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Exploring Students' and Instructors' Perceptions of Engineering: Case Studies of Professionally Focused and Career Exploration Courses

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Work in Progress

Abstract

Previous work developed a working definition of engineering professional identity (EPI), defined as the degree of internalization of the norms, behaviors, language, values, and practices of engineering. This EPI definition is rooted in historical perspectives of U.S. engineering education and incorporates four levels of engineering professional identity across three domains of development (individual, social, systemic). We found that the historical perspectives played a role in how students understood what engineering is and does, in turn affecting their level of professional identity development. We suspect that the type of course (technical versus non-technical) may contextually influence students' perspectives on engineering. This work-in-progress study explored two different courses (cases). The first course was a junior-level communication course for engineering majors. The second course was all women-in-engineering course tailored to entry-level undergraduate engineering majors. Both courses are offered in the same College of Engineering at a western U.S. research university, are taught by female instructors, and are considered professional development (non-technical) courses within the undergraduate curriculum.

Preliminary findings suggest that women in engineering hold different perspectives of engineering compared to those in the majority group (e.g., male/Caucasian). On the other hand, engineering courses focused on communication shifted students' understanding of engineering and their self-proclaimed levels of engineering professional identity. Results also suggest that non-technical engineering courses may be advantageous towards guiding students' development of a more societally relevant engineering professional identity.

Introduction

The increasing demands for a 21st century postsecondary education-- that incorporates the liberal arts, humanities, and social sciences--in contrast to the stasis of engineering curriculum, has catalyzed an engineering education "identity crisis" [1]-[9]. Without an understanding of the engineering norms, practices, and worldviews that engineering students and instructors carry from their courses, there is an increased risk that underrepresentation in engineering continues.

This work in progress paper aims to expand a previously developed study on *engineering professional identity* by exploring two unique engineering courses (serving as case studies) at a college of engineering at a western institution in the U.S. One course had the central focus to help engineering students develop professional skills based upon communication while the other course aimed to help underrepresented women in engineering to understand and plan for careers in engineering. Both cases are uniquely positioned to help engineering education researchers to understand how professionally-focused and career-planning engineering courses could guide students' perceptions about engineering. A sub-element of this work was to understand if there were any time-dependent (e.g., freshmen versus junior) or gender-dependent differences in their perceptions. Finally, we aimed to understand if the instructors' perception of engineering varied or paralleled their students' perceptions about the field.

Literature Review

Developing a Working Definition of Engineering Professional Identity

In 2017, Villanueva and Nadelson developed a working definition of *engineering professional identity* in response to the term being conveyed inconsistently in the literature [10]. In turn, the authors sought to create a working definition of engineering professional identity that considers how "seasoned professionals might self-describe who they are in relationship to their profession" [10, p. 640]. Furthermore, the working definition was developed to consider sources of information and interactions that are derived from individual, social, and systemic experiences and that these are not fixated with time and experience.

Engineering professional identity premises on an individual's perception of engineering and the sources they identify as integral to their understanding of the engineering profession. Based on prior research from some of the authors, three sources were suggested. Individual sources consist of the personal levels of engagement and motivation that enables an individual to internalize the norms, practices, and views about a profession [11]. The social sources involves the interactions within social environments that inform an individual about a profession [12], [13] while the systemic sources involves the professional conditions and guidelines that enables the transmission of norms, sharing of information, and practices of a profession (e.g., classroom, professional organizations) [10].

For engineering professional identity, the authors recognized that this construct is evolving and intertwined in that the design of an engineering curriculum (from a historical standpoint) could play on students' perception. Three historical foci (along with its potential combinations) were identified in a prior paper [10]: *Mediator* (established in 1802), *Designer/Tinkerer* (established in the 1880s), and *Social/Servant* (established in 1918 to present). *Mediator* was used to categorize those perspectives where the field of engineering is described by the application of science and math. *Designer/Tinkerers* were used to classify perspectives that identify engineering as a field that builds or fixes objects or things, refines products, or creates inventions. *Social/Servant (21st century definition of engineering)* encompassed the perspectives of engineering that imply a service to society while applying scientific/technical knowledge and skills. A summary of these historical foci are found in Table 1. An understanding of these perspectives from students and instructors can allow researchers to identify the predominant norms that are emphasized on engineering courses.

Table 1. Summary of Three Historical Foci of EPI [10]

Mediator (established in 1802)	**Designer/Tinkerer** (established in 1880s)	**Social/Servant** (established in 1918 to present)
Engineers trained as mediators of science, math, and technological innovation	Engineers trained to be designers and planners of industrial processes	Engineers trained to be Social/Servant professionals meeting humanistic-social needs

New Considerations of Engineering Professional Identity

It is important to note that while work has been developed in engineering identities [14]-[17], the working definition of engineering professional identity posed by the authors is different.

In the authors' views, engineering professional identity is more holistic and requires an integration between how an individual develops an identity (formational identity) and how they perceives their identity within a profession (professional perceptions; Figure 1).

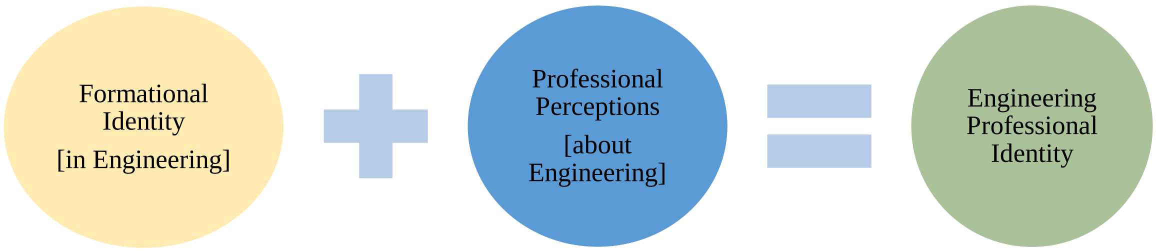

Figure 1. Proposed relationship between formational identity and professional perceptions about engineering

Formational Identity: This umbrella term incorporates various forms of identities that are enacted and internalized in response to the presence of culture, gender, sex, age, ethnicity, social economic status, education, religion, and geographical region [18], [19]. This form of identity can substantially influence an individual's sense of ability, success, and belonging within a profession, in this case, engineering [20]-[22].

Professional Perceptions: Professional identity perceptions about engineering is the manner by which "seasoned professionals might self-describe who they are in relationship to their profession" [1, p. 640]. Professional perceptions takes place through socialization and exposure to the practices, interactions, goals, and requirements of the profession. Professional perceptions may associate with success and skill acquisition of that profession. Also, individuals may hold multiple identities within a profession [23], particularly if an individual has varied and at times disparate commitments and responsibilities or if their profession changes over time.

Engineering Professional Identity: This holistic term encompasses the internalization and enactment of the *norms, behaviors, language, values, and practices* unique to the contextual work of engineers [10] and whose internalization is dependent upon an individual's formational identity and perceptions of the field. The authors also recognize that norms, behaviors, language, and values are situational and may not be able to be standardized. As such, it is important to explore/extract these contextually and from the individuals themselves.

Previous findings on engineering professional identity
Recent work published by Villanueva and colleagues [10], found that for 275 undergraduate engineering students (84% male and 16% female; response rate of 95%) surveyed at a western U.S. institution, engineering students taking primarily technically-driven engineering courses (e.g., statics, dynamics, capstone design), self-identified themselves as engineers. However, when communicating the practices, norms, and behaviors of engineers, most of these students could not accurately explain the requirements of the field. Furthermore, over 91% of students indicated that the roles of engineers resembled more closely with the *Mediator* definition, which greatly differs to more a recent *Social/Servant* definition of engineering [30] where global competencies and social responsibilities are emphasized.

Scope of Work In Progress Paper

The authors aimed to first expand the engineering professional identity framework originally proposed [10] by understanding engineering courses whose central focus are on professional skill development and career exploration/planning. The intent is to begin to understand how course foci can influence students' and instructors' perceptions about engineering.

Positionality
All authors in this work come with varied perspectives of engineering education through teaching experience, research experience, or professional experiences in engineering. Some of the authors are first-generation or underrepresented in engineering and all have a stake at informing engineering educators about the role course foci could have on engineering students' and instructors' perceptions of the field.

Research Questions
This work-in-progress paper follows a collective case study design and aims to answer the following central and sub-research questions:

- *Central Question: In engineering courses where professional skill development and career exploration/planning are central, how do engineering students' perceptions of the field vary?*
    - *Sub-research question 1: In what ways are the course instructors' perspectives similar or different to students' perceptions of engineering?*
    - *Sub-research question 2: In what ways (if any) does gender and level of engineering education influence students' perceptions of engineering?*

Course and Instructor Descriptions
In the Work-In-Progress study, the research team explored two differing engineering courses as cases. The first course (case) was a Technical Communication course, which is considered a non-technical course to support students' writing skills. The course is a mandatory course for engineering majors at the same institution of the original study [10]. The students enrolling in the course are primarily in their junior year in engineering and represent the majority of disciplines in this college. The semester prior to this work in progress paper, data on the original iteration of the engineering professional identity study was published [10]. The authors followed the same participants in this Technical Communication course in an effort to capture the changes in perceptions about engineering for this same cohort contextualized to a new course.

The second course was a Women in Engineering course. This is an elective course offered by the engineering college for female engineering students during their freshmen and sophomore years. This case was selected for two reasons. The first was based on preliminary findings from Villanueva [31] suggesting that students' perspectives of engineering professional identity vary by gender and race. The second reason is that a woman engineer who formerly worked in industry and currently works in engineering advising teaches this particular course. The authors believed that the experience of this instructor may provide a different perspective of engineering to the students that may be both perceptually- and formationally-guided.

Both of these courses are bounded by the location (same U.S. western university) and college (covered within the same college of engineering), and population (all engineering students). The authors aimed to provide an in-depth understanding on how engineering course types and their foci could guide students' and instructors' perceptions about engineering.

One additional boundedness of the study are the instructors' expertise. For the Technical Communication course, the instructors were two female lecturers who are not engineers by training but have ample experience teaching professional courses to undergraduate students. One has 6 years of experience teaching communication to business, English, and engineering majors. The other instructor has over 15 years of experience in teaching professional and technical communication courses in colleges of engineering and business. One of the instructors has an additional 10 years of experience in student service administration (i.e., career services) and has served as consultant for leading employers and nonprofit organizations across the country in providing communication-based training to employees. While they are not trained engineers, they have taught engineering students for many years about the required communication competencies of their profession and disciplinary expertise (e.g., Mechanical Engineering versus Civil Engineering). For the Women in Engineering course, the instructor comes with a combined 16 years of engineering experience. Since then, she transitioned roles as a recruitment and retention specialist for the engineering advising office of this college for nearly six years. The Women in Engineering course was established in 2005 as an effort to retain women engineering students in the college.

Participants

Participants in the Technical Communication course consisted of 24 undergraduate engineering students (primarily juniors and seniors; 98% male). The Women in Engineering course was composed of 20 female undergraduate students in the first and second year of their engineering degree.

For both courses, disciplines of engineering included Mechanical Engineering, Computer Science, Civil and Environmental Engineering, and Electrical and Computer Engineering. Participation for this study was 98% for the Technical Communication course and 100% for the Women in Engineering course. Instructors provided incentives in the form extra credit. All procedures were compliant with Institutional Review Board policies.

Data Collection

In both courses, students were provided with a semi-structured survey developed by Villanueva and Nadelson [10]. The students in the Technical Communication course only participated in the first survey in the middle of the semester (around eight weeks into the semester) due to time constraints in the course. The students in the Women in Engineering course participated around the middle (eight weeks of the semester) and end of the semester survey (15 weeks of the semester). The survey questions were self-reflective in nature and designed to gather data representative of the students' perspectives of themselves as engineers and of the field (Table 2). The same questions were provided to the instructors to complete in written form via email.

Table 2. Summary of survey questions used [10]

(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 on working in group engineering projects?

Data Analysis

Axial and thematic coding of the responses occurred for the survey responses to these questions. Interrater reliability was derived among three individuals who had over a 90% agreement in the codes. Instructor responses were also coded in a similar fashion and were member-checked with the instructors themselves.

Results

The central research question asked: *In engineering courses where professional skill development and career exploration/planning are central, how do engineering students' perceptions of the field vary?* In the Technical Communication course, 47% of the students identified themselves as *Designers/Tinkerers*, 18% identified themselves as *Mediators*, and 35% identified themselves as *Social/Servant*. These results are starkly different from those based on data collected from a similar population and age group of engineering students enrolled in technical engineering courses (4%, 73%, and 2%, respectively; Villanueva & Nadelson [1]). For the Women in Engineering course, the authors found differences in responses between the middle and end of the semester values for historical definitions of engineering and the work of engineers (42% and 46% for *Designers/Tinkerers*, 15% and 13% for *Mediators*, and 42% and 42% for *Social/Servant*, respectively). Only the shift in historical references for *Mediator* was statistically significant ($p<0.001$). Representative responses from students for each course and category is summarized in Table 3.

The first sub-question was: (a) *In what ways are the course instructors' perspectives similar or different to students' perceptions of engineering?* The grade-level (freshmen versus level) and foci (professional versus career exploration) of the courses resulted in different instructors' and students' perspectives about what engineering is about (refer to the examples in Table 3). In the Technical Communication course, each instructor had a different perspective about engineering. One instructor mirrored the definition of *Designer/Tinkerer* while the other instructor mirrored the *Social/Servant* definition of engineering. While both instructors maintained the same course content and consistent lesson plans and assignments, students' perspectives about engineering varied between Designer/Tinkerer and Social/Servant. Few students (18%) acknowledged the *Mediator* definitions and none of the instructors mirrored this perspective.

For the Technical Communication course, we found that 54% of students identified individual sources in their responses (e.g., mindset) whereas social (e.g., mention of peers) and systemic (e.g., mention of institutional, departmental, or curricular initiatives) sources were not as influential in their perspectives (13% and 33%, respectively). It was interesting to note that compared to the original study, the social and systemic sources varied (13% versus 20% and 33% versus 25%, respectively) suggesting that engineering students enrolled in this Technical Communication course are beginning to understand the systemic elements behind their educational programs. The instructors for this course placed a greater emphasis on the individual development of the communication competency development (62%) and focused on teamwork and face-to-face communication as a secondary priority (38%). No mention on systemic components were identified.

Table 3. Representative quotes of engineering students' and instructors' responses about their perceptions of engineering; note that combinations of perceptions (e.g., Mediator with Designer/Tinkerer) were not included

	Foci	Mediator	Designer/Tinkerer	Social/Servant
Technical Communication (Junior-Level)	Professional competency development around technical communication	**Students (18%):** *"An engineer is someone who can apply knowledge of physics, chemistry, biology, math, how the nature/world works." (ID 03)* **Instructors (0%):** N/A	**Students (47%):** *"An engineer is someone who takes the time to think through a problem and find a solution. They have a technical knowledge of engineering principles." (ID 04)* **Instructors (50%):** *"Engineer is both a noun and verb. An engineer is a problem solver. An engineer is someone who can look at all the "parts" and create a "whole" that is better than the individual parts." (ID 01)*	**Students (35%):** *"a person who seeks to improve the quality of their own life and the lives of others by creating innovative things or ideas with the resources available to them." (ID 07)* **Instructors (50%):** *"An engineer is an individual who uses his/her creativity, problem-solving skills, ingenuity, and analytical skills to improve quality of life. Engineers influence all aspects of daily life: including the water we drink, the food we eat, the cars we drive, the medicines we take, the galaxies we explore"(ID 02)*
Women in Engineering (Freshmen-Level)	Career Exploration on Engineering Careers	**Students (46%):** *"Applied science to help others and solve problems by developing innovative solutions"(ID 13)* **Instructor (0%):** N/A	**Students (13%):** *"Learning to solve problems in new ways to make situations better, more efficient and safer"(ID 06)* **Instructor (0%):** N/A	**Students (42%):** *"Engineering is solving a problem to improve a part of our lives"* **Instructor (100%):** *"An engineer is an individual with specific knowledge, training and skills, who uses the knowledge, training and skills to solve individual and societal problems, enhance quality of life, advance technologies, and explore our world and beyond"(ID 03)*

For the Women in Engineering course, students gained perspectives of engineering via their individual (80%-middle of semester versus 45%-end of semester) and social (20%-middle of semester to 55%-end of semester) domains. Surprisingly, none of the participants seemed to suggest that they have acquired any systemic perspectives at that point of their engineering education (0% for both time points). The latter finding mirrored preliminary work by Villanueva [31] where women and underrepresented minorities do not have a strong grasp of engineering via systemic means. It is possible that these students may have not been actively involved in student organizations that would have saliently supported their sense of identity and professional skills development [33]. Student organizations and the need for students to engage in their engineering education, mirrored what the instructor of the course emphasized are important social sources (e.g., clubs; 36%) compared to individual sources (e.g., technical skills; 52%) and systemic sources (e.g., lifelong learning; 12%).

Our second sub-question was: (b) *In what ways (if any) does gender and level of engineering education influence students' perceptions of engineering?* In the Technical Communication course, primarily composed of Caucasian male students in their junior year, findings suggest that the students focused on the need to develop individual and systemic skills (Tables 3 and 4) whereas for the Women in Engineering course resulted in a change from individual sources to social skills (Tables 3 and 4).

Discussion

For the central research question, preliminary findings suggests that most students, regardless on the course and point in time that the data was collected, commonly identified that one of the primary roles of engineers entails that of a *Designer/Tinkerer*, which is a shift from the results of prior studies where most students identified with *Mediator* (Villanueva & Nadelson [1]). This suggests that professional engineering courses may influence students' perspectives of engineering but may not be sufficient to help them shift to a *Social/Servant* perspective. This may require a more connected community and societal experience (e.g., service-learning) in their engineering education [34], [35]. In future research, the authors intend to use a more granular approach to understand how the framing and structure of a course may influence students' perspectives about engineering.

For the first sub-research question, differences between instructors' and students' perspective of engineering and the sources used to describe engineering were explored. For both courses, the individual domain (those that involve an individuals' identification to a profession by knowledge and internalized factors; Table 4) predominated in students' perspectives about engineering. However, in the Technical Communication course, an increase was found in the systemic domains (those that involve an individuals' identification to a profession by a growing understanding of norms and expectations; Table 4) compared to the original study where students were enrolled in a technical engineering course. For the Women in Engineering course, individual domains decreased and social domains (those that involve an individuals' identification to a profession by their interaction with their social environment via peers, colleagues, and teachers; Table 3) increased. This finding may suggest a gender-specific role that these types of courses may play in the formation of students' identification with the profession. This mirrors findings from the Villanueva [31] where gender and race influence students' perspectives of engineering. Also, the lack of change in the systemic domain for the latter course suggests that there is a lack of familiarity about the systemic factors (e.g., accreditation) in engineering among female students [36], which may limit the full development and solidification of an engineering professional identity [10], [37]. Additional work is needed to the latter point.

Table 4. Representative examples of students' perceptions during the middle of the semester (Technical Communication Course) or middle to end of the semester (Women in Engineering course)

	Foci	Sources for Perceptions about Engineering
Technical Communication (Junior-Level)	Professional competency development around technical communication	**<u>Students:</u>** **Individual (54%):** -*“I would not consider myself an engineer to a hundred percent before I started working as one after my studies. But I believe I have a mindset of an engineer. I think of solutions not problems.” (ID 26, File 03)* **Social (13%):** -*“Being able to unify everyone’s ideas to conform the best solution.” (ID 13, File 05)* -*“A successful professional engineer communicates clearly and honestly with clients, co-workers, and others.” (ID 54, File 05)* **Systemic (33%):** -*“Working on [identifier removed] team has helped me gain these skills: I have learned to document my work clearly for other teammates to view; I have learned the importance of meetings and keeping to an agenda, and many other things pertinent to the nature of engineering, because we have placed ourselves in such an environment; not a classroom.” (ID 50, File Name 06)* -*“A professional should be proficient with engineering practices. A professional must be a continual learner.” (ID 54, File 05)* **<u>Instructors:</u>** **Individual (62%):** -*“Math is the skill that springs to mind first, but there are more skills that define a professional engineer. A “professional” has a level of expertise, responsibility, and accountability that he or she lives up to.” (ID 01, File 03)* **Social (38%):** -*“Engineers do not work in vacuum. They must be able to work with other people. People skills such as conversation, conflict management, trust, and credibility are essential.” (ID 01, File 03)* -*“The essential skills of an engineer go beyond technical skills. To be an engineer, students must also develop communication (written, oral, interpersonal), teamwork, initiative, problem-solving, leadership, and analytical skills.” (ID 02, File 02)* **Systemic (0%):** *N/A*
Women in Engineering (Freshmen-Level)	Career Exploration on Engineering Careers	**<u>Students:</u>** **Individual (80% to 45%):** -*“I would consider myself as an engineer; I feel that I am capable of the mindset and thought processes needed.”(ID 04, File 01)* -*“I do not consider myself an engineer because I have no skills, or knowledge base to solve important problems. If I am an engineer then anyone can be one, and then there is no point in working hard for four years.” (ID 12, File 01)* **Social (20% to 55%):** -*“Everyone has contributions to add, and engineers need to be willing to accept, and carefully consider suggestions and proposals.” (ID 14, File 02)* **Systemic (0% to 0%):** N/A **<u>Instructor:</u>** **Individual (52%):** -*“Many engineering students think the only things they need to be a good engineer are technical skills.” (ID 03, File 01)* **Social (36%):** -*“Having been in the engineering workforce, I know firsthand the necessity of communication, teamwork, leadership, and many other transferable skills…I repeatedly emphasize the critical need of involvement beyond the classroom, in research, clubs, student projects, etc.” (ID 03, File 01)* -*“I advise and mentor engineering students in various clubs and organizations so they can gain necessary professional skills.” (ID 03, File 01)* **Systemic (12%):** -*“Transferable skills are gained and strengthened in non-classroom environments.” (ID 03, File 02)* -*“…Life-long learning as tools and technologies improve.” (ID 03, File 03)*

Related to the second sub-research question, the authors assessed if gender or level of course influenced students' perspectives. While it was difficult to assess any changes in perspectives for the Technical Communication course for students' perspectives, it was interesting to note how the instructors' perspectives regarding the social and systemic sources did not mirror students' perspectives on such. This is contrary to what studies on professional engineering courses have suggested in its role at improving engineering students' perspectives of the implicit and explicit requirements of their profession [32]. It is possible that the instructors' gender compared to the student population (majority male) could have a role on this finding. Future work is needed to assess if gender and/or the instructors' experiences played a role in this difference.

For the Women in Engineering course, students resulted in a change among the individual and social domains with no changes in the systemic sources. It is possible that with the instructor's past experiences as an engineer in industry and her student advising experience, a significant emphasis was placed on teamwork and communication for this course, which may position these students to understand the expectations of the profession earlier in their careers. It is also possible that the presence of a female role model for a class of this nature, can influence on a positive extent, students' academic experiences and the process for uncovering of the expectations of the engineering profession [38]-[40]. Additional work is needed to this end.

Conclusion

Collectively, this study aimed to expand upon our definition of engineering professional identity by considering an individual's formational identity and their professional perceptions about the field. Preliminary findings suggests that students' individual sources and perceptions still continue to guide their perceptions of engineering. Interestingly, course foci (and grade level), instructor experiences, and perspectives about engineering may influence how students' internalized their views of the field. Also, a potential role of an instructor's gender and classroom composition in guiding these perspectives may have been found. Additional work to explore the latter phenomenon is warranted.

Implications for Practice

The findings from our Work-In-Progress study may begin to help engineering educators uncover how courses (and their instructors) can shape students' perspectives of engineering and of their roles in the field. Findings suggest that there is a gendered-role in students' perspectives of engineering as it relates to the domains that students use in describing the work and skills of engineers. Finally, while non-technical engineering courses may help students identify a "more modern" view of engineering, it may not be sufficient to fully shift students' perspectives to a Social/Servant definition of engineering professional identity. Possibly complementing instruction with service learning experience may help students develop a more holistic view of engineering.

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