engineering activities, and pursue engineering careers. Recognition means being recognized by others (e.g., faculty, friends, and family) as an engineer.

It is reasonable to expect that since many engineering graduate students hold bachelor's degrees in engineering that the constructs would also be relevant at the graduate level. According to our analysis of Survey of Earned Doctorates data, 84% of engineering PhD recipients from 2006 to 2017 hold bachelor's degrees in engineering (National Center for Science and Engineering Statistics, n.d.). Two quantitative studies using independent samples of engineering graduate students at different U.S. institutions have confirmed that engineering performance/competence, interest, and recognition translate to the graduate level (Choe & Borrego, 2019; Perkins, Bahnson, Tsugawa-Nieves, Miller, & Kim, 2018). However, simply adapting these aspects of engineering identity from the undergraduate to graduate level is not inclusive of the many professional roles and associated identities of engineering graduate students, particularly as they consider careers in industry, academia and government. Specifically, we focus on including research as an important aspect of graduate training and, therefore, the identities of engineering graduate students.



**FIGURE 1** Framework of factors affecting engineering graduate student identities. After the style of Carlone and Johnson (2007), Hazari et al. (2010) and Godwin et al. (2016)

## 2.1 | Overview

Our theoretical framework for predicting engineering graduate students' interest in industry, academic, and government careers is based on their multiple professional role identities. Figure 1 demonstrates a model of major factors that affect the identities of graduate engineering students. We adapted the main factors that impact engineering identity and research identity from a well-studied undergraduate engineering and science identity model (Carlone & Johnson, 2007; Godwin, 2016; Hazari et al., 2010; Prybutok et al., 2016). We anticipated that three factors would influence these students' engineering identities: disciplinary engineering competence/performance, disciplinary engineering interest, and recognition as an engineer by others. We use extensive literature and preliminary results to argue that performance/competence, interest and recognition may also apply to research. We also include interpersonal skill competence in the framework because it affects both engineering and research identities as both require interpersonal skills. For the purposes of this paper, engineering and research identity, including interpersonal competence, will be collectively referred to as *graduate engineering identity*.

## 2.2 | Research identity

Engineering graduate programs are designed to educate students to use research to produce marketable products and peer-reviewed research papers (Carlin & Denecke, 2008). To develop these research skills, many students are required to complete a thesis or dissertation (Crede & Borrego, 2012; Rogers & Goktas, 2010). In engineering, it is common for graduate students to complete their theses and dissertations as part of projects with faculty members in a research group with other students (Carlin & Denecke, 2008). Through participation in these related research projects, engineering graduate students develop research skills such as generating ideas, conducting experiments, analyzing data, collaborating with others, and communicating results (Saddler, 2009). We acknowledge that not all engineering master's students in the United States are required to complete thesis research but nonetheless focus our attention on master's students completing thesis research along with doctoral students.

Since research is a substantial part of the training of many engineering graduate students, several prior studies suggest that engineering graduate students develop a research identity alongside their disciplinary engineering identity. For example, Park and Schallert's (2019) longitudinal qualitative study of doctoral students found that graduate students develop both a disciplinary and a research identity. Hall and Burns (2009) argued that research identity is a substantial aspect of graduate identity and that engineering graduate students develop a distinct identity as a researcher apart from any disciplinary identity as an engineer. Svyantek and McNair (2015) described the multiple professional identities that engineering doctoral students develop during their programs, including research and teaching. Rogers and Goktas (2010) reported that engineering graduate students develop their research knowledge

and skills over the years, and those skills are highly related to their educational performance. Burt (2014) observed that engineering graduate students develop their identities through research experiences during their graduate programs, finding that engineering students' disciplinary identity development is influenced by several factors including perceived performance/competence in engineering and research, and collaborations with other research group members.

Other prior studies strongly suggest that the framework of performance/competence, interest and recognition may apply to research identity as well as engineering identity. According to Richardson (2006), graduate students' research identity can be developed in two ways: performing as a researcher (performance/competence) and being recognized as a researcher (recognition). Svyantek et al. (2015) explained that one result of having a strong research identity is demonstrating specific research skills in the discipline (performance/competence). Borrego et al. (2018) found that engineering undergraduates with higher research self-efficacy (similar to research performance/competence) were more likely to express interest in graduate study. Corte and Levine (2002) argued that research identity is highly related to one's research interests. Indeed, two independent prior studies present evidence that performance/competence, interest, and recognition related to research are relevant factors in studying engineering graduate student identity (Choe, Borrego, Martins, Patrick, & Seepersad, 2017; Perkins et al., 2018). In one of these studies, Perkins et al.'s (2018) separate exploratory factor analysis (EFA) on research-related items only yields factors for performance/competence, interest and recognition. In our own prior work, we ran a combined EFA of engineering disciplinary and research items, which yielded an additional factor that we named interpersonal skills competence as a part of professional skills competence (Choe et al., 2017).

### **2.3 | Interpersonal skills competence**

A final construct in our model of engineering graduate student identity is interpersonal skills competence as a part of professional skills competence. In the interviews we used to develop the current survey, skills such as collaboration and communication were cited several times, but as relevant to success in both researcher and engineer roles. We created items to address interpersonal skills competence specifically, and we found that at least some of these items factored separately from engineering and research performance/competence items (Choe et al., 2017). We acknowledge that interpersonal skills competence may be only one factor that links both engineering identity and research identity. Rogers and Goktas (2010) found that engineering graduate students perceived that both oral and written communication skills are important components for conducting their research work. Similarly, engineering graduate students indicated that communication skills competence is an important aspect for engineers (Choe & Borrego, 2019). Prior work has developed a scale to measure affect toward professional aspects of engineering identity among undergraduates (Patrick et al., 2017) and found that this professional scale explained an additional 18% of engineering identity over models considering only engineering performance/competence, interest and recognition (Choe et al., 2019). While interpersonal skills are only one aspect of professional skills, this prior result is compelling support for including interpersonal skills in a model of graduate engineering identity.

## **3 | METHODS**

### **3.1 | Overview**

We surveyed 249 engineering doctoral and thesis master's students about their graduate engineering identities, personal characteristics, and interest in careers in industry, academia, and government. We used multiple imputations to account for missing data. We conducted exploratory factory analysis to measure graduate engineering identity constructs. We also used student characteristics items and identity factors to predict interest in industry, academia, and government separately. We then used cluster analysis to create groups of students who were considering multiple options in similar ways. Finally, we used ANOVA and chi-squared tests of independence to understand whether components of graduate engineering identity and the characteristics of the students in each cluster were significantly different from the other clusters.



### 3.2 | Participants

Participants were engineering graduate students at a large, research intensive, public university in the Southwestern United States. We chose the three departments with the highest graduate student enrollments, which also arguably represented diversity in terms of gender representation and alignment with industry, academia and government career options. The three departments were electrical and computer engineering, civil and environmental engineering, and mechanical engineering. A total of 249 engineering graduate students completed the survey. Based on the enrollment profile of the departments surveyed (ASEE, 2018), the overall response rate for this survey was 20.1%. Among 249 student participants, the gender breakdown was 194 (78%) men and 55 (22%) women, which is the same proportion of students enrolled in the targeted programs. Three quarters (73%,  $n = 183$ ) of the participants sampled were doctoral students, and 66 (27%) were thesis master's students. Doctoral students are slightly overrepresented in our sample compared to enrollment in the target programs (69%). Of the students surveyed, 99 students identified as U.S. citizens or permanent residents, 124 identified as international students, and 26 preferred not to answer regarding their nationality. Three engineering disciplines were included in the final sample, with 99 (40%) participants in electrical and computer engineering, 83 (33%) participants in civil or environmental engineering, and 67 (27%) participants in mechanical engineering. More than 90% of the graduate students surveyed held bachelor's degrees in engineering. Cluster analyses used all 249 participants' responses.

### 3.3 | Measures

We generated and adapted a total of 74 items from previous research: Sixty-seven 5-point Likert-scale items measuring independent and dependent variables and seven student characteristic questions. The independent variables are graduate engineering identity constructs, and the dependent variables are three items of student career preferences (i.e., industry, academia and government). The student characteristic questions included individual profiles (e.g., gender, nationality, current degree program) and experience related to engineering (e.g., bachelor's degree in engineering, engineering work, and internship experience).

### 3.4 | Multiple imputation

Missing data from more than 10% of participants can result in biased or inefficient estimates of parameters in statistical analyses (Bennett, 2001). In this study, more than 13% of participants had at least one item with missing data; thus, we conducted multiple imputation to address potential bias. Since the missing items regarded topics that were not particularly sensitive for participants to answer, we assumed that the missing data are missing at random, meaning the pattern of missing data can be predicted based on other variables in the data set. For all variables with missing values, the multiple imputation model included student characteristic variables (e.g., gender, degree program, work experience, bachelor's degree in engineering) and all three dependent variables (Moons, Donders, Stijnen, & Harrell Jr, 2006). We used the multivariate normal distribution method (Allison, 2010; Enders, 2010; Graham, 2009). Any missing Likert scale items and participant characteristics variables (e.g., nationality, internship experience) were imputed to reduce bias in the results of EFA, correlation, and regression analyses. We followed White, Royston, and Wood's (2011) suggested "rule of thumb that the number of imputations should be at least equal to the percentage of incomplete cases" (p. 388). Thus, 13 imputed data sets were created for this multiple imputation.

### 3.5 | Dependent variables

We used three items to measure engineering graduate students' likelihood of pursuing careers in industry, academia or government. The question stem read, "How likely are you to pursue each of the following career options after graduation?" We worded the industry item as "profit sector (industry) engineer," the academia item as "college professor/post-doctoral researcher," and the government item as "government engineer, e.g., at a national lab." Participants responded using 5-point Likert-type scales in which 1 corresponded to "definitely no" and 5 to "definitely yes."

### 3.6 | Independent variables

To capture student characteristics, we asked participants their gender, nationality, engineering discipline, degree program (master's without thesis, master's with thesis, or PhD), whether they held an engineering bachelor's degree, and details of work experience in engineering prior to graduate study as well as internship experience during graduate study.

The remaining 38 items measured graduate engineering identity constructs. Table 1 lists the eight factors, the number of items comprising each factor, the internal consistency measured by Cronbach's  $\alpha$ , and an example item. All Cronbach's  $\alpha$  values are larger than .70, which indicates each factor is within the acceptable internal consistency range (Brace, Kemp, & Snelgar, 2012). The full list of items with factor loadings is included in the appendix.

To develop these items, we used the following procedures. We adapted disciplinary engineering identity items from Godwin et al. (2016) and Prybutok et al. (2016) and research interest, recognition, and performance/competence items from Bieschke, Bishop, and Garcia (1996). Interviews with graduate students, faculty members and practicing engineers with graduate degrees informed our adaptation of the graduate engineering identity items as well as expert review of the items by engineering education researchers, graduate students and PhD engineers. In previous work, we piloted these items with engineering graduate students, submitting their responses to exploratory factor analyses (Choe et al., 2017). We then revised items as described in detail below and ran a second round of EFA on the current data. For both rounds of EFA, we used the Principal Axis Factoring (PAF) extraction method and Oblique (nonorthogonal) rotation. PAF is appropriate for relatively simple factor patterns and interpretations (Loewen & Gonulal, 2015). We conducted Promax (nonorthogonal) rotation since the factors could be inter-correlated with one another (Velicer & Jackson, 1990). We eliminated items with either significant cross-loadings higher than .32 on multiple factors or initially low factor loadings of less than .40. Based on considerations of face validity and internal consistency of factors, we raised the final factor loading cutoff to .45 for all items (Field, 2009). Among 67 Likert-scale items, three items were used for the dependent variables, and the remaining 64 items were reduced to 38 items for the current study after several iterations of EFA yielded an eight-factor solution, presented in the appendix (Child, 1990; Field, 2009).

Specific changes to items based on EFA of pilot survey data are as follows. In the pilot study EFA (Choe et al., 2017), none of the engineering or research recognition items emerged as a factor (separately or combined). We believe recognition factors did not emerge because they were based on items originally written for first-year undergraduates that focus on relationships with family members and instructors and were adapted to focus on faculty advisors and peers. We added items to include recognition by family, friends and "other students in my program" as well as having an engineering undergraduate degree (this item was specific to engineering recognition). These new items resulted in a separate disciplinary engineering recognition factor and a research recognition factor in the current analysis (Table 1).

Based on the items, we labeled and described each factor as follows. *Research performance/competence* captures engineering graduate students' perceptions of their research abilities, knowledge, and skills relevant to conducting research. *Research interest* describes the interest level of graduate students in research topics, as well as their interest in learning about and working on research. *Research recognition* from others presents engineering graduate students'

**TABLE 1** Cronbach's  $\alpha$ , number of items, and example items for scales measuring independent variables

Variables	$\alpha$	Number of items	Example item
Disciplinary engineering performance/competence	.88	6	Building and testing systems to learn more about how they work
Disciplinary engineering interest	.91	7	I think engineering is interesting
Disciplinary engineering recognition	.89	5	Other students in my program see me as an engineer
Research performance/competence	.86	5	Understanding and applying scientific and mathematical relationships based on the conditions
Research interest	.91	3	I am interested in my research topic
Research recognition	.86	4	My peers view me as a researcher
Interpersonal skills competence	.80	5	Communicating verbally, for example in discussion with others
Advisor support	.78	3	My advisor gives positive feedback on my research work

perceptions of how others (e.g., advisor, peers, friends, family members) acknowledge their research identity. *Disciplinary engineering performance/competence* captures engineering graduate students' perceptions of their engineering abilities, knowledge, and skills relevant to engineering projects. *Disciplinary engineering interest* comprises engineering graduate students' interest in working on and learning about engineering. *Disciplinary engineering recognition* captures engineering graduate students' perceptions of how others (e.g., advisor, peers, friends, family members) acknowledge them as an engineer. *Interpersonal skills competence* includes graduate students' perception of their communication and collaboration knowledge, skills, and abilities. *Advisor support* captures engineering graduate students' perceptions of advisor feedback and assessment of their engineering and research work. The survey stem for the items measuring competence was "How competent are you with the following tasks?" Participants responded using 5-point Likert-type scales in which 1 corresponded to "not competent" and 5 represented "highly competent." The survey stem for items measuring interest or recognition was "To what extent do you disagree or agree with the following statements?" Participants responded using Likert-type scales in which 1 corresponded to "strongly disagree" and 5 to "strongly agree."

### 3.7 | Data collection

Graduate coordinators in electrical and computer, civil and environmental, and mechanical engineering distributed an email survey invitation to all current graduate students in these programs. The graduate students responded to surveys via Qualtrics, an online survey application. Each graduate coordinator sent three email invitations or reminders over several weeks during Spring Semester 2018. Students who participated in the survey were entered into a drawing for one of five \$50 gift cards. The online survey form began with participants giving informed consent. Marking "yes" on the consent form allowed the participant to proceed to the survey.

### 3.8 | Data analysis: Multiple linear regression models

We utilized IBM SPSS® 24 for cluster analysis (IBM Corp., 2016) and Stata Statistical Software: Release 15 (StataCorp., 2017) for all other analyses. To address Research Question 1, we created three sets of sequential multiple linear regression models to identify which student characteristics and independent variables significantly predicted the three dependent variables of engineering graduate students' likelihood of pursuing careers in industry, academia, and government.

Prior to the regression analysis, we conducted several tests of linear regression assumptions such as normality, linearity, and homoscedasticity. We used histograms, scatter plots, and quantile–quantile plots to confirm these assumptions were met. We calculated variance inflation factors (VIF) to detect multicollinearity in regression models. All VIF coefficients were less than two, below the cut-off value of 10 (Hair, Black, Babin, & Anderson, 2009), meaning there were no multicollinearity issues in the regression models. We also conducted bivariate correlation to find correlation among independent and dependent variables (see Table 3).

Each sequential regression analysis included the same two steps to predict each of the dependent variables. In the first step, we ran a baseline model of student characteristics including gender, nationality, engineering discipline (electrical/computer, civil/environmental, and mechanical engineering), current degree program (PhD and thesis master's), obtained bachelor's degree in engineering degree, full-time work experience in engineering prior to graduate study, and internship experience during graduate study. In the second step, we added the seven graduate engineering identity factors from Table 1 (excluding advisor support) in a combined model.

We dummy-coded all student characteristics variables to convert categorical variables to dichotomous except the year in program. The year in program was a range from 1 indicating first year to 7 indicating seventh year. Table 2 shows how student characteristics were dummy coded.

### 3.9 | Data analysis: Cluster analysis

To answer Research Question 2, we conducted a two-step cluster analysis. While some engineering graduate students may consider only one career option, it is more reasonable to expect that some students have multiple career preferences (Reis, 1997). To more accurately describe the different focus of career planning for engineering graduate students, we created several clusters of students who have similar likelihood of future careers in industry, academia and



**TABLE 2** Dummy coded student characteristics

Student characteristic	Reference group	Other group(s)
Gender	Male	Female
Nationality	Domestic students (U.S. citizen or permanent resident)	International students
Obtained bachelor's degree in engineering	Students without an engineering bachelor's degree	Students who hold an engineering bachelor's degree
Engineering work experience prior to graduate program	Students without work experience	Students with work experience
Internship experience during graduate program	Students without internship experience	Students with internship experience
Engineering discipline	Electrical and computer engineering	Civil and environmental engineering; mechanical engineering
Engineering graduate program	PhD	Master's with thesis

government. Cluster analysis is a way to assign participants to a specific classification based on their pattern of dependent variables (Norušis, 2012). In other words, cluster analysis is a useful method for identifying homogenous groups of participants, cases, or observations named clusters (Sarstedt & Mooi, 2014). The goal of cluster analysis is to identify groups of individual participants that are related to one another and unrelated to individual participants in other groups (Norušis, 2012). In this study, we wanted to identify clusters that group students with similar career preferences to one another and different career preferences from other students. In the cluster analysis, we included the three likelihood of careers in industry, academia, and government variables. Although discrete clusters may not capture the continuum of career preferences, it is a method for better understanding students' certainty about one sector in relation to others, particularly since the topic of the career sector interests of engineering graduate students has not been previously studied in depth. Among several different types of cluster analysis, we conducted two-step cluster analysis over K-means or hierarchical clustering because we were exploring the number of clusters and the three variables have continuous characteristics (Sarstedt & Mooi, 2014).

Two-step cluster analysis includes two stages. The first stage is similar to the K-mean cluster algorithm, which is not based on distance measurement but on how objects are homogenous within each cluster. The second stage involves a modified hierarchical cluster algorithm. This second stage combines objects sequentially to shape homogenous clusters (Mooi & Sarstedt, 2011). IBM SPSS Statistics software (IBM Corp., 2016) determined the optimal number of clusters by calculating the Bayesian Information Criterion (BIC) value. Fraley and Raftery (1999) described BIC as the ratio of changes in the distance at each merge. The optimal number of clusters is estimated based on the step where the largest jump in BIC value is observed (Chiu, Fang, Chen, Wang, & Jeris, 2001). In this study, the suggested optimal number of clusters was four.

Among various ways to measure the overall goodness-of-fit measure of a cluster solution, we selected a two-step clustering Silhouette coefficient measure of cohesion and separation. The measure is based on the average distance between objects. It measures whether the elements within a cluster are homogenous to one another and whether each cluster is different from the other clusters. In other words, the Silhouette coefficient indicates whether the students' career interest in industry, academia, or government are similarly grouped within one cluster as well as whether the cluster is different from other clusters. The measurement ranges are between  $-1$  and  $1$ . In a good solution, the distances within a cluster are small and the distances between clusters are large, resulting in a Silhouette coefficient value close to  $1$ . A Silhouette coefficient less than  $.20$  is poor, between  $.20$  and  $.50$  is fair, and more than  $.50$  is good (Sarstedt & Mooi, 2014). In this study, the Silhouette measure was  $.40$ , which is in the fair range of cluster quality. We computed the BIC values for each potential number of clusters. Three criteria need to be considered in optimizing a cluster solution: the smallest BIC value, a large ratio of distance measures, and a large ratio of BIC changes. In this study, the BIC value ( $402.15$ ) of the 4-cluster solution was the second smallest compared to the BIC value ( $400.73$ ) of the 5-cluster solution. However, the 4-cluster solution had the largest ratio of distance measures ( $1.743$ ) and had a larger ratio of BIC changes ( $.31$ ) compared to the 5-cluster solution. Therefore, we chose the 4-cluster solution for this study.

### 3.10 | Data analysis: ANOVA and chi-squared test of independence

To answer Research Question 3, we conducted two types of tests to understand whether responses of the students in each cluster differed significantly from the other clusters. To compare means of the components of graduate engineering identity, we used ANOVA. To compare student characteristics that were categorical, we used chi-squared tests of independence. If the chi-squared test of independence was significant, we also reported the relationship between expected and observed value combinations of cluster and student characteristic variables with chi-squared standardized residuals larger than 2 because these combinations contribute to the chi-squared test significance (Sharpe, 2015). To reduce the risk of Type I error resulting from several iterations of chi-squared tests of independence, we used a Bonferroni correction to lower the  $p$ -value to .0083. We calculated the new  $p$ -value by dividing an  $\alpha$  of .05 by the total number of chi-squared tests.

### 3.11 | Limitations

We acknowledge several limitations. We conducted this study with students in three engineering disciplines at a single institution, and different engineering disciplines might emphasize career preferences differently. We have provided details about the institution and the students enrolled in the programs to help readers judge transferability of the results to other settings, and we note that most engineering PhDs in the United States are trained at research institutions. Although this study is relatively unique in its inclusion of master's students, there was not a good control for students earning a master's degree en route to a PhD. We asked students in which degree program they were currently enrolled, with no option to indicate whether master's students intended (or had been admitted) to complete a PhD before entering the workforce. The wording of the academia item as "college professor/postdoctoral researcher" would have been better worded without postdoctoral researcher since 12% of engineering postdoctoral researchers work in government and less than 4% are in industry (based on our own analysis of Survey of Earned Doctorates cohorts completing PhDs 2006–2017, National Center for Science and Engineering Statistics, n.d.). However, our cognitive interview piloting of the survey led us to conclude that participants may interpret this item as indicating an interest in an academic career, and the National Academy of Engineering (2014) emphasizes that postdoctoral positions are widely viewed as a stepping stone to a tenure-track faculty position. Academic career paths additionally encompass a wide variety of permanent employment options, including researcher and instructor positions and faculty positions in 2-year colleges, baccalaureate, and master's institutions. These distinctions were not captured by the current survey. Finally, government career opportunities and survey items may be interpreted very differently by students depending on their citizenship. The wording of our survey items did not allow for students to indicate plans for entering the workforce in one sector with plans to change to another later. Similarly, the discrete groups generated by cluster analysis may not effectively describe the continuum of career sector preferences. Fit statistics indicate that the regression models and cluster analyses presented here were acceptable but not particularly strong, suggesting that additional factors not captured in this study contribute to graduate students' interest in industry, academic, and government careers. Nonetheless, this study is an important first step in understanding industry, academia and government career interests of engineering graduate students, and it identifies several nuances to be considered in future work.

## 4 | RESULTS

### 4.1 | Bivariate correlation

We calculated bivariate correlations to investigate relationships between career preferences and the independent variables comprising graduate engineering identity. The results of the correlation analysis are presented in Table 3. As a test of construct validity, we calculated bivariate correlations among independent variables. All bivariate correlation coefficients were less than .70, indicating the constructs of each independent variable did not overlap with one another at a problematic level (Meyers, Gamst, & Guarino, 2006). The significance level of correlation is  $\alpha = .01$ . The correlation results between dependent variables revealed that the likelihood of pursuing a career in industry had a significantly negative correlation with the likelihood of pursuing a career in academia ( $r = -.44$ ). There was a positive correlation

**TABLE 3** Bivariate correlation between dependent and independent variables

Variables	1	2	3	4	5	6	7	8	9	10	M	SD
1. Career in industry	1										3.94	.86
2. Career in academia	-.44*	1									3.50	1.12
3. Career in government	-.05	.22*	1								3.38	1.05
4. Disciplinary engineering performance/competence	.19*	-.09	-.04	1							3.54	.79
5. Disciplinary engineering interest	.02*	.11*	.03	.19*	1						4.35	.75
6. Disciplinary engineering recognition	.14*	-.01	-.01	.26*	.54*	1					4.18	.85
7. Research performance/competence	-.12*	.17*	.06	.40*	.21*	.21*	1				3.89	.72
8. Research interest	-.08	.23*	.09	.13*	.42*	.38*	.32*	1			4.22	.93
9. Research recognition	-.08	.26*	.11*	.22*	.31*	.43*	.43*	.54*	1		4.21	.90
10. Interpersonal skills competence	.01	-.01	.13*	.30*	.24*	.28*	.49*	.14*	.23*	1	3.97	.56
11. Advisor support	.07	.05	.03	.26*	.49*	.62*	.31*	.63*	.56*	.29*	4.21	.80

\* $p < .01$ .

between likelihood of pursuing career in academia and government ( $r = .22$ ), but due to low coefficients (below .30), two the variables are not highly correlated. There was no significant correlation between government and industry.

Overall, the correlations between dependent and independent variables have relatively low coefficients (below .30). Among eight independent variables, advisor support has no significant correlation with any of the dependent variables. Thus, we excluded advisor support from regression modeling and included only the other seven independent variables as predictors in them.

## 4.2 | Multiple linear regression models

Table 4 presents the regression models for predicting graduate students' likelihood of pursuing careers in industry, academia, and government. For the first two columns predicting industry, Model 1 shows that graduate student characteristics explain 4.6% of the variance in likelihood of pursuing a career in industry. Having an internship during graduate study ( $\beta = .141, p < .05$ ) significantly predicted pursuing a career in industry, while being female was a negative predictor ( $\beta = -.171, p < .05$ ). In Model 2, we added the seven independent variables of graduate engineering identity. A total of 8.5% of variance was explained by Model 2. Graduate engineering identity variables explained an additional 3.9% of variance in pursuing a career in industry. In this model, among the seven independent variables, disciplinary engineering performance/competence ( $\beta = .183, p < .05$ ) was a significant positive predictor of pursuing a career in industry. Among significant student characteristics variables in Model 1 only Female remained significant in Model 2.

Models 3 and 4 predict likelihood of a career in academia. Model 3 indicates that student characteristics explain 17.7% of the variance. Master's students with thesis ( $\beta = -.313, p < .001$ ) were less likely than doctoral students to express interest in an academic career. Being an international student ( $\beta = .231, p < .001$ ) significantly predicted interest in an academic career. In Model 4, graduate engineering identity variables explained an additional 7.4% of variance in pursuing career in academia, while a total of 25.1% of variance was explained. Among the seven identity variables, three variables significantly predicted likelihood of pursuing a career in academia. Research performance/competence ( $\beta = .160, p < .05$ ) and research recognition ( $\beta = .178, p < .05$ ) were significant positive predictors, while disciplinary engineering performance/competence ( $\beta = -.137, p < .05$ ) was a significant negative predictor. All student characteristic variables that were significant in Model 3 remained significant in Model 4, and year in program ( $\beta = -.133, p < .05$ ) became a significant predictor in Model 4.

Models 5 and 6 predict interest in a career in government. Model 5 indicates that graduate student characteristics explain 2.2% of the variance. The F test of Model 5 was not significant, indicating that none of the student characteristics significantly predicts likelihood of a career in government. In Model 6, identity independent variables explained an additional 6.2% of variance in pursuing a career in government, while a total of 8.4% of variance was explained by this model. Research Recognition ( $\beta = .239, p < .01$ ) was a significant positive predictor of pursuing a career in government,

**TABLE 4** Results of multiple linear regressions with independent variables

Variables	Industry		Academia		Government	
	Model 1 $\beta$	Model 2 $\beta$	Model 3 $\beta$	Model 4 $\beta$	Model 5 $\beta$	Model 6 $\beta$
<i>Student characteristics</i>						
Female	-.171*	-.153*	-.056	-.064	-.073	-.081
International	.106	.146	.231***	.187**	-.002	-.088
Civil/environmental	-.047	-.011	.148	.093	.185*	.173*
Mechanical	.031	.064	.047	-.013	.176*	.129
Thesis master's	.100	.045	-.313***	-.272***	.084	.124
B.S. degree in engineering	.024	.017	-.046	-.020	-.075	-.042
Work experience	-.076	-.054	.117	.081	.024	-.002
Internship	.141*	.122	-.070	-.046	-.043	-.018
Year in program	.040	.028	-.114	-.133*	.139	.117
<i>Graduate Engineering Identity Scale</i>						
Disciplinary engineering		.183*		-.137*		.009
Performance/competence						
Disciplinary engineering interest		.080		-.055		.059
Disciplinary engineering recognition		.111		-.029		-.238**
Research performance/competence		-.117		.160*		.058
Research interest		-.047		.148		.085
Research recognition		-.136		.178*		.239**
Interpersonal skills competence		.105		-.014		-.050
Adj. R <sup>2</sup>	.046	.085	.177	.251	.022	.084
Adj. $\Delta$ R <sup>2</sup>	—	.039	—	.074	—	.062
F test	2.22*	2.26**	6.53***	5.654**	1.78	2.12**

Note: All terms are standardized regression coefficients. Adj. R<sup>2</sup> = adjusted R-squared, Adj.  $\Delta$  R<sup>2</sup> = change in adjusted R-squared.

\* $p < .05$ ; \*\* $p < .01$ ; \*\*\* $p < .001$ .

while disciplinary engineering recognition ( $\beta = -.238$ ,  $p < .01$ ) was a significant negative predictor of pursuing a career in government. In terms of characteristics, civil/environmental engineering students ( $\beta = .173$ ,  $p < .05$ ) were more likely than electrical/computer engineering students to indicate pursuing a career in government. We conducted F tests, which indicate that all models are significant except Model 5.

#### 4.3 | Cluster analysis for likelihood of career preferences

Since engineering graduate students may entertain multiple career preferences simultaneously, we employed two-step cluster analysis to characterize their likelihood of pursuing industry, academia, and government careers. The cluster analysis revealed that the career preferences of the engineering graduate students in this study can be categorized into four groups. We assigned descriptive if unwieldy names to these clusters by assigning high (mean  $> 4.0$ ), middle ( $4.0 > \text{mean} > 3.0$ ) and low (mean  $< 3.0$ ) designations to industry, academia, and government. Table 5 presents details of the clusters, including means and standard deviations for industry, academia, and government, as well as the independent variables. Table 5 shows the frequency and percentage of student characteristics in each cluster.

Cluster 1 is labeled “LowIND/HighACA/MidGOV” to reflect the preference for academia (mean = 4.25 on a 5-point scale) over government (mean = 3.42) and industry (mean = 2.55). This cluster is the smallest of the four. All other clusters had high interest in industry careers. Cluster 2 is labeled “HighIND/MidACA/LowGOV” to reflect the

**TABLE 5** Cluster analysis results, graduate engineering identity variables

	Cluster				
	Cluster 1 LowIND/HighACA/ MidGOV ( <i>n</i> = 55) mean ( <i>SD</i> )	Cluster 2 HighIND/MidACA/ LowGOV ( <i>n</i> = 68) mean ( <i>SD</i> )	Cluster 3 HighIND/LowACA/ MidGOV ( <i>n</i> = 70) mean ( <i>SD</i> )	Cluster 4 High for all ( <i>n</i> = 56) mean ( <i>SD</i> )	Total ( <i>n</i> = 249) mean ( <i>SD</i> )
Industry	2.55 (.63)	4.21 (.53)	4.36 (.59)	4.25 (.44)	3.89 (.91)
Academia	4.25 (.78)	3.22 (.90)	2.16 (.69)	4.30 (.50)	3.39 (1.15)
Government	3.42 (.67)	2.28 (.67)	3.76 (.96)	4.07 (.69)	3.35 (.99)
Disciplinary engineering interest	4.28 (.59)	4.26 (.76)	4.37 (.48)	4.34 (.58)	4.31 (.61)
Disciplinary engineering performance/competence	3.48 (.81)	3.71 (.71)	3.78 (.69)	3.78 (.74)	3.69 (.74)
Disciplinary engineering recognition	4.06 (.70)	4.15 (.67)	4.12 (.66)	4.10 (.63)	4.11 (.66)
Research interest	4.22 (.82)	3.97 (.97)	4.17 (.75)	4.32 (.61)	4.16 (.81)
Research performance/ competence	3.91 (.69)	3.84 (.70)	3.80 (.68)	3.97 (.70)	3.88 (.69)
Research recognition	4.18 (.80)	3.93 (.85)	4.01 (.61)	4.14 (.58)	4.05 (.73)
Interpersonal skills competence	3.96 (.67)	4.03 (.60)	4.09 (.57)	4.00 (.58)	4.02 (.60)
Advisor support	4.12 (.73)	4.02 (.76)	4.11 (.63)	4.07 (.74)	4.08 (.71)

Note: Means are based on items with Likert scales of 1 to 5 with 5 = strongly agree. High scores = those above 4.0; mid score = those between 3.0 and 4.0; low scores = those below 3.0.

preference for an industry career (mean = 4.21) over academia (mean = 3.22) and government (mean = 2.28). Cluster 3, “HighIND/LowACA/MidGOV,” indicates a strong preference for industry (mean = 4.36) over academia (mean = 2.16) and moderate preference government (mean = 3.76). Cluster 4 is labeled “High for all” to reflect the strong preference for all three careers: industry (mean = 4.25), academia (mean = 4.30), and government (mean = 4.07).

#### 4.4 | Data analysis: ANOVA and chi-square test of independence

ANOVA tests of the means presented in Table 5 indicate there is no significant difference between components of graduate engineering identity and cluster membership. In other words, students' mean responses on components of graduate engineering identity are similar across the various profiles of engineering graduate students' career interests.

Chi-squared tests of independence indicated that several of the student characteristics reported in Table 6 are significantly different across the four clusters. First, nationality is significantly different,  $\chi^2(3) = 26.51, p = .000$ . Domestic students are overrepresented in Cluster 3 (HighIND/LowACA/MidGOV) and underrepresented in Cluster 4 (High for all). Correspondingly, international students are underrepresented in Cluster 3 and overrepresented in Cluster 4. Second, master's and PhD students are not evenly distributed across the clusters,  $\chi^2(3) = 16.63, p = .001$ , because master's students are overrepresented in Cluster 3 (HighIND/LowACA/MidGOV). Third, electrical/computer engineering students are overrepresented in Cluster 2 (HighIND/MidACA/LowGOV), and mechanical engineering students are overrepresented in Cluster 3 (HighIND/LowACA/MidGOV),  $\chi^2(6) = 19.49, p = .003$ . Finally, students who had internship experience during their graduate study are underrepresented in Cluster 1 (LowIND/HighACA/MidGOV), which is the only cluster without a mean industry interest above 4.0,  $\chi^2(3) = 11.80, p = .008$ . Although the chi-squared test of gender with cluster appeared significant ( $\chi^2(3) = 8.40, p = .038$ ), after applying the Bonferroni correction, gender is no longer significant. There was no significant association between work experience prior to graduate program and the four clusters.



**TABLE 6** Cluster analysis results, student characteristics with chi-square tests

		Cluster					Chi-square tests		
		Cluster 1 LowIND/ HighACA/ MidGOV (n = 55)	Cluster 2 HighIND/ MidACA/ LowGOV (n = 68)	Cluster 3 HighIND/ MidGOV/ LowACA (n = 70)	Cluster 4 High for all (n = 56)	Total (n = 249)	df	Value	p
Gender	Female	31%	24%	24%	9%	22%	3	8.40	.038
	Male	69%	76%	76%	91%	78%			
Nationality	International	48%	66%	34%	80%	56%	3	26.51	.000*
	Domestic	52%	34%	66%	20%	44%			
Program	Doctoral	76%	81%	56%	84%	73%	3	16.63	.001*
	Thesis master's	24%	19%	44%	16%	27%			
Major	Electrical/ computer	27%	56%	33%	41%	40%	6	19.49	.003*
	Civil/ environmental	47%	26%	27%	36%	33%			
	Mechanical	25%	18%	40%	23%	27%			
Internship experience	Yes	24%	54%	36%	44%	40%	3	11.80	.008*
	No	76%	46%	64%	56%	60%			
Work experience	Yes	35%	31%	21%	36%	30%	3	3.88	.275
	No	65%	69%	79%	64%	70%			

Note: Nationality—Sample size of Cluster 1, 2, 3, 4, and total are 52, 62, 64, 45, and 223 respectively. Internship experience—Sample size of Cluster 1, 2, 3, 4, and total are 54, 67, 69, 54, and 244.

\*Chi-square of independence test was significant with Bonferroni correction.

## 5 | DISCUSSION

We utilized several analyses—multiple linear regression models, cluster analysis, ANOVA, and chi-squared tests of independence—to understand master's and doctoral students' career preferences for industry, academia, and government. First, we ran separate multiple linear regression models for each employment sector, but the models explained less than 10% of the variance in students' likelihood of pursuing a career in industry or government. The model for academia explained 25.1% of the variance. To account for the possibility that students are considering multiple options simultaneously, we next conducted cluster analysis. Four clusters emerged. While Cluster 1 had a strong preference for academia over industry, the other three clusters indicated students had a strong interest in industry. All 249 students in the sample were placed into a cluster, and no students were placed in multiple clusters. We ran ANOVA and chi-squared tests of independence to identify differences among the clusters. There were no significant differences among clusters in graduate engineering identity variables, but several student demographic characteristics were significantly different among career preference clusters.

Research Question 1 focused on the student characteristics and components of graduate engineering identity that predict engineering graduate students' career preferences toward industry, academia, and government. Since the industry and government models predicted less than 10% of the variance, these models will not be discussed separately in detail. The model predicting interest in an academic career, however, described 25.1% of the variance and is, therefore, more informative. In this model, three graduate engineering identity variables were significant predictors: Research recognition, research performance/competence, and engineering disciplinary performance/competence (negative predictor). Doctoral (vs. master's) students and those who identified as international (vs. domestic) were more likely to indicate higher likelihood of an academic career. Year in program was a negative predictor, suggesting that students may abandon initial plans for an academic career as they progress through their graduate programs.

Taken together, the results of the three regression models suggest a positive relationship between engineering disciplinary identity variables and industry career interest and a correspondingly negative relationship of engineering disciplinary identity with academic and government career interest. Specifically, engineering disciplinary performance/competence was the only significant identity-related predictor in the model of industry career interest, and it was a negative predictor in the model of academic career interest. Similarly, engineering disciplinary recognition was a significant negative predictor of likelihood of a career in government. Further, research identity variables were positive predictors of academic and government career interest but were not significant in the model of industry career interest. Research performance/competence was a positive predictor of likelihood of a career in academia, and research recognition was a positive predictor of likelihood of a career in academia and in government. While the models for industry and government career interest were not particularly strong, the results collectively suggest an intriguing direction for future work to explore the extent to which engineering disciplinary identity aligns with industry career paths and research identity with academic and government career paths.

The positive relationship among research recognition, research performance/competence and academic careers is consistent with the findings of prior studies. Mosyjowski, Daly, Peters, Skerlos, and Baker (2017) found that engineering students returning from full-time industry experience who have a goal of working in academia or government were more likely to express interest in conducting research as a part of their PhD training. Roach and Sauermann (2010) found that engineering and science doctoral students who preferred an industry career path had less interest in research aspects and a greater concern for access to cutting-edge technology than students who preferred academia. Conti and Visentin (2015) reported that PhD engineers and scientists who were employed in academia in Switzerland published significantly more articles during their PhD training compared to those who were employed in industry.

There is substantially less prior work with which to compare the negative relationship between engineering disciplinary performance/competence and likelihood of pursuing an academic career. The association of strong disciplinary engineering identity with pursuit of an industry career is consistent with Roach and Sauermann's (2010) finding that these students are particularly interested in access to cutting edge technology. However, this may be the first study to show that engineering disciplinary identity factors have a negative relationship with academic career preferences. Students' identification with engineering depends on their perceptions of the engineering profession, which for graduate students would be based on their educational and work experiences. Most of the students in this sample hold undergraduate engineering degrees and have limited professional work experience. It is possible that they are basing their perceptions of engineering identity on undergraduate programs which emphasize bachelor's level industry work since that is the career path of the majority of engineering undergraduates.

Research Question 2 led to cluster analysis combining the likelihood of academic, industry, and government careers. Among the most important results of this study is that cluster analysis indicates that most engineering graduate students are keeping their options open. All four clusters featured high interest in at least one sector, corresponding to a mean of "yes" to "definitely yes," and medium (or higher) interest in another sector, corresponding to "yes." Three clusters indicated a clear ordering of sectors, for example, high industry, medium academia, and low government (Cluster 2), while the fourth indicated high interest in all three sectors. That engineering graduate students are keeping multiple career options open is appropriate given the decreasing likelihood of new engineering graduates landing tenure-track faculty positions (Austin, 2010; Fiegener, 2010). This study demonstrates empirically that most engineering doctoral students are seriously considering careers in industry and government, while most prior studies focus on doctoral students' interest in faculty positions. We were surprised at the extent to which students were considering multiple options, suggesting discrete clusters may not be the most appropriate means of describing engineering graduate students' career preferences.

Research Question 3 asked what differences in the graduate engineering identity variables and student characteristics among the clusters were statistically significant. There were no significant differences in the graduate engineering identity variables. Chi-squared tests of independence indicated that several student characteristics were significant and warrant discussion.

Students with internship experience during graduate study were underrepresented in Cluster 1, which is the only cluster without high interest in an industry career. It is not clear from these data whether internships increase interest in an industry career or whether students already interested in industry pursue internship experiences. This result is more promising support for how engineering graduate programs are preparing students for multiple career paths, as recommended by the recent National Academies report on STEM graduate education (National Academies of Sciences, Engineering and Medicine, 2018). We also note that in the regression models of likelihood of an industry career, internship experience was initially significant (Model 1) but was no longer significant after the addition of identity

variables—specifically engineering disciplinary performance/competence (Model 2). Again, whether internships strengthen disciplinary engineering identity or are sought by students with stronger engineering identities is unclear, but this study suggests a relationship between work experience and identity worth exploring in future work.

Master's students were overrepresented in Cluster 3, which had a low mean for likelihood of an academic career. Typically, there are fewer (or at least fewer commonly discussed) employment opportunities in academia for those with terminal engineering master's degrees, and it is possible that students interpreted this item to refer primarily to tenure-track faculty positions at research institutions like theirs. This result is similar to the American Chemical Society's (2013) finding that doctoral students surveyed were more likely to be interested in becoming a professor compared to master's students. Chemistry master's students were more likely than doctoral students to want to work in government or educational administration/management, university research, or industry (American Chemical Society, 2013).

U.S. domestic students were overrepresented in Cluster 3 (high industry, low academia, medium government) and underrepresented in Cluster 4 (high industry, high academia, and high government), and international students were correspondingly overrepresented in Cluster 4 and underrepresented in Cluster 3. This result may indicate that international students are keeping more options open. Due to their legal status in the United States, international students would be less certain about employment opportunities in the United States and are likely expanding their career preferences to consider other countries. Employment opportunities may also vary considerably for international students, depending on their country of citizenship and whether their government is funding their graduate education with the expectation they will return home after completing their degree.

Electrical/computer engineering graduate students were overrepresented in Cluster 2, and mechanical engineering students were overrepresented in Cluster 3. Both clusters feature high likelihood of a career in industry. Cluster 2 features academia as medium likelihood and government as low, while Cluster 3 has a low likelihood for academia and medium for government. This result may be characteristic of the institution, including local industry or other underlying characteristics of the student populations, and should be studied further before conclusions are drawn.

## 6 | IMPLICATIONS

These findings reinforce the message that graduate education should be reformed to prepare students for a broad range of potential careers (National Academies of Sciences, Engineering and Medicine, 2018). Most engineering graduate students are keeping several options open. We do not know from these data whether students are being realistic about an unpredictable job market (Reis, 1997; Roach & Sauermann, 2010; Thiry et al., 2007), are genuinely undecided, or have sequential plans (i.e., industry experience before a faculty position), none of which could be captured by our survey items. As suggested by their history and continued prevalence in the literature, professional development programs for graduate students typically focus on future faculty (e.g., DeNeef, 2002), and some are emerging to focus on future industry professionals. We would argue for these programs to include advice on deciding among different options or framing skills as useful in a wide range of careers instead of forcing students to choose a “track” for their professional development activities. Imagine PhD ([imaginephd.com](http://imaginephd.com)) is a model program that is focused on career development for humanities and social sciences. Internships are important but in some local settings may be discouraged for fear of disrupting students' degree progress. Again, it is not clear from these data whether graduate students self-select for an industry track before pursuing an internship or if the internship experience increases interest in an industry career. Nonetheless, removing any taboo associated with completing an industry internship as part of a thesis master's or doctoral engineering degree program would better prepare students for a wider and more realistic range of career options.

The factor analysis presented here provides insight into how engineering identity frameworks developed for undergraduates translate to the graduate level. As we and others have previously found (Choe & Borrego, 2019; Perkins et al., 2018), we were able to adapt engineering disciplinary performance/competence, interest, and recognition scales to the graduate level. This result was expected since 90% of our sample and 84% of recent engineering PhDs hold bachelor's degrees in engineering. However, this analysis also demonstrates that the framework of research performance/competence, interest, and recognition holds for doctoral and thesis master's engineering students. This result is again similar to Perkins et al.'s (2018) EFA of research-related items only. The current study expands this finding through a combined EFA, which demonstrates that disciplinary engineering and research identity items are distinct, and it includes master's students. Additionally, a professional skills factor emerged for skills identified (in interviews) as important to both research and disciplinary engineering success.

It is important to note that although these graduate engineering identity variables were not particularly strong predictors of graduate student preference for industry and government careers, they provided some insight into academic career interest as well as directions for future work. Specifically, research recognition, and research performance/competence were positive predictors of academic career interest, while engineering performance/competence was a negative predictor. Similarly, research recognition was a positive predictor of government career interest, and engineering disciplinary recognition was a negative predictor. Finally, engineering disciplinary performance/competence was a positive predictor of industry career interest. These are intriguing preliminary findings that may be explored in future work, specifically to understand the extent to which graduate students associate research with academic and government careers (but not necessarily industry careers) and why disciplinary engineering identity constructs would be negatively related to interest in academia.

The regression models of likelihood of pursuing careers in industry and government were less informative since each model described less than 10% of the variance. We were able to locate prior studies, which suggest that engineering graduate identity may predict persistence among engineering graduate students, but we found few studies that focus on master's or PhD recipients' career sectors and what may influence those decisions. Graduate education tends to be individualized based on close relationships with the advisor, strong influences at the program level (Golde, 2005), variations in access to professional development programs, and unique experiences arising from funding mechanisms (Borrego, Choe, Nguyen, & Knight, 2019), all of which can be difficult to account for in regression models. For example, graduate students may have access to industry or government professionals who serve as mentors or role models through sponsored projects or research centers with substantial participation from industry. We expect that when underlying factors are identified and measured that some of the student characteristics, which were significantly different across the clusters presented here, would no longer be significant in improved regression models. The limited predictive power of Models 1, 2, 5, and 6 may be reflective of the relative lack of attention in the literature and (we argue) in existing graduate professional development programs to understand what factors may influence interest in industry or government careers. In addition, we argue that academia, including tenure-track faculty positions, is the most valued career path in many graduate programs, and we emphasize academic career preference was more effectively explained using graduate engineering identity factors. The performance/competence, interest, and recognition identity theory may not be sufficient to capture career preferences that are less closely related to persistence in a major, such as industry or government. The personal and social components of Gee's multiple identity theory (2000) are a possible new direction to consider as well as different aspects of professional skills competence.

## **7 | FUTURE WORK**

Future work might seek to replicate and explain the preliminary finding that disciplinary engineering identity is related to industry career preference and research identity is related to academic and government career preferences. Related research might explore the perceptions and identities of undergraduate engineers interested in graduate study and whether they believe master's and doctoral degrees can prepare them for industry careers. Future work might explore additional influences on interest in industry and government careers, specifically by expanding beyond the performance/competence, interest, and recognition model of graduate engineering identity. Future work might also consider additional detail in career interests, for example, in terms of management, research or teaching job functions. Research focused on academic career paths may more carefully distinguish between various tenure-track and alternative options, gather data on pressures and messages students receive regarding faculty careers, and further explore the preliminary finding that engineering disciplinary performance/competence may be negatively correlated with academic career interest. Teaching identity may be particularly informative with respect to academic career preferences. Future research designs should accommodate changes in career sector over an engineer's career and in particular, whether some graduate students are considering their career options sequentially. Given the low percentage of PhD engineers who work in sectors other than industry, academia or government, qualitative research methods may be particularly appropriate for exploring interest in other sectors such as nonprofit.

## **8 | CONCLUSION**

This study provides additional insight into the extent to which engineering doctoral and thesis master's students are considering careers in industry, academia and government. Like most research studies, it raises more questions than it

answers. Our results show that engineering graduate students are keeping multiple options open. A substantial portion of engineering graduate students is more interested in industry or government careers than in academic careers (55% of our participants were placed in one of the two high industry interest clusters). The results support recent calls for broader professional preparation for engineering graduate students. More research is needed to understand their decisions and better prepare engineering graduate students for industry and government career paths.

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## APPENDIX

Exploratory factor analysis results for survey measures of the Graduate Engineering Identity Scale.

Factor	Survey items	Factor loading
Disciplinary engineering performance/competence	Building and testing systems to learn more about how they work	0.79
	Creating prototypes to test an idea	0.78
	Designing and conducting experiments to test an idea or learn more about a system	0.76
	Designing a system, a part/component of a system, or a process based on realistic constraints	0.61
	Identifying technical solutions that are as simple as possible	0.60
	Improving a design to make it more efficient (faster, better, cheaper)	0.52
Disciplinary engineering interest	I think engineering is fun	0.78
	I think engineering is interesting	0.76
	I like to figure out how things work	0.76
	I feel good when I am doing engineering	0.67
	I am interested in learning more about engineering	0.64
	I enjoy engineering activities as part of my work week	0.55
	I like doing engineering	0.54
Disciplinary engineering recognition	Other students in my program see me as an engineer	0.77
	My family sees me as an engineer	0.64
	My friends see me as an engineer	0.62
	My advisor expects me to continue my career as an engineer	0.56
	My peers view me as an engineer	0.52
Research performance/competence	Understanding and applying scientific and mathematical relationships based on the conditions	0.69
	Applying math and science concepts to make new systems/models	0.68
	Using calculations and equations to evaluate things	0.67
	Understanding derivations and equations in journal papers	0.64
	Understanding current research findings by using sufficient math, science or engineering knowledge	0.60
Research interest	I am interested in my research topic	0.85
	My current research topic aligns with my research interest	0.77
	I enjoy doing my current research	0.66
Research recognition	Other students in my program see me as a researcher	0.73
	My friends see me as a researcher	0.69
	My peers view me as a researcher	0.65
	My family sees me as a researcher	0.64
Interpersonal skills competence	Communicating verbally, for example in discussion with others	0.80
	Presenting my professional work to others	0.72
	Communicating my ideas in writing	0.61
	Working with people with different skills and interests	0.55
	Working collaboratively in teams	0.55

(Continues)

Factor	Survey items	Factor loading
Advisor support	My advisor gives positive feedback on my research work	0.79
	My advisor gives positive feedback on the engineering aspects of my work	0.76
	My advisor thinks that I do good work	0.58