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Am I an engineer yet? Perceptions of engineering and identity among first year students

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ABSTRACT
Development of a professional identity may contribute to persistence in an engineering major. Further, perceiving alignment of one's career values to engineering as well as believing that one is enacting engineering during coursework are expected to support identity formation. Using mixed methods approaches, we explored data provided by 186 undergraduate students responding to four open-ended questions at the end of an introduction to engineering course. Our results indicated alignment of perceptions of engineering and personal values, such as when students who emphasised the role of engineers as helping others tended to have altruistic professional goals. When considering identification with engineering, we found that definitions focused on the role of math and science as well as altruistic definitions were less likely to co-occur with a belief that students were already practicing engineering. Findings suggest certain definitions of engineering inhibit perceptions that the student is already enacting engineering and may affect identification.

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Engineer identity; occupational value; perceptions of engineering; gender differences

Understanding how and why college students commit to a career path is critical for developing programmes supporting academic development and career planning. The engineering field struggles more than others in retaining promising students through graduation (U.S. National Science Foundation [NSF] 2014). Further, the U.S. and Europe both recognise the necessity for a larger and more diverse pool of students entering the study of engineering (Becker 2010; Prieto et al. 2009). In light of this, research exploring how students develop an identity in engineering is instrumental to advance this goal of increasing the size and diversity of the student engineering population, as well as promoting the success of those students. The goal of this study was to explore how first-year engineering students define both the field of engineering and their career identifies in order to explore how these perceptions may affect retention and diversity.

Defining 'Engineering'

Identifying how students view engineering and engineers helps formulate a baseline for this inquiry. Villanueva and Nadelson (2016) explored student perceptions of engineering within a framework of historical definitions. They found students hold three impressions of engineers: tinkerers (pre-industrial view); those who apply science to practical problems (industrial view); and twenty-first century interdisciplinary problem-solvers with a social impact (modern view). They posited the modern view would most likely support student development of an engineering identity that would be productive

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for the current engineering field, especially in the case of traditionally underrepresented groups (e.g. women and racial/ethnic minorities).

Engineering identity development

The development of a professional identity is considered a critical pathway to persistence in pursuing both undergraduate and graduate degrees in engineering (Dryburgh 1999; Merolla and Serpe 2013; Stevens et al. 2008; Tonso 2006), as well as working in the field after graduation (Cech 2015). Engineering programmes increasingly recognise the first year of college is a crucial time for student development of an engineering identity (Meyers et al. 2012). As Cech (2015) describes,

> Students who adopt professional identity traits that are most valued by their profession may be more likely to persist, sensing a fit between their identities and the priorities of their profession. Students who reject the most valued identity traits of their profession may cobble together professional identities that are quite different from the traits most respected by the culture of their profession, and thus may be more likely to leave the profession altogether. (p. 59)

Theorists believe engineering identity development is highly influenced by the culture of the university, students' understanding of engineering, and students' perceptions of their knowledge and skills (Cech 2015; Chachra et al. 2008; Faulkner 2006, 2007; Loshbaugh and Claar 2007; Meyers et al. 2012; Pierrakos et al. 2009; Tonso 2006; Zaharim et al. 2009) This is consistent with Social Cognitive Career Theory (SCCT; Lent, Brown, and Hackett 1994, 2000), which focuses on how students' educational and personal experiences influence three main constructs related to career development: self-efficacy (a person's belief they can be successful in activities related to the career field), personal goals (categorised into choice and performance goals which affect engagement and persistence in pursuing a career field outcome expectations), and outcome expectations (Lent, Brown, and Hackett 1994).

Significant to this study, outcome expectations are a person's beliefs about the probability that *valued* results will be achieved (Lent, Brown, and Hackett 1994). It is important for students to feel they can be successful in the field and value the outcomes from that choice to decide to enter the career field. One of the most important factors leading to students identifying with engineering are their competence and performance beliefs (Carlone and Johnson 2007; Godwin et al. 2016; Hazari et al. 2010; Patrick, Prybutok and Borrego 2018). Therefore, it is not only important for students to believe they can be successful in engineering to choose the major, it is also important for building their identity with the field.

Student experiences and perceptions of their engineering knowledge and skills influence identity development (Meyers et al. 2012; Pierrakos et al. 2009). In identifying what necessary knowledge and skills are needed to become an engineer, students in Meyers et al. (2012) focused on individual and intangible factors, including the ability to make competent design decisions; working with others by sharing ideas; accepting responsibility for the consequences of actions; speaking/communicating with accurate technical terminology; completing an undergraduate engineering degree; and making moral/ethical decisions. Additionally, students reporting future goals in engineering were more likely to identify as engineers (Meyers et al. 2012).

How students define disciplinary knowledge also impacts the ability to form an identity as an engineer (Stevens et al. 2008). Through the course of their education, engineering students alter their definition of engineering knowledge and what actions 'count' as engineering. These definitions relate strongly to their model of becoming, and considering themselves to be, engineers. In Stevens et al.'s work, students evolve their understanding of engineering knowledge through the structures of the engineering programme. This includes the opportunities that many of the students in a first-year programme have yet to experience: displaying knowledge through project-based course work, increasing autonomy in posing and solving problems (again more common in advanced courses), and increased opportunities to work in and be evaluated as part of a team. Although problem-based learning is increasingly used throughout undergraduate education, Stevens et al. note that these types of experiences are typically more common in upper level courses.

Other factors influence the development of an engineering identity, retention, and persistence in the field. In comparing the stories and engineering identities of first-year students who persisted in engineering studies to those who transferred out of the major, not only is identification with the field important, but also persistence occurs when students have more knowledge and exposure to the field; an interest in engineering; contact with actual engineers; a sense of preparedness; and connections with peers and faculty (Pierrakos et al. 2009). In some cases, identity development has also been shown to be more influential than grade point average (GPA) in persistence. In STEM majors as a whole, identity develops independently of GPA. Students with a strong GPA and more salient identities in STEM are more likely to pursue graduate studies (Merolla and Serpe 2013).

In addition to the personal definitions that students hold, campus culture further influences the perception of the characteristics of an engineer. In conducting an ethnographic study to understand the culture of engineering education, Godfrey and Parker (2010) developed themes of 'An Engineering Way of Thinking', 'An Engineering Way of Doing', and 'Being an Engineer'. The engineering way of thinking describes a variety of ways of thinking, including valuing efficiency, focusing on problem-solving and design, focusing on applications and real world issues, and holding an interest in and application of science or math. The engineering way of doing describes the academic rigour and difficulty of the educational pathway, specifically 'the belief that anything worthwhile was hard' (12) and the need to challenge students so they learn helpful skills and work ethic for their future career. Finally, being an engineer describes the personal characteristics of engineering students within the school culture (e.g. having pride in their academic major, trusting their colleagues, and also having particular personality traits).

Of course, the professional field of engineering provides the profession's formal definition via accreditation standards for higher education, including the U.S.'s Accreditation Board for Engineering and Technology (ABET 2019) and the European-Accredited Engineer (EUR-ACE) Framework Standards and Guidelines (European Network for Engineering Accreditation [ENAEE] 2015). Unsurprisingly, the first student outcome for ABET accredited engineering programmes is 'an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics' (ABET 2019, 5). The EUR-ACE programme outcomes (ENAEE 2015) similarly emphasise technical aspects of engineering knowledge, analysis, design and practice. However, both agencies also emphasise the importance of social awareness and interpersonal communication to the modern practice of engineering (Estes, Brady, and Laursen 2018). For example, the 2019 ABET student outcomes include

(1) an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
(2) an ability to communicate effectively with a range of audiences
(3) an ability to recognise ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
(4) an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives (5–6)

Similarly, the EUR-ACE outcomes include recognising 'non-technical – societal, health and safety, environmental, economic and industrial – considerations' in engineering problem solving, design, and practice' (p. 5). They further highlight the importance of reflecting on 'relevant societal and ethical issues' in making engineering judgments and the importance of communication and teamwork' (p. 6).

Confluence of values and identity development

Student values have a further influence on their interest, commitment, and identification with career fields. One of the leading frameworks addressing the importance of student values and goals is the

Goal Congruity Theory (GCT), which predicts students will experience greater interest in, or commitment to, a career field when there is alignment of their career values and their *perceptions* of the field in terms of what outcomes they can expect or what values with which it aligns (Diekman et al. 2010; Klotz et al. 2014). GCT shares similarities with SCCT as the theory focuses on how students' personal values influence career decisions. However, GCT further emphasises how career decisions are influenced by student perceptions of what values certain careers provide, referred to as career affordances. In particular, GCT advances the concept that student perceptions of career affordances ultimately influence their career choices and their outcome expectations. As a result, a student who values altruistic goals and perceives engineering as aligning solely with status goals may experience mismatch with the engineering field and their valued outcome expectations. Thus, GCT focuses on the intersection of student perceptions of a career field with their perceptions of themselves and their perceived values to predict interest in, and commitment to, a career field.

One example of the importance of value congruity comes from Klotz et al.'s (2014) examination of whether students believed their careers would address sustainability issues, such as access to clean water, energy availability, equal economic opportunity, and environmental degradation. This study concluded that individuals interested in people-focused sustainability issues (e.g. economic opportunities, food availability, poverty, and disease) were less likely to major in engineering; whereas those who were interested in more general sustainability issues (e.g. energy, climate change, environmental degradation, and water supply) were more likely to major in engineering.

Gender and cultural differences in career values

Goal congruity is particularly important relative to recruiting diverse students because the engineering field is traditionally seen as affording more status and individualistic goals; whereas underrepresented students, such as women and students of colour, are more likely to have communal and helping goals (Diekman et al. 2010, 2017). This creates an appearance of incongruency with altruistic values and goals, leading women to opt for other fields that match their values (Diekman et al. 2010; Diekman et al., 2017). However, perceptions of career affordances are importantly malleable, value affordances can be altered with exposure (Diekman et al. 2011), and engaging activities and programmes allow students to explore the potential of an engineering identity (Aschbacher, Li, and Roth 2010). Such activities and programmes provide student role-relevant experiences that create congruity with students' values and the value affordances of engineering (Diekman et al. 2017).

In light of the importance of self-efficacy, values, and professional goals in students' identification with engineering, we were interested in how student definitions of engineering align with their professional goals and current perception of themselves as engineers in the current study.

Current study

The goal of the present research was to explore the relationship between perceptions of engineering (including definitions of the field), students' perceptions of their role as an engineer, and their future career plans. We further wanted to consider whether being an underrepresented minority or a woman in engineering impacted these definitions.

Given the formal and informal definitions of engineering, we sought to expand the research on students' definitions of the field and how their definitions related to identification with the field. Our focus was on early identification with engineering via the definitions first-year engineering students have of what constitutes 'real' engineers and 'real' engineering. In contrast with earlier research on general definitions of the field, we sought to analyze the definitions from the perspective of goal congruity and SCCT. Specifically, we were interested in definitions that would inform efficacy beliefs (such as a strong emphasis on mathematics), values alignment (such as clear career values expressed in definitions), and the outcomes expectations on which students focus in defining their future career field. Because students in our study were first-year undergraduate students, their early definitions and expectations are important factors that will shape their engagement and persistence in the major. Essentially, we sought to tie together the different strands of prior research involving career identity development, the confluence of values and identity development, and gender and cultural differences in career values.

Our research questions were:

(1) How do first-year engineering students define ‘engineers’ and ‘engineering’?
(2) Do first-year engineering students believe they are engineers?
(3) What professional goals do first-year engineering students hold?
(4) Are there patterns of responses across the previous questions?
(5) Are there patterns in these responses based on race or gender?

Methods

At this institution, all freshmen and transfer students are required to take a two credit hour *ENGR 1110 Introduction to Engineering* course. To gather a representative sample of the pre-engineering majors at this university, we approached the instructors of this course to invite their students to participate. Each of the College’s nine programmes teach one or more sections of the course and students are encouraged, but not required, to take the class from the department they are most interested in. The class size, format, and specific activities vary between departments, but all sections include: (1) a design experience requiring teaming, creative problem-solving, ethics, and written and oral communication; and (2) activities and assignments fostering readiness for sophomore level engineering problems. Many sections include guest speakers from industry and/or require students to attend talks given by industrial guest speakers for various engineering societies. This survey occurred within the last two weeks of the semester and online.

Instrumentation

To address our research questions, surveys were gathered from 266 first-year engineering students responding to the following open-ended questions (adapted from Villanueva and Nadelson 2016):

- What is engineering?
- What is an engineer?
- Do you consider yourself an engineer? Why or why not?
- What are your professional goals in becoming an engineer?

In addition to a series of Likert-type rating scales and demographic variables (developed and administered for a related evaluation study), students were asked to respond to these four open-ended question prompts, which explored the participant’s engineering identity and commitment. Along with these four focal questions, students were also asked to report their gender, race, and whether they were a first-year student, transfer student, or other (occasionally students do not take this course until their second year at the university).

As described in the analysis section, qualitative themes were used to classify student responses, and quantitative methods (primarily descriptive statistics) were used to consider the prevalence of different themes among subgroups of students.

Sample

In Spring 2016, six course instructors allowed us to survey their students. A total of 208 students completed the survey (approximately 1200 engineering majors enrol each year, so our sample represents approximately 17.33% of the population of interest). However, the sample size of women and underrepresented minorities was too small for reliable analyses. Therefore, in the Fall of 2017, the survey was administered again, and we augmented our study data with a random sample of 50 students from this response pool who indicated they were either women or from an underrepresented minority. Data from both samples were analyzed without any knowledge of which respondents were women or minority students.

For the open-ended questions, 266 students responded resulting in a response rate of 89.42% of those sampled in the larger survey. Consistent with the College of Engineering reported demographics, the student makeup in the Spring 2016 sample was predominantly white (87%), with about 20% of the students being female, which is comparable to the U.S. 2015 enrolment percentage of 21.4% (Yoder 2015), and representative of this institution (the freshman engineering class at this university was 18% female). Our augmented pool was 74% White, 13% African American, 5% Asian, and 8% other races or multiracial. Nine percent were Hispanic. Women comprised 24% of the augmented sample.

As expected, 91% of respondents (87% of the augmented sample) were first year students, while 7% were transfer students and the remaining reported 'other'. Participating faculty came from a variety of engineering programmes including Biosystems, Chemical, Industrial and Systems, Mechanical, Polymer and Fiber, and Computer Science and Software Engineering. Further, because students are encouraged to enrol in a section offered by their intended specialisation, this suggests that the students sampled for this study come from a variety of engineering fields.

Analysis

This study used an exploratory sequential approach to a mixed methods design (Morse 2003), where we first used thematic analysis (Braun and Clarke 2006) to identify repeated patterns of meaning in the data, then explored trends and similarities of the identified themes with quantitative analyses.

The first and second authors both participated in the initial coding and analysis process of the open-ended survey questions. The authors first analyzed the data separately, and utilised analytic memoing (Saldana 2016) to keep track of their meaning making, reflect on their interpretations of the data, and explain their reasoning behind their coding. Analytic memoing serves as a way to help the researcher work towards deeper levels of analysis while providing more transparency in the research process. As Saldana (2016) described, analytic memos help create an intellectual workspace, and help the researcher work toward solutions from their data. Analytic memoing bolsters the credibility of the analysis, providing documented accounts of the researchers' meaning making while situating them in the research process. The authors also used analytic memos as central discussion points for the analysis meetings, guiding the co-creation of their codebook and final themes.

To develop key themes across and within each of the open-ended questions, the first and second author individually reviewed the responses for broad themes, reading and annotating each set of questions (i.e. all responses to question 1, then 2, etc.) separately. This was done to help gain a better understanding of participants' responses to each question collectively, and the repeated patterns of meaning within each question. After each question was analyzed separately, the patterns were then compared across questions, looking for key repeated themes. The questions were deductively and inductively analyzed to situate this project within the current literature while allowing for emergent patterns and themes to have voice. For questions one and two, special attention was paid to how the participants' responses mapped onto previous research on how engineering was defined (Villanueva and Nadelson 2016), and the value affordances placed on engineering following GCT (Diekman et al. 2010). Although we started with the distinctions made by previous researchers, we also expanded these definitions in accordance with our participants' responses. Question 3 was inductively coded to see how the participants in this specific study explained their reasoning for why or why not they identified as an engineer. In the analysis of this question we focused heavily on participants' own words and evidence of meaning making. We wanted to examine what it meant for them to identify as in engineer, and what criteria they used, hoping to move beyond a surface level examination of identification. Therefore, we paid special attention to the participants' reasoning for identifying or not identifying as engineer rather than merely taking into account whether they identified as an engineer. The authors (1 and 2) believed that focusing on how the participants justified their decisions to identify could potentially have more explanatory value and relevance for future work. Question four was analyzed both inductively (to examine the participants' expressed career goals) and deductively (to identify how these descriptions mapped onto definitions of engineering) (Villanueva and Nadelson 2016).

Once the authors separately identified sets of themes for each question and across questions, the two researchers then worked together to create a shared understanding of the range of responses to the questions. This was done in analysis meetings, where the researchers' analytic memos took a central role. As previously discussed, the first and second authors participated in analytic memoing (Saldana 2016) throughout the coding process to help them make sense of their understanding of the identified patterns in the data, as well as a starting place for the analysis meetings. The memos were used to examine how each of the authors coded and were beginning to interpret the data, to help initiate agreement and understanding between them. The authors used the memos to identify similar themes in their separate analysis of the data and came together to establish consensus on the major themes and coding scheme for the data. Interpretive disagreements, as well as theme names and categorizations, were discussed until a consensus was met between the two authors. The analysis meetings served as a way for the authors to conduct peer debriefing with each other on their interpretations of the data and establish the co-creation of a codebook. The authors named the themes based on key words the participants used, and groupings that already existed within the literature, pointing to how this work fits into previous findings. Once these were condensed, defined, and agreed upon, the authors created a codebook for the themes.

The codebook was created to represent our findings and ensure similar coding of the data across researchers. The codebook also represented the researchers' shared understanding and interpretation of the data. We next reviewed all participant responses again based on this coding scheme (reported in the results). The coding scheme resulted in mutually exclusive themes (overlapping in definitions but not in coding) and each response was coded to one theme. Finally, we calculated descriptive statistics to capture trends found in the codes across questions and by demographic variables, expanding the qualitative results with some quantitative insights.

Results

Table 1 integrates our coding schemes for each question. We will describe our findings and problem examples of each code in the sections that follow.

Defining engineering and engineers

The first two questions related to defining the field: 'In your own words, define "engineer"' and 'In your own words, define "engineering"'. For these questions, we found sufficient overlap to use the same coding system for both sets of responses. In our analysis we focused on what appeared to be the most salient part of their description because many students focused on engineers as problem-solvers but varied in their descriptions of how they solved problems, what problems they solved, and the purpose of problem-solving. We found that engineering/an engineer was defined in four main ways: (1) **designer/design process**, (2) a person or field **applying math and science** to solutions, (3) the **characteristics of problems** they solve in terms of process style (e.g. efficient, complex) or types of problems tackled (e.g. 'real world'), and (4) **helper to others or society**. Responses to each question were categorised into one of the four themes. See Table 1.

Student statements defining engineering as building, inventing, design, and innovation characterised the theme **engineers as designers**. For example, one student stated that an engineer is 'one that uses innovation to build and design solutions to given problems', indicating that engineers

Table 1. Findings by theme.

Questions 1 & 2: Define Engineer(ing)			
Designer/Design Process:	*Applying Math and Science:*	*Characteristics of problems:*	*Help Society or Others*
Engineering is building, inventing, design, and innovation. They solve problems through design and building, or simply build and create.	Engineers use math and science to solve problems, or apply math and science to the real world.	Engineers solve problems that are difficult, technical, and require creativity and help efficiency. The focus was on the types of problems engineers solved.	Engineers solve problems to make the world a better place, or help people. In this perspective to be an engineer meant to do certain jobs for the purpose of helping
20% of responses	15% of responses	45% of responses	20% of responses
Question 3: Why are (or aren't) you an engineer?			
Mindset:	*Skillset:*	*Degree:*	*Still in training:*
Identification based on a way of thinking or solving problems. Engineering is a mindset or a specific way of approaching, solving problems	Described engineering as a specific set of skills that must be learned. Identified based on their perception of having those skills.	These students felt that to be an engineer they must have the engineering degree and graduate.	Felt that they were not yet engineers or did not identify as an engineers because they were still learning skills or knowledge.
Did identify: 71%	Did identify: 29%	Did identify: 0%	Did identify: 0%
No/Not yet: 3%	No/Not yet: 45%	No/Not yet: 30%	No/Not yet: ~10%
Question 4a: What are your professional goals?			
General Career Goals:	*Specific Career Goal:*	*Did not know or leaving the field:*	
Vague descriptions of what they wanted to do and did not specify a specific area of engineering	Discussed the engineering field, the type of jobs, and even specific companies they hoped to work for.	Expressed they did not know what they wanted to do with their degree or expressed leaving the field	
45%	47%	8%	
Question 4b: Career Values of Goals			
Altruistic:	*Individualistic:*	*Altruistic and Individualistic:*	
Wanting to make the world a better place and/or helping people through engineering	Wanting to make money, have a good career they enjoyed, and/or work their way up through engineering	Want to fulfil their goals of helping others while maintaining their personal goals of success and a higher income	
23%	34%	6%	

solve problems through building and innovation. Other students framed engineering as building, such as, 'the act of creating something out of parts'. The student responses fitting into this theme, therefore, represent a central view that to be an engineer or to do engineering is to build and create. This could include building and creating to solve a problem, or merely building physical models or products (including resolving problems with devices).

The second theme that emerged was that engineering and engineers are ones who **apply math and science**. Responses in this theme were characterised by students' views that engineers used math and science to solve problems, or apply math and science to the real world. This perspective saw engineers as having specific knowledge that was useful and technical. For example, one student defined an engineer as 'a person who use their knowledge of science and mathematics in the practical application of solving problems'. Another student stated that an engineer was 'a person that solves problems that incorporates concepts of math, science, and physics in the real world'. Additionally, another student defined engineering as 'making the world a better place through the application of advanced math and science'.[1] For these students, engineering was the possession of knowledge, specifically in science and mathematics, that was used to solve problems and/or to make the world a better place.

The next theme defined engineers/engineering in terms of **the characteristics of problems engineering solves**. This perspective saw engineering as solving problems that are difficult, technical, require creativity, and help efficiency. To these students, being an engineer meant solving certain types of problems. For example one student described an engineer as 'someone who designs and builds stuff or solves **difficult and challenging problems that others can't**'. This response was grouped here because of the focus on the types of problems engineers can solve. Another student described the field as 'developing creative, effective, efficient and affordable solutions to problems'. In other words, engineers provide certain qualities in their solution, and the focus is not necessarily on the methods used to solve those problems or the impact they have. Similarly, another student expressed this perspective by saying, 'an engineer is one who can solve a complicated problem in the easiest most efficient way possible'. For this group, engineering is defined by the way they solved problems.

The final theme characterised engineering as **helping others**. These responses viewed engineering as problem-solving to make the world a better place, or that engineers helped people. In this perspective, to be an engineer meant to do certain jobs for the purpose of helping. For example, one student described an engineer as 'a person that solves problems that are occurring in the world **to better society**'. Another student defined their role as 'someone who helps to better life and make things safer'. To be an engineer is to create solutions *for others*.

In addition to understanding the themes of students' responses, we also wanted to quantify how common different themes were in the data. See Table 2. This type of information is helpful for understand the shared understanding that many engineering students will have as well as less common views. When designing an introductory course, an instructor may want to introduce multiple views of engineering and problem solving that appeal to different interests and perceptions. By far the most common definition focused on engineering and the work of engineers as problem-solving. This is a dominant conception in their answers; with a large minority of students further specifying that the problems solved are for others or are technical or creative in nature.

Do you consider yourself an engineer? Why or why not?

Based on the literature, we expected that students with stronger identification with engineering would also report that they were already engineers or enacting engineering. When students were asked if they considered themselves to be an engineer, 37% responded 'no', 10% responded 'maybe' or that they were an still training to be an engineer, and 53% stated that they were engineers already. We focused our attention within the broad categories of students who responded yes or no for themes within these broad answers. Intriguingly, most of the 'yes' responses involved reporting behaviours or mindsets that the student considered to define engineering. Students in this group tended to report that they used engineering skills daily to solve problems, such as to improve things they use. They focused on skills they believed they had (or did not yet have) to ground their reasoning as to why they were engineers. Many emphasised that engineers seek efficiency, use creativity and innovation, and experience enjoy their work. Other key factors were solving problems that impacts others and solving practical problems that impact daily life.

In addition to grouping the responses as initial identification or not (yes/no/not yet), we coded each response by the reasoning they used to identify or not identify as an engineer. We found that students' reasoning for identifying or not identifying as an engineer could be grouped into five themes: mindset, skillset, degree, training, and fit. Overall, participants explained their reasoning

Table 2. Percent of students defining engineers or engineering across themes.

	Define Engineer		Define Engineering		
	Freq.	%	Freq.	%	% same category on Q2 as Q1
Only mentions building or solving problems (D)	43	16.2	47	17.7	72%
Mentions role of math/science (A, DA)	38	14.3	30	11.3	61%
Characteristics of problem (DAC, DC, C)	101	38.0	112	42.1	79%
Problems solved for others (AH, DH, DAH)	50	18.8	39	14.7	44%
Missing	34	12.8	38	14.3	
Total	266	100	266	100	

for identifying with the field based on a perception of the field and how it matched their abilities or perceived milestones.

The first theme students used to ground their engineering identity was **mindset.** Participants in this thematic grouping expressed that they did or did not identify as an engineer because of a way of thinking or solving problems. They viewed engineering as a mindset or a specific way of approaching and solving problems. Many saw this as something that they had always done. One notable response for this theme was 'Yes, I do consider myself an engineer because, **I feel that is the way my brain works**. I get an idea of a new product or something that will help the world and have **the desire to build/ design it.** Plus I am a **huge fan of math and science'**.

Among students who felt they were already engineers, 71% gave this type of explanation. Among students who said they were not or not yet engineers, only 3% used mindset as a reason they were not. One example of this type of response reflected the student's lack of confidence in how they solved problems: 'no because I struggle solving problems in a beneficial way'. This group focused on engineering as a specific way of thinking.

The second theme for identifying or not identifying as an engineer was **skillset**, which describes the explanations used by the other 29% of 'yes' responses and 45% of the 'no/not yet' responses. These were students who described engineering by the specific set of skills used to solve problems, or a specific set of skills that must be learned, which was different from other students' description of a mindset or cognitive approach to the world. These students focused on the specific process or actions taken to solve problems. One student stated, 'I consider myself to be an engineer because I find **creative ways to fix problems** that occur in different machines and other processes'. Another student cited research projects they were already involved in: 'Every day I work to build the satellites **I apply the laws I have learned** thus far in ways that were not spelled out for me'.

Among those students who gave 'skillset' reasons for not being an engineer (or not yet), typical responses included naming specific skills or general training needed, such as, 'No; I have not progressed far enough in **necessary knowledge of the physics** needed for precision engineering to what I consider sufficient'. Others cited the need to engage in design and problem solving in order to consider themselves engineers: 'No. I won`t consider myself an engineer until I **design a solution to a problem outside of [the university]**'. To these students, engineers have already solved important problems and built solutions, so they focused on not having reached that milestone or proof of skill.

The third theme students used to ground their responses were whether they had an engineering degree or met the requirements for a professional engineering license. This was cited as a reason for 30% of students who said they were not or not yet an engineer because they had not finished their degree, or met the criteria for being a licensed Professional Engineer. For this group, being an engineer was similar to being a medical doctor in that specific education, training, and licensing criteria have to be met. For example, one student expressed, 'I will not consider myself an engineer until I have the degree in my hand and have passed all exams needed. As of now, I'm in the process of becoming an engineer'. Other responses were simple, where one student stated, 'Not yet. I'm still a freshman!' All of these responses focused on obtaining a degree as the main requirement for being qualified as an engineer.

The fourth, and related theme, was that students did not identify as an engineer, but saw themselves as in the process of training as engineers ('*still in training*'). The students in this group (10% of the 'no' or 'not yet' responses) felt that they were not yet engineers or did not identify as an engineers because they were still learning, and did not have the necessary skills or had not taken enough course work to 'do' engineering. To them, engineering was a skill to obtain; they were working towards the title. Like the previous group, these students seemed to emphasise the specific professional requirements of being an engineer. Similar to the skillset group (who focused on the problem-solving process), students in this group focused on whether they had demonstrated achieving the skillset yet. For instance, one student stated, 'no because I am not fully trained nor capable of designing and/or creating new technologies at this point'. Many students expressed that engineering was a skill and to consider themselves an engineer they needed to be able to perform certain tasks or be capable of doing certain jobs. Students in this group were actively working toward their identification as an engineer.

The final grouping and theme was **fit** with engineering. Students in this group (13% of 'no/' not yet' responses) did not identify as engineers because they felt they did not fit the engineer 'mold'. Additionally, students expressed that they were leaving engineering because of a poor fit with their interests or skills. Overall, this group was characterised by a mismatch in how they perceived engineering and how they saw themselves and their interests (some even stating they had already changed college majors). For example, one student said, 'No, because I find **no interest** in engineering'. An ambivalent student said, 'Yes, because of my **title and status** in school. No because I don't fit the **engineering mold**'. It is promising that, in our sample, this group represented the smallest group of students. Therefore, most of the students in our sample either identified as an engineer or could see themselves identifying in the future.

To further explore responses, we contrasted students' response to this question to their answers to questions 1 and 2. We found that, among students who defined engineers as the application of math and science, these students were more likely to say that they were *not* currently engineers (around 50% said they were not) compared to those who focused only on the problems engineers solve (design/inventing; 38% said they were not engineers) or those who focused on the characteristics of the problems solved (34% not engineers).

Similarly, 56% of students who defined engineers as working to benefit others also said they were not currently engineers. This group had the highest proportion responding 'no' (28%), and 18% responding 'not yet'. Defining engineering in terms of the types of problems solved was associated with higher identification than definitions based on either altruistic views or a classical view of engineering as the application of math and science. Both groups of students' responses may reflect an accurate view of engineering as a licensed profession heavily dependent on technical skill, but may also reflect a sense that greater expertise is needed to create solutions to problems. Those who focus on everyday mindset and skills could identify more readily as engineers.

What are your professional goals in becoming an engineer?

As one might expect, students gave a wide range of responses to this question concerning their professional goals. We found that some students had very specific plans, such as hoping to work for a specific company, while others had general plans, such as simply getting a job in their field. Additionally, some participants expressed altruistic or status values in their career goals, supporting previous research (Diekman et al. 2010). We first grouped the students by generic career goal, specific career goal, and those students who did not know or indicated that they were leaving the field. For responses that expressed a value, we used the framework of value affordances (Diekman et al. 2010) to assign categories.

Those students who expressed a general career goal gave vague descriptions of what they wanted to do and did not specify a specific area of engineering. For example, one student in this grouping stated their career goal was to '**get a job** as an engineer in a field I enjoy'. Another student expressed their goal was 'to become skilled in my field of study and become highly educated to **perform well** in my job industry'. The students expressing specific career goals tended to name the engineering field, the type of jobs, and even specific companies they hoped to work for. This group expressed a clear direction and understanding of what they could do with their engineering degree. For example, one student expressed that their goal was to 'be a designer for a civil engineering firm and **help fix the American infrastructure**'. Another student in this group said their goal was 'to **work for Boeing on the SLS** and other rockets'. Students in this group expressed a specific goal as well as more information on how they wanted to achieve it. For example, one student stated, 'I would like to develop a career in ecological engineering and **help develop technologies to protect the environment**'.

The third grouping included students who did not know what they wanted to do or expressed they were going to leave the field. One student stated that their goal was 'to become an Army Officer and **pray to God I never have to actually apply my engineering degree** in a boring work environment. To be 1000% honest, this degree is basically a huge back up plan'. Other students expressed they had just been 'trying out' engineering and had figured out it was not the right fit for them. One student expressed this as

> I wanted to see if it was what I wanted. I still want to design, build, and create but **I feel like my strengths live outside of the engineering pathway**. I will still work closely with engineers as a designer.

Although a few students expressed that they intended to leave the field, the majority of students indicated that they were planning to enter the field in some aspect.

In order to examine the role of value affordance perception in the students' goals and identification, of most interest to us was whether those plans included a career value that clearly aligned with individualistic (e.g. make money) or altruistic goals (e.g. help others). Therefore, we cross-coded the general and specific responses into value groupings. We found that 28% of students had no clear value orientation, simply stating they wanted to earn the degree or work at a specific company. Another 6% indicated that they were unsure about their career path or that they intended to leave engineering.

Of the remaining students, we grouped responses into altruistic goals, individualistic goals, and the emergent grouping of individualistic and altruistic goals. Statements about wanting to make the world a better place and helping people characterised the **altruistic** grouping. We found that 23% of students gave this type of response. Some students were specific in what they would achieve with their engineering career, while others only expressed general altruistic statements. For example, one student said their goal was to 'change the world', while others gave more detailed accounts. An example of a specific altruistic goal was:

> When I become an engineer, my goal is to be able to use the knowledge that I will attain in these next four years to help make a better society. I am from a country that does not have the best roads back home. **I believe that my knowledge and experience after graduation can eventually lead me back home in creating a better infrastructure for my country.**

This student was unusually focused in how they wanted to use their engineering expertise to help others.

We found that 34% of students provided an **individualistic** value in their goals, including wanting to make money or have a good career where they could potentially gain promotions. For example, one student stated that their goal was 'to have a good paying job to provide for my future family'. Another expressed that 'my professional goals are to **get a good career** right out of college and eventually work my way up to a **management position** at an engineering company'.

Another interesting grouping was the students who expressed both individualistic and altruistic goals (6%). These goals are seen to be incongruent in the career values literature; however, students in this group saw engineering as a way to fulfil their goal of helping others while maintaining their personal goals of success and a higher income. Students responded in ways such as '**make a difference** while **getting paid**' and 'making an **impact in society** and being **successful and happy** at my profession'.

Finally, in order to examine the potential role of Goal Congruency Theory in our data, we contrasted students' responses to Questions 1 and 2 defining engineers and engineering with their responses to question 4 about their professional goals to explore whether a student's definition of the field related to their goals. We found an interesting pattern where students who defined engineers as those who design or solve problems for others (helping) were more likely to state an altruistic professional goal (about 53% of these students) compared to an individualistic goal only (about 23%). Student who gave definitions focusing on design, application of math and science, or the characteristics of problems were more likely to state an individualistic professional goal (40%) compared to an altruistic or altruistic plus individualistic goal (20% of these students). It was interesting to see that of those individuals who included career values in their definitions of engineering, it was altruistic and matched their career goals.

Race and gender patterns

In addition to overall trends, we looked at the patterns of responses for women (N = 63) and underrepresented minority students (N = 53; 18 of these were also women) to provide additional insight into the patterns across important demographic groups. Using chi-square tests, we found a significant difference in the number of women expressing altruistic professional goals (over 30% of women compared to 17% of men). Similarly, we found more men expressed individualistic professional goals (23% of men compared to 10% of women). See Table 3.

For underrepresented minorities, we found significant chi-square tests for every thematic grouping of responses. URM students were more likely to focus their definitions of engineering on building or problem solving. They were less likely to mention the application of math/science in their definitions. Given other findings regarding identification, URM students were more likely to focus on definitions that were also associated with greater identification.

Consistent with the overall pattern, URM students were substantially more likely to feel they were currently engineers (70% agreeing compared to 54% of non-URM students). Their reasons for this answer were more likely to focus on an engineering 'mindset' and training, rather than focusing on a degree or skillset, which were more common among non-URM students. Finally, URM students were more likely to profess individualistic career goals. Thus, having a comfortable life and a secure career path were more common motivators for URM students pursuing engineering in this sample.

Discussion and conclusions

In comparing our current work to past research on definitions that students hold, we found some overlap and other interesting contrasts. Our findings related to each question are reviewed.

When students were asked to define engineering or an engineer, we found patterns of responses indicating students defined the field in terms of the activities (design), the technical skillset (math and science), the process or quality of solutions reached by engineers, or the value of engineers in terms

Table 3. Differences in percentages in each coding theme by gender and race.

Define engineer	Women	Men	Non-URM	URM
Only mentions building or solving problems (D)	44%	44%	38%	**62%***
mentions role of math/science (A, DA)	14%	20%	**21%**	9%
Characteristics of problem (DAC, DC, C)	10%	19%	18%	11%
Problems solved for others (AH, DH, DAH)	**32%**	17%	23%	17%
Define Engineering				
Only mentions building or solving problems (D)	52%	49%	44%	**67%**
mentions role of math/science (A, DA)	21%	21%	22%	15%
Characteristics of problem (DAC, DC, C)	7%	15%	15%	8%
Problems solved for others (AH, DH, DAH)	21%	15%	19%	10%
Am I an engineer?				
No	22%	21%	22%	19%
Somewhat	15%	23%	**23%**	11%
Yes	63%	56%	54%	**70%**
Why or why not?				
No degree	12%	13%	15%	6%
Fit to engineering	3%	6%	6%	4%
Mindset for engineering	46%	38%	36%	**55%**
Skillset for engineering	27%	35%	**40%**	11%
Minimum training required	7%	3%	1%	**15%**
Unsure, not specified, or leaving field	5%	4%	3%	9%
What are your professional goals?**				
No clear value	55%	47%	**52%**	38%
Altruistic	**30%**	17%	21%	17%
Individualistic	10%	**23%**	15%	**35%**
Both goals	2%	4%	4%	0%
Unsure or leaving field	3%	9%	7%	10%

*Significant differences (X^2) in bold.

of their impact on others (helping others). These conceptualizations of engineering are similar to previous research on descriptions of engineering (Villanueva and Nadelson 2016), although we did not identify the same types of distinctions that previous work identified.

Villanueva and Nadelson (2016) found that students in their study defined engineering in terms of either (a) tinkering, (b) the application of math and science, or (c) as twenty-first century problem solvers. They conceptualised the first two definitions as outdated views inconsistent with a twenty-first century definition of engineering emphasising teamwork to solve complex problems. Although we replicated their second category, we did not find the 'tinkering' definition in our data. Instead students focused on a more sophisticated idea of designing and problem solving (although certainly some responses might be similar to tinkering). Our respondents gave two types of the 'twenty-first century problem solver' definitions, some that focused on the quality of solutions (e.g. efficient, creative, complex) while others focused on the important role of the solutions (e.g. helping others, solving real-world problems). Therefore, although some students still cling to the perception of mathematical skills and scientific facts as the foundation of engineering, students in our study held a variety of conceptions of engineering.

In response to the question 'Are you an engineer?' posed to our participants, a large number of students said they were not engineers because they lacked degrees, coursework, and examinations, which are all significant passage points in engineering education. This is consistent not only with professional definitions, such as ABET (2016–17). It is also consistent with the work of Stevens et al. (2008), where engineering students changed their definition of engineering knowledge and what actions 'count' as engineering, including a 'navigation' dimension related to official and unofficial waypoints of becoming an engineer. We observed similar distinctions in the definitions focusing on the identification with engineering, the disciplinary knowledge of engineering, and navigation of the official pathway to becoming an engineer. However, the perception held by some students in our sample, who focused on behaviours and mindsets to define the engineering practice, may conflict with the institutional definitions of engineers, which emphasises key bureaucratic points along the trajectory to becoming an engineer (e.g. passing a course, completing the degree, and passing an exam).

What was most intriguing in our results was the large number of students who *did* identify as engineers even though they were first year students. Many of these students defined engineering as a set of practices (designing, improving), values (efficiency), and mindsets (creativity, helping others) available to students before they pass the traditional waypoints described in the previous paragraph. Definitions focused on design and building were the most likely to support engineering identity development in Stevens et al.'s framework. Importantly, definitions that focused on the application of math and science *or* that emphasised the helping role of engineering were less likely to currently identify as an engineer.

Students based their reasoning for identifying or not identifying as an engineer on their perceptions of their skills and what they believed were necessary to be successful in engineering. In line with SCCT (Lent, Brown, and Hackett 1994) and current research on engineering identity (Carlone and Johnson 2007; Godwin et al. 2016; Hazari et al. 2010; Patrick, Prybutok and Borrego 2018), they begin to build their identity and explain their identification with the field based on their beliefs that they had the necessary skills needed to succeed. In this way, they expressed self-efficacy for their future profession. Future research should explore students' sources of these framings and efficacious beliefs. It may be that their high schools offered engineering programmes that framed engineering as a skill (consistent with NAE's, 2013, Messaging for Engineering) and mindset or perhaps their specific section of the Introduction to Engineering course was more effective at conveying this definition.

Our analysis of responses to 'What are your professional goals?', supported our contention that contrasting altruistic and individualistic values could lead to important insight about identification. This is consistent with previous work on a related quantitative dataset (authors, in press) finding that perceptions of the value affordances of engineering (i.e. whether engineering careers can have altruistic or status-focused outcomes) were related to students' personal career values and their commitment to staying in the engineering field.

Although a substantial number (28%) did not include a value orientation, many did. When we contrasted this answer to previous responses, we found an interesting pattern where students who defined engineers as those who design or solve problems for others (helping) were more likely to state an altruistic professional goal (about 53% of these students) compared to an individualistic goal only (about 23%). Students who gave definitions focused on design, application of math and science, or the characteristics of problems were more likely to state an individualistic professional goal (40%) compared to an altruistic or altruistic plus individualistic goal (20% of these students).

This suggests that students tended to have definitions of engineering aligned with their personal goals. Unfortunately, these specific value-focused definitions were also associated with lower identification with the field. Students providing either math/science-focused or altruistic-focused definitions of engineering were less likely than other students to say they were current engineers. An area for immediate research is to associate the definitions held by first-year engineering students with their pre-engineering experiences. As the craze for STEM programming in the pre-college curriculum continues to expand, the potential for a mismatch between what is promised in pre-engineering programmes and what is delivered by engineering courses and even the career field may expand (Lachney and Nieusma 2015). It could also be that lofty definitions of engineering create less identification because students set a very high standard for contributing to a field that has profound impacts through their work. Future research should examine exactly how values-focused definitions of engineering may help or hinder identification with the field. It is a common belief in engineering education that students will feel more empowered if they feel they are currently 'doing' engineering.

We hypothesised that, similar to GCT, alignments of these definitions of the field and one's career goals is part of forming commitment to a field like engineering. To this existing theory, our study adds that how you define engineering influences the criteria you use to identify with it and what career goals you have in the field.

When looking at response patterns by gender, we found a non-surprising trend where women were more likely to express altruistic goals. This is consistent with extensive literature showing gender differences in values (Su, Rounds, and Armstrong 2009). For URM students, we found they were more likely to focus their definitions of engineering on building or problem solving and were less likely to mention the application of math/science in their definitions. One interpretation could be that these students are more likely to hold modern definitions of engineering and the relationship of this definition to identification with the field should be explored in more detail.

Interventions to support engineering identities

Whether these values and mindsets are fixed or acquired may have important implications for promoting the identity development of other students. Cech (2015) found that engineering students were more likely to hold stereotypical definitions of engineering that would characterise this mindset as being a stereotypically male mindset, valuing efficiency and rigour while devaluing social skills. We found that women and URM students were more likely to hold definitions that focused on engineering solutions for others as well as professional goals that were altruistic or communal in nature. Cech suggested that women and minorities are more likely to create an engineering identity they consider atypical of the field, and that this may not support long-term commitment or the development of a strong engineering identity. In our sample, students from minority groups were more likely to give the most common definition of the field (focused on problem solving) and were more likely to already identify as engineers.

This study does not suggest that interventions should be focused only on altruistic applications of engineering, but instead indicates that interventions should provide multiple entry points for students (NAE 2013). Whether their interest comes from altruistic, individualistic, or another value, students can be led to see alignment between their values and the characteristics of engineering.

This seems likely to build identification in the field because students do appear to show congruency between their values and field perceptions.

Importantly, this study found that orientation toward the problems being solved (e.g. creating solutions, being creative) was associated with greater identification with the field compared to definitions focused on either the application of math and science or a purely altruistic definition (engineers help others). Both of the latter definitions were associated with a lower rate of identifying as engineers. It may be that narrow or lofty definitions preclude students from feeling they are already acting as engineers or providing solutions.

An important limitation of this study is that we do not know which students persisted in their engineering major. Future work should explore how early identification relates to continued engagement and persistence with the field. Although theory has richly argued for this relationship, longitudinal studies specifically focused on values and field perceptions are needed. Additionally, this is a relatively small sample from one university. Across the globe, institutions are developing innovative approaches to engineering education. Exploring the interaction of programme design and perceptions of the field of engineering are needed to better understand how changes in perceptions of engineering may relate to increased persistence.

This paper highlights important issues the field of engineering should explore as its members seek innovations that lead to more and more diverse students entering the workforce. Students' perceptions of engineering tend to be congruent with their own values, but when these perceptions are not shared by their classmates or reinforced by their professors, their identification may be at risk. Further research, both quantitative and qualitative, is needed to continue to study how pre-engineering and first-year programmes can enhance engineering identity formation and how these identities interact with persistence.

Note

1. Occasionally students included a vague 'helping' statement along with a more specific aspect of their definition. When a definition fit more than one category, we assigned it based on the most specific aspect.

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