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Are We Preparing Our Students to Become Engineers of the Future or the Past?*

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A critical part of students' development and persistence as engineers is their acquisition of a professional identity. Prior research indicates that science, technology, engineering, and math (STEM) students tend to over calibrate their level of professional identity. This suggests that their self-determined level of professional identities are likely inflated when compared to the levels of identity that their communication would indicate—which may appreciably influence their professional engagement and tenacity as an engineer as well as their perceptions of engineering as a profession. One area that has not been explored is the underlying factors that influence these self-elevated perspectives by the students. The study explores the individual, social, and systemic domains as well as historical foci of 275 undergraduate engineering students' perceptions of the engineering profession. Findings indicate that students' self-proclaimed levels of professional identity are higher than the development levels they convey in their survey responses. We found that their perceptions tended to be aligned with their individual view of engineering, which were guided by the historical notion that an engineer is a *Mediator* of science, math, and technology, a perspective that is not aligned to current definitions of 21st century engineering. Our exploratory study supports the importance of helping engineering students develop professional identities by attending to their understanding of the work, norms, and expectations of professional engineers and the role of a 21st century engineering professional.

Keywords: professional identity; engineering education; history; undergraduate; engineering student perceptions

1. Introduction

Like other professions, engineering is self-defining [1] and guided by a historical core. In part, this historical foundation can be traced back to the formal introduction of engineering education at West Point Academy in 1802 [2, 3], in an effort to reduce dependence on foreign engineers and artillerists in times of war. The educational foundation established in West Point has cemented what many leading educational institutions believe is as an effective and proper way to prepare and educate engineers [4–7].

The ever changing needs of the market, the emergence of interdisciplinary projects, the increasingly complex social and systemic paradigms, has required engineering to re-imagine their role in society [8, 9]. On the other hand, the educational "DNA" of the United States (U.S.) engineering curriculum has remained practically untouched since its introduction in the early 1800s [1, 5]: a three-year core of common courses including calculus, physics, chemistry, mechanical drawing, statics, dynamics and other courses followed by a final year of professional courses [1]. The stasis of engineering curriculum and its preparation programs has raised concerns among the engineering education and research community calling for an evaluation of the factors affecting engineering's "identity crisis" [8–12].

We maintain that a lack of engineering education alignment to the quickly evolving norms, practices, and paradigms of engineering in the 21st century opens the door to "professional confusion" by engineering students. Furthermore, when engineering educators fail to recognize the persistence of a historical influence by engineering education on students' perceptions of the field, undesirable consequences can result [1]. For example, a lack of progressive curricular content may limit students' understanding of their future professional roles [13], which may hinder students' sense of "ownership" of their professional actions and beliefs [8, 14–18].

The purpose of our exploratory mixed methods cross-sectional study was to examine engineering students' level of professional identity development and explore how their perceptions of engineering relate to the dominant historical frameworks of engineering education in the United States. Note that we are making a distinction in our study between "engineering identity" and "professional identity" in engineering. Engineering identity has been primarily defined as being individual, intrinsic, and socially guided [8, 14–18]. On the other hand,

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"professional identity" is a more generalized perspective of identity which is influenced by experiences and interactions with others [19]. Through exploration of a professional identity in engineering education, we hypothesized that the themes framed within historical periods of engineering education would influence how students perceive themselves as professionals [20].

To determine the level of professional identity achieved by the students, we examined an array of student responses to multiple free response items using a validated model for science, technology, engineering, and math (STEM) professional identity development [21]. To determine the students' perceptions of the role of an engineer we simultaneously examined student responses for references aligned with the three historical engineering education frameworks [5, 8, 9]. We also examined the students' responses for references to professional *domains* or contexts that engineers engage in as they do their work of engineering to determine the sources of professional identity students use as references for their perceptions about being an engineering professional.

Prior to sharing the methods and results for our research, we provide a conceptual framework for our investigation with support from the literature.

2. Literature review

2.1 Defining professional identity

Post-secondary education, by design, is intended to substantially contribute to students' "cognitive growth, professional identity development, and career preparation" [22, 23]. However, there is limited knowledge on how students develop their professional identity [24] and what faculty members can do to foster students' professional identity development, particularly along cognitive dimensions and with respect to supporting appropriate dispositions and progressions in students' capacities to engage as professionals [25, 26]. Although many aspects of professional identity are ubiquitous (e.g., proficiency with 21st century skills) there are some variations in how professional identity is considered and fostered, as the norms, processes, content knowledge, epistemological paradigms, and professional foci tend to be domain specific and may be aligning with specific educational components [18, 27–31]

The definition of *professional identity* is conveyed broadly and inconsistently in the literature [18], with some published studies on professional identity development failing to provide a discernable definition of the construct [24]. The lack of a consistent definition of professional identity led us to consider a working definition of professional identity based on how seasoned professionals might self-describe who they are in relationship to their profession. Thus, similar to Ibarra [32] and Nadelson and colleagues [21], we consider professional identity to be defined by the attributes, skills, knowledge, beliefs, practices, and principles, which are representative of professionals as they work within and evolve with their profession. More specifically, we embrace the perspective of Nadelson et al., [21] by considering that the level of student professional identity is effectively indicated by the extent to which an individual has internalized the elements of a profession and effectively expressed those elements in relation to complex professional situations. We also recognize that the development of a professional identity is a longitudinal process and is influenced by experience, knowledge, and professional interactions [18]. For our research, we focused on current level of students' professional identity at their stage of education and did not assess their on-going development, although this will be a future direction of our research. Further, we focused on indicators of a general professional identity such as communication, teaming, cultural sensitivity, life-long learning, and contribution to society (i.e. 21st century skills).

2.2 Domains of professional identity

Recent initiatives across Australia, the United Kingdom, The Netherlands, and to a smaller extent the United States, have begun to explore how professional identity is defined, described, understood, and applied to student development as professionals [15, 16, 18]. The process of exploring professional identity has led to the recognition of three major domains of influence or reference: *individual, social, and systemic* (see Table 1). To align our working definition of professional identity with the domains of influence, we identified instances where professional identity development was alluded to in the engineering education and other STEM education literature (see Table 1). We maintain that a classification of professional identity along these three domains is useful for determining the dominant lens through which students identify themselves as professionals, and potentially as future engineers.

As shown in Fig. 1, contextualizing professional identity by individual, social, and systemic domains allow us to better understand how students' frame (and develop) their professional identity in a given field. We focused on professional identity of engineering students for our work based on reports pointing to a dire need to prepare over 1 million engineers in the United States by 2025 to be competitive global technological leaders [8] and the multi-

Table 1. Examples of Engineering 'Professional Identity' Mentions in the Literature Along Three Domains

Individual Domain: Identification with the Profession
• The 'personal epistemology' and ways of knowing through development of self-authorship [14] • The engagement with 'ambiguity and uncertainty', to find 'self-authorship', and 'make connections between externally validated knowledge and inner ways of knowing' [33] • 'The sense of being a professional' and the 'use of professional judgments and reasoning' [34] • A 'dynamic portfolio' of one self [35] • A 'sense of professional agency' [36] • 'The relatively stable and enduring constellation of attitudes, beliefs, values, motives and experiences' where individuals define themselves in a 'professional role' [32] • The 'attitudes, beliefs, and standards which support the practitioner role' and the development of an identity as a member of the profession with a clear understanding of the responsibilities of being a . . . professional' [37] • 'Double sided process' of being positioned by others and oneself [38]
Social Domain: Requirements associated with the profession
• 'The relatively stable and enduring constellation of attitudes, beliefs, values, motives, and experiences' where individuals define themselves in a 'professional role' [32] • Meeting of specified 'standards of the professional community' [12, 39] • 'Closeness' to how an individual 'relates to a particular field, profession, or occupation' [29] • The 'attitudes, beliefs, and standards which support the practitioner role' and the development of an identity as a member of the profession with a clear understanding of the responsibilities of being a . . . professional' [33] • "Double sided process" of being positioned by others and oneself [38] • The social dynamic of the interplay between individuals and their environment in terms of 'situated social practices' [40]
Systemic Domain: Interplay between individual professional development and their situated social environment
• The 'systemic' process of professional learning that occurs in the 'interplay between individuals and their environment in terms of situated social practices' [40] • A process where 'traditional academic disciplines' author the position of a professor or student [41, 42]

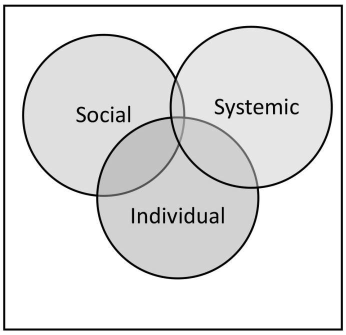

Fig. 1. Proposed domains of professional identity.

ple calls to resolve the professional identity "crisis" [9] in engineering [5, 9, 12, 29, 39].

We sustain that the development and evolution of a professional identity is influenced by the interplay among systemic, social and individual domains. For the *systemic* domain, the influences on professional identity are based on recognition of professional conditions and environments that guide externally validated knowledge, transmission of norms, sharing of knowledge, and practices with other professionals. In the *social* domain, interactions with others informs ways of knowing. The *individual* domain consists of personal levels of motivation and engagement that lead to an internalization of a profession [12, 14, 32, 33, 39, 40–42]. Given that different but critical aspects of professional identity are influenced by each domain, it is possible for students to frame their professional identity within all domains. However, it is more likely that students will tend to emphasize one domain over others.

2.3 Historical domains of engineering education

The influence of knowledge, experience, and professional interactions on the development of a professional identity provides justification for examining the environment in which engineering students are prepared. Downey and Lucena [5] developed a conceptual framework that focuses on how engineering is perceived across nations. The framework, referred to as "code-switching", calls attention to the salient influences of identity management, particularly the process "through which engineers build legitimacy for themselves and their knowledge in professional and popular terms" [5, pp. 396]. Downey and Lucena [5] recognize that engineering knowledge must help engineers to be "maximally appropriate for the time and place" [5, pp. 395] and conclude that the cultural and historical associations with engineering education illustrate the extent to which engineering knowledge and professional identity are linked. It is worth noting that while these researchers focused on a global historical perspective of this phenomena, our work is narrowed to the historical events present from the inception of engineering education in the United States in 1802 to the present [1, 5, 9, 43].

Thus, the historical perspectives of engineering are perpetuated in engineering education curriculum and therefore influence students' perceptions of engineering and their professional identity development. We posit that there is a link between the structure of engineering preparation programs, the historical perspective students use to describe engineering, and students' levels of professional identity development. For the purpose of our study, we selected three U.S. historical perspectives that reflect three unique engineering education curriculum genres in post-secondary programs. By focusing on these three genres of engineering education curriculum, we can assess if and how the curricular emphases might influence students' perception of engineering and their future professional roles. The three historical engineering preparation genres, the associated characteristics, and corresponding labels are:

(a) *Historical Focus 1: Engineers trained to be mediators of science, math, and technological innovation—Mediator*: U.S. engineering education was established in 1802 at the West Point Academy where its founders relied on the curriculum model of the École Polytechnique to emphasize training of scientific and mathematical theories to advance societal progress; *engineers were seen as mediators of science and math* [44]. It is important to note that similarly, in 1955, the Grinter Report, commissioned by the American Society for Engineering Education re-analyzed U.S. foundational engineering programs and compared them with European models. The Grinter Report concluded that engineering curriculum should have a *professional-scientific* focus to create structures that would help augment federal funding for universities in support of the research enterprise [5, 45]). The conclusion influenced engineering education curriculum in the U.S., reinforcing the notion that preparation programs should address the perception that *engineers are professional-scientific and mediators of science and math that use technological innovation* [5, 45]. The recommendations of the Grinter Report [5] continue to substantially influence the structure and focus of U.S. undergraduate engineering preparation curriculum and associated instruction today [7]. Thus, when students consider engineering from this perspective, they are very likely to view the work of engineers as *mediators* of math, science, and technology to achieve a given task or goal [46].

(b) *Historical Focus 2: Engineers trained to be designers and planners of industrial processes and tinkerer of products—Designer/Tinkerer*: From the 1880s to the first half of 20th century, the United States began bridging connections between engineering preparation programs and industry to expand training elements that considered designing products for mass consumption [47]. The term "tinkerer" in this focus emphasizes the invention or re-purposing of products. Thus, when students consider engineering from a designer/tinker perspective, they see the work of an engineer as being a *tinkerer* perhaps fixing something that is broken or refining a product or as a *designer* of new or novel products or inventions. Engineering education programs that include opportunities to tinker may reinforce this student perception.

(c) *Historical Focus 3: Engineers trained to be 21st century professionals meeting humanistic-social needs—21st Century*: In 1918, the Carnegie Foundation for the Advancement of Teaching published the Mann Report [48] describing the state of engineering education programs and curriculum on land grant universities beginning with the Morrill Act of 1862 [7]. The report recommended that engineering curriculum should include two areas of emphasis: one area that focuses on *scientific-technological* studies and a second area that focuses *humanistic-social* studies [45]. The more recent recognition of shifting role of engineers has brought humanistic-social aspect of engineering education to the forefront of the conversations about engineering [43], resulting in a call to redefine "engineering" to align with 21st century needs [43, 49–53]. The result is an expectation that 21st century engineering education must prepare students to consider the process of designing the human-made world to satisfy people's needs and wants [43]. Thus, when students consider engineering from this perspective, they recognize the *21st century* role of an engineer is to provide a needed service to society (humanistic-social) while using important scientific, mathematical, technological principles (scientific-technical).

Collectively, identifying the historical framework that United States undergraduate engineering students rely on to define engineering, can provide a more holistic way of assessing how students are being prepared as engineers and how they identify themselves as engineers and professionals. One of the goals of our exploratory mixed method cross-sectional study was to determine if patterns of historical influences in engineering education were present in student perceptions and to explore the potential for an association of these historical domains to levels of student professional identity development.

3. Methods

3.1 Motivation and research questions

The motivation for our research was our consideration that professional identity includes an interplay of individual, social and systemic influences, and is associated with student knowledge of the practices and norms of professional engineers. Therefore, we situated our research as an exploratory mixed method cross-sectional design during a critical period in undergraduate students' engineering education and level of professional identity development (e.g., transition from sophomore to junior year). We conducted our research at a doctoral granting and public land grant research university in the western United States.

The overall goal of our research was to gain a deeper understanding of the association between the current level or stage of student engineering professional identity development, the identity domain focus they use to communicate their perceptions of the engineering profession, and the historical perspectives they use to describe the work of engineers. We structured our cross-sectional exploratory research to determine how these three constructs might be related, rather than how individual students develop over time.

We used the following research questions to guide our investigation:

- What levels of undergraduate engineering students' professional identity development do they communicate when asked about their perceptions of the engineering profession?
- What historically-grounded perspectives or foci do undergraduate students use to describe the professional work of engineers?
- What dominant domains (individual, social, or systemic) do engineering students use when describing the professional work of engineers?

3.2 Research participants

Our participants were the 275 undergraduate engineering students who volunteered to participate in our study—a sample of convenience—and the participant response rate was 95%. Participants were enrolled in an engineering preparation program in a doctoral degree granting university in the western United States for an average 2.16 (*SD* = 0.51) years, had taken an average of 82.76 (*SD* = 30.45) university-level science and math curriculum semester credits with an average of 34.52 (*SD* = 21.21) semester credits in engineering. The participants had completed an average of 3.79 (*SD* = 1.28) years of post-secondary education. The students worked an average of 3.27 (*SD* = 2.14) hours in a job while attending classes. The students were distributed among Mechanical (32%), Civil and Environmental (32%), Biological (18%), Electrical and Computer (11%), and Other/undeclared (7%) Engineering. The students had an average age of 22.8 (*SD* = 3.49) years (a common average for undergraduate students attending this institution) and were composed of 16% female and 84% male. The majority of the students were in their sophomore (73.6%) or junior (20%) year and enrolled in an engineering degree program.

3.3 Data collection materials

To gather our data, we designed a two-part survey. We designed the first part of the survey to gather demographics, and designed the second part of the survey to gather the engineering students' knowledge and perceptions of engineering and perspectives of themselves as engineers.

3.3.1 Demographics

To collect participant demographic data, we created a 34-item survey associated with students' personal data (e.g., age, gender), academic experience and achievement (e.g., year in school, number of semester credits, GPA), their engineering work experiences and activities (e.g., club membership, employment, engagement in engineering experiences or research).

3.3.2 Students' perceptions of engineering

Given the exploratory nature of our research it was necessary for us to develop original items aligned with our guiding research questions that would prompt responses reflective of the students' perceptions of professional engineering. Thus, to collect the participants' perceptions of engineering and themselves as engineers we designed a series of open-ended, free response items. Given the nature of our targeted constructs we determined that selected response items may lead to students selecting the "right answer" which is likely to be misaligned with their communicated perceptions [21] which led us to consider free-response items. Given the contextual nature of professional identity and the exploratory framework of our research we recognized the need to develop original items to achieve our goals of gathering meaningful data (see Table 2). Because our research was exploratory and we were unaware of the information students may share, we were left with a limited basis for judging item validity. However, to guide and justify our item development we considered our research goals, the research literature, our many years of interacting with engineering students, and the exploratory framework of our study. The result of our item development was six free-response prompts

Table 2. Self-Reflective Free-response Questions about Student Professional Identity in Engineering

Item prompt
(1) In your own words, define 'engineer'.
(2) In your own words, define 'engineering'.
(3) Do you consider yourself an engineer? Why or why not?
(4) What are your professional goals in becoming an engineer?
(5) What are the essential skills of a professional engineer?
(6) What challenges do you have when working in group engineering projects?

intended to elicit data reflective of students emphasized domain of professional identity at the point in time of the study since their development and perceptions may evolve over time and with further experience in the field. As such, we developed our items to gather data that would allow us to determine the cross-sectional levels of the students emphasized professional identity domain, their historical perspective of engineering, and levels of professional identity development.

3.4 *Data collection*

All data collection took place online using web-based surveys (Qualtrics). We contacted several engineering professors at the university to request access to their students and allowed the faculty members to determine if and how they were going integrate the survey into their courses (e.g., participation points) and the timeframe for student participation. We provided the professors with the names of those students who participated in our study (for extra credit incentive purposes) but we did not provide them access to the students' responses. We allowed two weeks for data collection.

3.5 *Data coding*

To examine our participants' responses to the six free-response items, we used a constant comparative approach [54] applying a series of *a-priori* codes (see Table 3) based on our research questions and the extant research (e.g., level of professional identity development; [21]). For example, we examined the engineering students' survey responses through three different lenses: (1) level of professional identity and their perceptions of themselves as engineers (*students' self-proclaimed level and our researcher-coded level*); (2) the domain of professional identity emphasized in their descriptions of the work of engineers (*individual, social, systemic*); and (3) the historical focus they used to describe engineering (*Mediator, Designer/Tinkerer, 21st century*). We did remain open to the emergence of additional codes but found that our coding was comprehensive enough to effectively analyze our data.

We began all coding with a discussion of the codes and examples of each of the possible coding outcomes based on the students' responses. We then independently coded 20 student responses and compared our results. We discussed differences and again coded 20 more responses. After the second iteration of coding we had nearly complete alignment of coding at which point one of our research team members completed the coding of the data set. Intercoder agreement for both iterations of coding exceeded 90%.

3.5.1 *Coding for professional identity development*

In our examination of the current students' level of professional identity development, we conducted two phases of coding. The first phase of professional identity coding was based on the level participating students' self- proclaimed or self-identified themselves as engineers. The second phase of coding was based on the communicated levels of professional identity reflected by the students' responses to our items.

In the first phase of coding, we examined the data for the students' self-proclaimed level of engineering professional identity, scoring the students' responses on a four-point scale ranging from 0

Table 3. Criteria used to Code Student Self- Proclaimed and Communicated Levels of Professional Identity Development

		Phase 1 Coding (Self-Proclaimed)	**Phase 2 Coding (Researcher-Coded)**
Engineering Professional Identity Level	**Scoring Value**	**Engineering Professional Identity Criteria**	**Criteria for Scoring Level of Engineering Professional Identity**
Follower (No or very low Engineering Identity)	0	Responded with a "No" or synonym. Or left response blank.	References to norms, practices, behaviors, and interactions not specific to engineering and lack details related to engineering, references external.
Inquirer (Low Engineering Identity)	1	More negative in response than positive. "little bit," "I'm learning," "I'm working toward."	Responses have some references to norms, practices, behaviors, and interactions of engineering, but not detailed enough to demonstrate deep knowledge of the profession.
Contributor (Moderate Engineering Identity)	2	More positive in response than negative. "Almost an Engineer," "Engineer in training," "becoming an Engineer."	Responses reference norms, practices, behaviors, and interactions of engineering are consistent with professional engineers but are void of professional leadership.
Collaborator (High Engineering Identity)	3	Responded with a "Yes" or synonym	Responses reference norms, practices, behaviors, and interactions of engineering are consistent with professional engineers and reflect professional leadership.

and 3 as shown in Table 3. In this coding scheme a "0" represented students who do not consider themselves as "engineers"; "1" represented students' perceptions of them becoming "a little bit like engineers"; "2" represented students' perceptions of themselves as "engineer-in-training"; and "3" represented students' perceptions of themselves as "fully trained engineers" (see Table 3).

In the second phase of professional identity coding, we determined the level to which the students' current responses for *all* six free-response items were aligned with the four levels in the STEM professional identity model proposed and applied by Nadelson *et al.* [21]. The scale allowed us to classify the level of identity on a four-point scale (from none to high levels of professional identity) where a "0" represented the identity of a *follower* which may be associated with the equivalent self-proclaimed response of "I am not an engineer" while a "3" was representative of a *collaborator* which was associated with the equivalent self-proclaimed response of "I am an engineer." Also, we examined students' descriptions of engineering and the work of engineers for indicators of level communication of the professional norms, practices, behaviors, knowledge of the engineers, and interactions associated with the work of professional engineers. In Table 3, we provide the criteria used for coding level of engineering professional identity.

3.5.2 Coding for historical focus of engineering education in the United States

The second major lens through which we examined the data focused on coding the participants' responses for the engineering education historical emphasis students used to describe engineering as

Table 4. Framework used to Code Historical Reference to Engineering Education

Historical Focus	Descriptive (Coding) Terms	Historical Characteristic
Mediator	Use science, math, and technology.	Engineers trained as mediators of science, math, and technological innovation.
Designer/Tinkerer	Inventor, problem solver; mechanics, fix things.	Engineers trained to be designers and planners of industrial processes.
21st Century	Professional, real world application, service, society.	Engineers trained to be 21st century professionals meeting humanistic-social needs

Table 5. Domains of Engineering Students' Profession Identity

Facets of PI (Dimension)	Elements of Facets of PI (Dimension Specific)	Examples of Codes
Individual	• Knowledge • Skills • Attributes • Internal Influences	• Time management • Dealing with rejection • Accountability • Responsibility—role • Leadership • Sense of belonging • Motivation—career • Mastery—beyond—exceed expectations • Performance—minimal—meet expectations • Creativity—potential solutions • Critical thinking • Content knowledge—math/science/writing/reading • Experience—similar work/clubs/internships/REU • Think like an engineer • Mindset/perceptions of the field
Social	• Activities • Practices • External Influences	• Problem-solving in groups • Completing projects • Working in teams • Communicating result—reports/presentation • Knowledge of the problem • Recognizing solutions • Solutions meet goals • Interactions—Family, peer, friend, teachers, neighbor, church • Media—web sites, news, entertainment
Systemic	• Norms • Relationships • Structures & Processes	• Meeting the needs of the stakeholders • Attends to criteria and constraints • Process—engineering design • Professional engineer exam/license • Professional responsibilities of instructors • ABET—Accreditation

Mediator, *Designer/Tinkerer*, or *21st Century* (see Table 4). In coding for historical emphasis, we considered the students' responses to the six free-response items collectively. We realized that students may have communicated ideas representative of multiple domains thus, in our coding we focused on the dominantly represented historical perceptive. We categorized descriptions of engineering that focused on applying science, math, and technology as *Mediators*. We categorized respondents' engineering descriptions focusing on mechanical work, repair, inventing, or problem solving as *Designer/Tinkerers*. We categorized participants' responses focusing on the meeting the needs or wants of others or making the world a better place and service to society in their explanations of engineering as *21st Century*.

3.5.3 Coding for domains of professional identity in engineering students

The third lens that we used for examining our data focused on determining the dominant professional identity domain that the students used in their communication of the work and goals of engineering professionals. In this round of analysis, we classified responses along *individual*, *social* or *systemic* domains (see Table 5). We categorized the participants' responses as being aligned with the *individual* domain of professional identity based on references to personal knowledge, skills, attributes, and internal influences. We coded responses as being aligned with the *social* domain of professional identity based on references to interactions with others in activities, practices, as well as others as being external influences. To determine alignment with the *systemic* domain of professional identity we coded the participants' responses for references to professional preparation, licensure, or professional norms.

4. Results

4.1 Levels of professional identity in engineering students

Our first research question asked: *What levels of undergraduate engineering students' professional identity development do they communicate when asked about their perceptions of the engineering profession?* To answer this question, we examined the coded levels of self-proclaimed professional identity, the coded levels of professional identity detectable in descriptions of engineering and the work of engineers, and the correlation between the two variables. Our analysis revealed an average of 1.64 (SD = 1.35) for the self-proclaimed levels of professional identity (using a 0–3 four-point scale), which is somewhere between an *inquirer* and *contributor* in terms of professional identity (see Table 3). In contrast, the level of professional identity found in coding the students' descriptions yielded an average of 0.32 (SD = 0.56) which is more closely aligned with a *follower* (using the 0–3 ratings four-point scale). Our correlational analysis of the coded levels of self-proclaimed professional identity and coded levels of professional identity detected from students' description revealed no relationship ($p > 0.05$). Further, our descriptive analysis revealed a much higher level or professional identity in the students' self-proclaimed responses than their communication suggests they actually hold (see Fig. 2).

The correlation between the researcher-coded and self-proclaimed levels of professional identity was not significant ($r = -0.02$, $p > 0.05$). Thus, our results suggest that our participants' perceptions of themselves as engineers was much higher than what they communicated to be the practices, norms and behaviors of engineers, and that there was no relationship between the levels of perceived and communicated engineering professional identity by the students. Our coding of responses did not exceed a rating of "2" for any of the participants. In Table 6, we provide responses to our six free-response items that were representative of those that we coded as having professional identities at levels 0, 1, and 2.

4.2 Historical focus

Our second research question asked: *What historically-grounded perspectives or foci do undergraduate students use to describe the professional work of engineers?* To answer this question, we examined the participants' responses coding for the *Mediator, Designers/Tinkerer*, and *21st Century* engineering historical foci. Our analysis revealed that 91.64% of our participants defined engineers as *Mediators*, out of which 21.83% (55 students) provided definitions for engineers as a mixture of *Mediators* and *Designers/Tinkerers*. Only 1.59% (4 students) defined engineers exclusively in alignment with the NAE's definition of a *21st Century* professional and

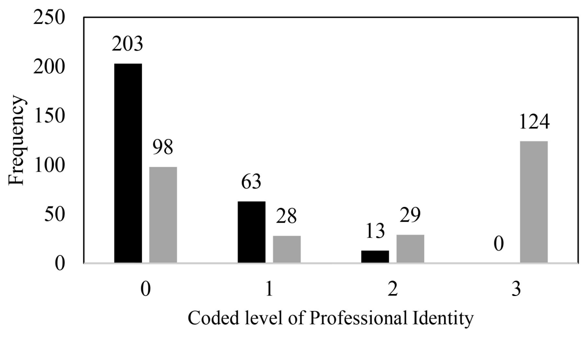

Fig. 2. Coded (left bars) and self-proclaimed (right bars) of engineering student professional identity.

Table 6. Example Student Responses to the Six Free Response Items Representative of our Coded Level of Professional Identity (PI)

Engineering Professional Identity Question	**Self-proclaimed PI level**		
	0	*3*	*2*
	Coded PI level		
	0	*1*	*2*
What are your professional goals in becoming an engineer?	*To find better work.*	*Work in the industry until I have enough money and connections to start my own company.*	*Honestly, I'd love to make something new that helps a lot of people, but everyone hopes to do that. I just look forward to continuing to learn and discover and build.*
Do you consider yourself an engineer? Why or why not?	*No. I don't know enough.*	*Yes. I love to innovate, invent, build, design, and fix things. it's my hobby and I'm good at it.*	*Yes, but not yet a professional engineer. Engineer is a broad term. Even just in studying something engineering related I'd consider myself an engineer through the homework and projects I do.*
In your own words, define 'engineering'	*Solving problems with discovered techniques.*	*The art of being an engineer.*	*Creating or building for the purpose of making something.*
In your own words, define 'engineer'.	*Tinkerer and problem solver.*	*One who invents, innovates, builds, designs, fixes things, and solves problems. 2. A practical mathematician/ physicist.*	*One who creates/improves using man-made/man-discovered techniques*
What are the essential skills of a 'professional engineer'?	*Math and common sense.*	*Creative, good at math, and an intuitive understanding of the way things work in the physical world.*	*Fortitude. Observant. Patient. Diligent. Ambitious.*
What challenges do you have on working in group engineering/ projects?	*I dislike working with others.*	*Dealing with slackers.*	*Communication is always difficult because many individuals can't communicate well and others just don't want to work with a group. Also, everyone works at their own pace and to get a group to be "engineers" together is unfair because undoubtedly a couple of individuals end up taking control because they get it while the rest of the group would get it, but get lost along the way . . .*

another 4.37% (11 students) mixed the *21st Century* with *Designer/Tinkerer*. Our results suggest that how undergraduate engineering students envision the scope and work of engineers is misaligned with the current perceptions of 21st century engineering. In Table 7, we provide some examples of student responses about what they perceive how the work and professional goals of engineers in aligns with the three prominent historical perspectives.

4.3 Professional identity dimensions

Our third research question asked: *What dominant domains (individual, social, or systemic) do engineering students use when describing the professional work of engineers?* To answer this question, we analyzed the frequency of students' referencing of *individual*, *social*, or *systemic* influences in their descriptions of engineering and the work of engineers (see Table 5). We used the references to code the dominant identity domain referred to by each student. Our analysis shows that most of the participants described engineering and the work of engineers using all three domains but the *individual* domain was the most coded domain (54%). The students' responses aligned with the *systemic* domain at a moderate level of incidence (25%). The least aligned domain found in the responses was the *social* domain at 20% (see Fig. 3).

Table 7. Example Responses of Students' Historical References to Engineering and the Work of Engineers

Representative student responses to the following survey question: *In your own words, define 'engineer'.*
• "An engineer is someone that designs technology for a living." (Designer/Tinkerer)
• "Person who uses scientific laws." (Mediator)
• "Someone who works to solve the world's problems or creates new technologies through innovation and invention." (21st Century)
• "Person that designs and builds." (Designer)
• "A leader in progression, development, and improvement." (21st Century)

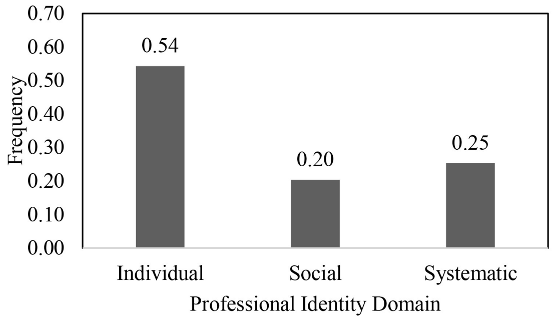

Fig. 3. The frequencies of domain references used by the students in their professional engineering descriptions.

4.4 Correlational analyses

We performed a Chi-square test of independence to determine if the *individual*, *social*, and *systemic* domains of professional identity were related to the students' levels of engineering professional identity development. Our Chi-square analysis indicated independence between the identity domains used to describe professionals and the coded levels of professional identity, as well as, the students' self-proclaimed levels of professional identity (non-significant—N.S., $p > 0.05$). The lack of association may be attributed to the low power due to minimal responses along the *social* domain of identity and few students at the level 2 and no students at level 3 in the coded communicated levels of professional identity.

Also, we performed a Chi-square test of independence to determine if the domains of professional identity (*individual*, *social*, *systemic*) were independent of the students' historical foci for engineering as a profession. Student responses that included a mix of historical references (e.g., *21st century* with *designer*) were removed from the analysis. Results showed that a statistical significance was found ($\chi^2 = 19.73$; $df = 9$; $p = 0.02$) suggesting a dependence between the professional identity domains and engineering education historical foci.

Finally, we performed a Chi-square test of independence to determine if the levels of self-proclaimed and researcher-coded engineering professional identity were related to the student historical foci used to describe engineering. Again, we did not include student responses that reflected a mixture of definitions (e.g., *21st century* with *designer*). Our analysis revealed independence between historical focus and the self-proclaimed levels of professional identity ($\chi^2 = 14.54$; $df = 9$; $p = 0.10$). However, we did find dependence between the historical focus and the researcher-coded levels of professional identity ($\chi^2 = 43.37$; $df = 6$; $p < 0.01$) suggesting that there is a relationship between the level of perceived professional identity and historical focus used by students to describe engineering.

5. Discussion and implications

In our research on engineering student professional identity development we exposed a number of findings that are likely to influence student persistence as professional engineers. We maintain that it is necessary for students to have an accurate understanding of the contemporary perspectives of engineering in order to develop as professionals and form a professional identity that is consistent with the work of engineers and expectations of engineering professionals. By determining and then addressing students' perceptions of professional engineering and professional identity, educators will likely increase students' professional understanding, professional preparation, and persistence as engineers.

In our examination of the students' professional identity development, we found that their self-proclaimed levels were much higher than the level of development than communication indicated, suggesting that students tend to inflate their perceived levels of professional identity development compared to the level their communications would suggest they have achieved. We maintain that the students tend to over inflate their levels of professional identity development because they have views of engineering that are not aligned with those of the profession, using academic references rather than professional references to frame their professional identity [21, 54]. While we cannot conclude a causal relationship between professional references and these perception, our findings do point to an over-inflation of students' current perceived levels of professional development. Literature suggests that a sustained mismatch between students' views of engineering as a profession during their engineering education and their perceptions of the engineering profession in the future may lead to a disengagement or withdrawal from engineering preparation programs [11, 12, 29, 55–63]. Thus, reiterating to engineering students' messages focused on their current and future professional roles in engineering will likely facilitate a persistent view and connection between their preparation as an engineer and their future profession. Examining the ways in which engineering education can be modified to help students effectively develop accurate perceptions of engineering and the corresponding professional identity is an important direction for continued research.

Our second finding was that the majority of the students held perceptions of engineering that align with the historical perspective of engineers as *Med-*

iator of science, math and technology, again suggesting that students' understanding of engineering is inconsistent with current conceptions of the profession. The NAE characterizations of the work of engineers [43] is that of serving the needs and wants of a 21st century society, yet the structure of our engineering preparation programs may be such that a perception of service to society by augmenting is not fostered in students. Rather, it is more likely that the curriculum and instructional approach of engineering programs and emphasis on academic performance, which has changed little over the decades, fosters student perceptions of engineering as the process of applying math, science, and technology.

The perception of engineers as *Mediators* may deeply influence students' development of an engineering professional identity leading to over inflated perceptions of themselves as being prepared to be engineers. The perception of the work of engineers as *Mediators* may be further reinforced by a strong instructional/curricular emphasis on problem-solving in course work that involves applying math, science, and technology. Thus, to help students develop a perception of engineering as being focused on service to citizens needs and wants in 21st century society we may need to shift the curriculum and instruction to emphasize more on the work of engineers in today's society. Also, providing a historical context about engineering education to the students and explicitly tying historical perspectives to the professional identity of engineers may improve outcomes in students' perceptions of the field. Inclusion of activities such as service learning or humanitarian engineering and explicit conversations about the role of engineers in a 21st century society may lead to shifts in students' perceptions of engineering and their role as engineers. The focus on 21st century skills may lead to more accurate perspectives of engineering and the corresponding development of engineering professional identity. Examining the students, perceptions of engineering and their professional identity before and after engaging in activities such as service learning or other humanitarian engineering opportunities is currently underway [54].

In our examination of the professional identity domains that the students relied upon to describe engineering and themselves as engineers we found a high reference to the *individual* domain, followed by the *systemic* domain. We speculate that the structure of engineering programs is such that students tend to be individualistic, and therefore self-reliant in their coursework and related activities, which reinforces an engineering professional identity based on individual efforts or tasks and not on interactions with others. The potential for engineering education programs to create contexts that promote students' focus on the *individual* domain when considering professional identity is likely to position the students to develop an inaccurate sense of themselves as engineers. As such, an individually focused professional identity would not take into account the engineering norms, processes, and skills needed to work in teams and interact with society members. The lack of attention to the *social* domain and the importance of social interactions to identity development may suggest that students do not consider the ability to work with others a part of their professional identity and therefore do not strive to develop social skills as part of their professional preparation, which would then be absent or substantially constrained in their future professional roles [54, 61, 62]. Again, engineering preparation programs may need to provide explicit attention toward the critical nature of social interactions to work in engineering to help students understand the importance of social interactions to the profession and internalize social interactions as part of their professional identity. Empirically documenting outcomes between efforts to enhance student understanding of social interactions in engineering and students' professional identity development is a future direction for our work.

Overall, our research indicates that there is likely a very strong association between students' historical perceptions of engineering, the identity domains that they associate with the profession, and levels of professional identity. Further work is needed to provide additional empirical documentation of the relations among these three variables and potential other elements critical to students' professional identity development. However, there is a possibility that the structures of our engineering preparation programs are reinforcing certain perceptions of engineering that are not consistent with 21st century engineering professionals. Consequently, there is likely a need to evaluate engineering preparation programs to assure they are promoting accurate understanding and perceptions of engineering, for it is upon their engineering education that students are forming their professional identity.

6. Limitations

In our research, we attempted to develop a series of methods to code for *individual, social*, and *systemic* domains relationship to students' levels of professional identity development while also considering the role that historical characteristics of students' engineering education play in formation of their perceptions. While our study exposed discernable trends in student perspectives (some consistent with the research of others), our research was limited to one institution and to primarily sophomore and junior level students. We recognize that institutional characteristics may influence the philosophy and approach used in engineering education, which may in turn influence the levels or rate of students' professional identity development. We also recognize that an engineering students' professional identity may be different across disciplines based on the goals and mission of a particular department in a given institution and region within the United States. Future work should compare levels of student professional identity development and perspectives based on institutional characteristics and with greater ranges of students to gain a better understanding on how differences may be influenced by systemic factors within and between institutions.

Our study did not consider how faculty members' understanding and perceptions of engineering education guide the *individual* and *social* domain that undergraduate students are exposed to in the classroom. Studies have pointed to the important and significant role that faculty members play in the identity formation of students [15, 21, 54] but further research is needed to explore how shifts in practice may influence student professional identity development.

Another limitation was the nature of our data collection. Although we chose to use free response items to mitigate the high level of probability that students would simply select the right answer in a selected response survey, they may have not spent the time to reflect on the items and provide complete thoughts and ideas related to questions. However, our analysis revealed responses consistent with the literature and among the students, suggesting the data were representative of the students' perceptions and effectively reflect their thoughts about professionalism, engineering, and their professional identity levels. Future research may include student interviews to gather even more in-depth data and determine the alignment between student written responses and their verbal sharing of idea. Also, future research should consider the similarities and differences of the historical patterns among disciplines, institutions, and student progression in their engineering education.

While students heavily relied on individual factors to consider their responses, we did not further explore the funds of knowledge [63] that may have contributed to these responses. As engineering education varies by region, culture, country, and historical characteristics [64], understanding deeper the epistemological sources that students use to frame their knowledge is needed. We are currently exploring these relationships.

7. Conclusion

In our research, we set out to determine how students perceive themselves as professional engineers, a critical indicator of their engineering professional identity development. To gain a deeper understanding of the students' perceptions we also coded their responses relative to historical references to engineering and the domains of professional identity they rely on when communicating their perspectives. Our findings revealed that with respect to the first research question (levels of undergraduate engineering students' professional identity development) that engineering students have elevated self-proclaimed levels about engineering compared to the actual development levels they communicate. For the second research question (historically-grounded perspectives of undergraduate students), we find that students reference the *Mediator* domain of engineering, a reference whose inception began in the 1800s and continues to be present in U.S. engineering education curriculum today [5, 7, 44, 45]. Finally, our third research question explored the domains used by students when describing the work of engineers and results showed that the *individual* domain predominated suggesting that engineering students rely heavily on their individual efforts as a basis for their perception and not on their interactions with others. Based on our findings, we suggest students' engineering education should focus on helping them understand the work, norms, and expectations of professional engineers and the role of a 21st century engineering professional play in today's society as it is likely critical for their development of engineering professional identities.

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