Examining the gender gap in engineering professional identification

Attracting women to the engineering profession has been a topic of ongoing discussion and examination. In light of perceptions of what it means to be an engineer, both male and female students are navigating and aligning their future career goals based on their understanding of engineering as a profession. This study examines 1) the extent to which there are gender differences in affinity towards elements of professional practice (*framing and solving problems, tinkering, collaboration, analysis, design,* and *project management*) and 2) whether gender differences in affinity towards these practices contribute to the gender gap in engineering professional identification. Survey data was collected from 2256 undergraduate engineering students in three majors at one large public institution. Results show significant gender differences in affinities towards five of the six professional practices considered. Additionally, multivariate regression analyses revealed the gender gap in engineering professional identification is partially explained by differences in these affinities towards engineering professional practices. Further analyses also revealed that affinity towards *framing and solving problems* was a stronger predictor of engineering professional identification for female students than for male students. Implications of results are discussed.

KEYWORDS: professional identity, engineering, undergraduate, gender, survey, quantitative

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1. Introduction

Increasingly, attracting diverse students to engineering education and retaining them in the engineering profession has been cited as important to national competitiveness (National Academy of Sciences, 2007). Although some researchers and policymakers disagree on the nature and extent of the engineering shortage in the United States, few dispute the need to attract the most capable students, especially women and under-represented minorities, into technical careers (National Academy of Engineering, 2008). *Changing the Conversation: Messages for Improving Public Understanding of Engineering*, named lack of diversity as one of four predominant problems contributing to the lack of capable students entering into technical careers. Furthermore, a more recent report from the Committee on STEM Education (2018) articulated the goal of increasing diversity, equity, and inclusion in STEM as part of building a larger and more diverse population of STEM-literate Americans. Thus, the rationale for the recruitment of more women into the engineering workforce has remained much the same over the last 15 years: to increase the pool of Americans engaged in STEM fields necessitates an increase of women in those STEM fields in which they are severely under-represented.

By the numbers, while men and women are represented approximately equally in the population, relative to employment in engineering men outnumber women at a ratio of nearly 9:1. At least part of this disproportionate representation has been linked to a misalignment of common perceptions of what engineering is and what engineers do in comparison to the common interests of girls and women (National Academy of Engineering, 2008). Building on this idea, if women who do pursue engineering programs are drawn towards professional practices that are considered less central to engineering (perhaps those involving interpersonal skills), there may be a resulting decline in their engineering professional identification in comparison to men. In other words, it is important to consider whether men and women have affinities towards different elements of engineering practice (defined as a liking or interest in practices associated with the engineering profession, such as design or project management) and if so, if this has implications for how strongly men and women identify with engineering. Although there is an emergent literature on engineering identity, and more specifically, gender differences in such identity (Cass et al., 2011; Hazari et al., 2010; Meyers et al., 2012; Pierrakos et al., 2010; Tate & Linn, 2005), prior research has yet to consider how attitudes towards professional engineering practice may contribute to women's generally lower levels of identification with engineering.

Using data gathered from a cross-sectional sample of undergraduate engineering students at a selective public university, we investigate this issue. Our sample includes nearly 2300 students from three different engineering disciplines and has a substantial representation of women as well as minority students. Our research design includes newly developed measures of affinity towards core elements of engineering practice (Authors, 2018; Authors, 2018a) that enable us to explore potential gender differences in such affinities and their contribution to gender differences in engineering identity. As such, our works moves beyond previous work on gender and engineering identity that has focused more on personal efficacy and interest (e.g., Marra et al., 2009), to consider how preferences for specific practices of the profession may be important.

2. Background

2.1 Gender Socialization, Gender Preferences, and STEM Choices

Drawing on the insights of gender theorists, this study is rooted in the recognition that gender is a socially constructed category, such that there are widely shared cultural beliefs and expectations about the roles, behaviors, and characteristics that differentiate women and men (Risman, 2004). These beliefs and expectations are embedded in social institutions, and are salient in social relations and interactions (Ridgeway & Correll, 2004). Specifically, stereotypes about the characteristics and behaviors that distinguish men and women continue to thrive in contemporary society, such that as children develop, they are likely to develop interests and skills that are largely consistent with these stereotypes (Ridgeway, 2011). For example, common gender stereotypes cast men as analytical, competitive, objective, and inclined to work with objects, while conversely women are characterized as more communal, caring, and inclined to work with others (Charles & Bradley, 2009; Diekman et al., 2017).

Further, the expectancy-value theory explains how socializers in young people's local environment, including their parents, contribute to the development of gender-differentiated skills and interests among children, via the messages they send and the experiences they provide and cultivate (Eccles, 1987). Thus, from a young age, male and female youth are socialized into gender roles (Eccles et al., 1990; Leaper & Friedman, 2007). Not surprisingly, the extant literature finds a strong link between parental beliefs about innate or socially appropriate gender roles and how they subsequently socialize their children, including the toys they select and even the peers with whom they encourage their sons and daughters to play (Caldera et al., 1989; Cherney & London, 2006). Even in this contemporary moment, while some progress towards use of gender-neutral activities and toys is evident, nevertheless there is still evidence of gender socialization, such that parents are more likely to read with their daughters and engage in building activities with their sons (Coyle & Liben, 2020; Levine et al., 2012).

Moreover, the expectancy-value theory also points out that in addition to parents, major societal institutions such as education, as well as popular culture and the media, function as gender socializers, sending messages about the kinds of topics and activities that are considered most appropriate for each gender (Musto, 2019; Steinke et al., 2007). Thus, as children develop, culturally-pervasive gender beliefs and expectations shape their attitudes and interests, and subsequently their behavior and choices (Freeland & Harnois, 2020; Lazarides & Lauermann, 2019; West & Zimmerman, 1987). As such, observed differences between young adult women and men in interests and preferences for different activities and pursuits are likely the result of many years of prior socialization, including participation in different activities that are deemed gender appropriate.

Further, building on the insights of expectancy-value theory, gender scholars have more recently utilized goal congruency theory to explain how gender-differentiated preferences and interests have direct implications for gender gaps in educational and occupational fields. Specifically, as outlined in goal congruency theory, both young women and men will seek out areas that appear congruent, and avoid areas that seem incongruent, with the gendered values and interests they have acquired (Diekman et al., 2010; Diekman et al., 2017). For example, as young women grow up internalizing communal goals of working with others and helping people, they will seek out fields of study and work that appear consistent with such goals, and avoid those that they perceive to be a poor fit. Likewise, young men will seek out fields that appear to be a good fit with more agentic goals, including prioritizing analytic skills and manipulation of objects.

Consequently, this theoretical framework has been applied to recent research which finds that women's greater emphasis on communal goals is linked to their lower likelihood of pursuing STEM fields, including engineering, as they perceive such fields to provide little affordance for values such as caring for others and improving society (Cheryan et al., 2017; Diekman et al., 2010; Miller et al., 2006). At the same time, young men's relatively greater preferences and experiences related to hands-on and problem-solving activities such as programming and videogames, are linked not only to greater interest and comfort using spatial skills (Sorby, 2001; Subrahmanyam & Greenfield, 1994), but are also consistent with engineering practices (Sorby, 2009; Uttal & Cohen, 2012), and consequently valuing such activities is linked to their relatively greater probability of entering engineering fields. Thus, the internalization of gender roles and accompanying goals and preferences has been found to lead to the endorsement of gender-stereotypic career interests (Evans & Diekman, 2009), and more specifically, to gender differences in the likelihood of choosing to enter the engineering field (Frehill, 1997; Oswald, 2008).

2.2 Gendered affinities and engineering practices

Building on what we know about the strength and salience of gender role conditioning from earlier stages in life and education, it is reasonable to assume that even among those women that persist through the engineering pathway and enter an engineering major, we might still expect that they have preferences for and are drawn to different parts of the profession than their male peers (Cech, 2013; Sax et al., 2016). Evidence of this may be most apparent in the gender disparities between engineering disciplines. Specifically, environmental and biomedical engineering majors are at or near parity in the percentage of men and women receiving bachelor's degrees; and the greater relative presence of women there may be due to perceptions of these fields as affording communal goals, such as helping improve the society and the health of its people. By contrast, other disciplines scarcely approach a representation of 15% female, such as mechanical, electrical, aerospace, and computer engineering (Roy, 2018) , fields that are perhaps perceived as congruent with more stereotypically male goals, such as working with objects and utilizing analytic skills. Indeed, consistent with goal congruency theory, the discrepancies in the number of women entering these majors is likely at least in part due to perceptions of some aspects of engineering as masculine, that is, embodying values and preferences that have traditionally been ascribed to the male gender role.

However, beyond choosing different engineering disciplines, we know very little about gendered perceptions of key elements of engineering practice among engineering students. Like other professions, engineering is defined by a certain set of practices. At the undergraduate level, engineering students are trained to enter a specific profession characterized by well-defined common practices (Downey, 2005). Key practices of engineering include design, professional responsibility, teamwork, and analytical skill. Prior work has established that many activities related to the professional practices of engineering positively impact engineering-related outcomes; these activities include building things, taking things apart, programming, playing computer games, or just being interested in how things work (i.e., Baenninger & Newcombe, 1989; Feng et al., 2007; Roberts & Bell, 2000). Thus, it stands to reason that students who have strong affinities towards key aspects of engineering practice will feel more of a fit with the profession and personally identify with it. For example, Pierrakos et al. (2010) found that affinity toward building and determining how things work predicted engineering identity in engineering undergraduates.

Given that young men and women often continue to participate in different activities into their collegiate years, reinforcing socialized preferences and goals developed in childhood, this can lead to related differences in affinities towards certain engineering practices. Therefore, gender differences in affinity to certain engineering practices, such that for example, men may be more drawn to the technical side of engineering and women somewhat more drawn to social aspects of the profession, are likely the result of the different kinds of tasks and interests that males and females individuals are typically socialized to prioritize (see Cech, 2013; Su et al., 2009). As young men and women then consider their future careers, these gendered affinities may have implications for who feels a strong fit with or strongly identifies with the engineering profession. Thus, drawing on the insights of goal congruency theory, this study moves beyond the relatively narrow treatment of gender and engineering identity in past research, to examine the role of affinities towards a range of different engineering practices.

In this study, we build on the growing body of work related to engineering identity and professional identification. Our research questions are as follows:

1. Are there gender differences in affinities towards professional engineering practices?
2. Which, if any, affinities towards professional engineering practices help to explain the gender difference in identification with engineering?
3. Which, if any, affinities towards engineering practices differentially predict identification with engineering for male and female undergraduate engineering students?

3. Methods

3.1 Author Positionality

Author 1 identifies as a Black cisgender woman. She is an engineering educator with a background in bioengineering and is currently a post-doctoral researcher in engineering education. Author 2 identifies as a White cisgender woman. She is a sociologist who studies gender and racial/ethnic inequality in STEM fields and is currently a professor in a college of education. Author 3 identifies as a White cisgender woman and engineering education researcher. She is currently a professor with appointments in engineering and education.

3.2 Participants

This study was a cross-sectional examination of the factors that contribute to engineering professional identification for students who are pursuing engineering majors in college. The setting was a large, public institution in the U.S. with high-ranking engineering programs where the students are admitted directly into specific majors (there is no general or first-year engineering program). The institution overall, and the College of Engineering within it, are quite selective; admitted students are typically in the top 10% of their high school classes, with an average SAT score of about 1400. The institution also has average retention rates that are well above the national average. Given these characteristics, engineering majors at this institution comprise a highly select group, which may have implications for their overall commitment or identification with engineering; we return to this point in the limitations section.

Prior to data collection, the research team obtained approval to conduct research with human subjects from the Institutional Review Board (IRB) at the institution, which included obtaining informed consent from respondents. Students were administered a survey, which took approximately fifteen minutes to complete, in class via Qualtrics. Survey responses were collected during the first month of class in three consecutive fall semesters: 2016, 2017, and 2018. This data set includes both lower and upper division students in civil engineering (CE), architectural engineering (AE), mechanical engineering (ME), and biomedical engineering (BME) courses. Architectural and civil engineering students are in the same department and share many required courses; for this analysis, they were grouped together (collectively labeled CAEE).

A total of 2788 participants consented to the survey; we only examined non-duplicate responses with complete data on gender, semester, major, student classification (division), race, the affinity towards engineering practice variables, and the outcome variable–engineering professional identification. Mean imputation was conducted to replace missing values on mother's education. The final data set (n=2256) included 1365 male and 891 female students, 61% and 39% respectively. Approximately 63.3% were lower division students and 36.7% were upper division students. The racial/ethnic composition of the sample was 50.9% White, 20.3% Hispanic, 24.1% Asian, 1.5% Black, 0.13% American Indian/Native Hawaiian/Alaskan Native, and 3.0% reporting two or more race categories. All demographic data was gathered from university records and self-report.

3.3 Dependent variable

Our dependent variable was composed of previously validated items (Authors, 2018). *Engineering professional identification (EPI)* was a variable composed of two questions (See Table A.1). The first question was a visual measure of professional identification. It stated:

> "Please describe your relationship with engineering by using the following diagrams. Imagine that the circles at the left represent your own personal identity (i.e., what

describes you as a unique individual), while the circles at the right represent the identity of an engineer (i.e., what describes an engineer). Which diagram best describes the level of overlap between your own identity and the identity of an engineer?”

The response categories were on a scale of 1-8 with “1” Far apart, “2” close together, but separate, “3” very small overlap, “4” small overlap, “5” moderate overlap, “6” large overlap, “7” very large overlap, and “8” complete overlap (see Figure A.1 in the Appendix). The second question that composed the dependent variable was a verbal measure of professional identification. The question asked: "To what extent does your own sense of who you are (i.e., your personal identity) overlap with your sense of what an engineer is (i.e., the identity of an engineer)?" Response categories were on a scale of 1-8, "1" not at all to "8" to a great extent. Participants were directed to mark one response for each question. The alpha for the two items is 0.83.

3.4 Independent variables

The authors previously developed the variables measuring students’ affinity towards engineering professional practices explored in this current study (Authors, 2017b). The motivation for developing these factors was to create a set of variables that explicitly measure affinity towards professional practices in engineering. There were few existing frameworks for professional engineering practice to inform this work, but there is a precedence of other fields using accreditation standards as a starting point for developing professional identification scales (e.g., Crossley & Vivekananda-Schmidt, 2009). The research team consulted ABET criteria (ABET, 2016) as part of the scale development process, and also followed the steps for psychometric validation of a new survey, including item generation, refinement, and instrument validation. The final refined list included 34 items that were included in the student survey, with the following prompt: "As you think about your future after you finish your education, to what extent would you enjoy a profession or career that usually requires each of the following?" Response categories were on a scale from "1" (not at all) to "5" (very much). Initial factor structure was established using exploratory factor analysis with an oblique promax rotation, given that factors were expected to be correlated, utilizing a random sample of the data. Ultimately, six factors emerged, with all item loadings at .35 or higher, and with the few instances of cross-loading resolved by consultation with engineering experts both inside and outside of the research team to assess face validity. The six factors were: 1) *project management, 2) framing and solving problems, 3) collaboration, 4) analysis, 5) design, and 6) tinkering.* These measures, summarized in Table 1, have subsequently been used in additional studies of engineering identity conducted by members of the research team (e.g., Authors 2019; Authors 2019a).

In this study, we conducted a confirmatory factor analysis (CFA) in order to validate the underlying structure of the factors using the present dataset. Fit statistics indicate an acceptable model fit, with an RMSEA of 0.06 (where values $\leq$0.08 and >0.10 are considered acceptable and poor, respectively), a CFI of 0.91 (where a range between 0.90 and .95 is acceptable), and a SRMR of 0.04 (where a good fit is based on the criteria of $\leq$0.08) (Kline, 2015). Table A.2 shows the standardized factor loadings and construct reliability (Cronbach's alpha). To generate the independent variables, composite variables were created by taking the mean of the items that composed each latent factor. Table 2 shows the correlations for the independent and dependent variables. Further, variance inflation factors (VIFs) were calculated to determine whether there might be a problem with multicollinearity between the factors; results indicated an average VIF of 1.95, with individual VIFs ranging from 1.5 to 2.6; this is well below the accepted threshold of 10 for multicollinearity.

3.5 Control variables

We also created several control variables to capture students' background. Gender was coded as 0 for male and 1 for female. Race/ethnicity was dummy coded for each category present in the dataset: White (reference category), Black, Asian, Hispanic, Multiracial, and American Indian/Native Hawaiian. Students' major is coded to distinguish between mechanical engineering (ME) as the reference group, civil/architectural engineering (CAEE), and biomedical engineering (BME). Students' academic classification was partitioned by division (freshman and sophomore = 0; junior and senior = 1). Additionally, participants self-identified the highest level of education their mother had completed; consistent with prior research, this was used as a proxy to control for socioeconomic status (Grzywacz et al., 2004; Ridolfo & Maitland, 2011). The categories of response were on a scale of 1-4: 1) Graduated from high school or equivalent (GED) or less, 2) degree or certificate from a vocational school, a junior college, a community college, or another type of 2-yr. school, 3) completed a college degree, and 4) completed a masters, doctoral or other advanced professional degrees (JD, MD, Ph.D., etc.). The semester the survey was taken was also included as a covariate. See Table 3 for descriptive statistics on each variable.

3.6 Research Design

All analysis was conducted using Stata Statistical Software: Release 15.1 (Press, 2017). Prior to statistical analysis, we conducted a normality check of the data. We also note that while the factors were not created to capture gender differences, the first three practices might be seen as aligned with more stereotypically feminine practices, as they center on skills involving organization, communicating with others, and working to solve societal problems. Likewise, the last three practices can be seen as more consistent with stereotypically male practices, as they capture preferences for building things and using both technology and math equations to solve engineering problems.

To address the first research question, whether there are gender differences in affinity towards engineering practice, we conducted a MANOVA to determine overall differences, and subsequently conducted post-hoc t-tests with a Bonferroni correction for multiple post-comparisons. To address the second question, whether affinities towards practices help to explain the gender gap in engineering professional identity, we used multivariate regression analyses. Specifically, stepwise models begin with a baseline model, a model with controls, and a final model that adds the variables for affinity towards engineering practices. We follow this up with mediation analyses to get a clear sense of which variables contribute the most to explaining the gender difference in identity. Finally, to address the third question, whether any of the affinity factors are more or less important based on gender, we rely on multivariate regression with interaction terms between gender and each of the affinity factors.

4. Results

4.1 Descriptive Results

The results reveal gender differences in affinities towards professional engineering practices. Table 4 shows the means and standards deviations for each of these variables overall and by gender. Cohen's d, a measure of effect size, was also calculated to capture gender differences. Results of the MANOVA reveal there is a significant gender difference in the means of the affinities towards professional engineering practice variables ($F(6,2249)=23.62$, $p<0.001$, Wilk's Lambda=0.9407). Post-hoc comparisons revealed statistically significant gender differences in each of the variables (using the Bonferroni corrected threshold of $p<0.007$) with the lone exception of *collaboration*. Specifically, male students had significantly higher means on the three measures that align with more stereotypically masculine attributes: *tinkering, analysis,* and *design*. In contrast, female students reported significantly higher means on two of the measures that align with more stereotypically female attributes: *project management,* and *framing and solving problems*. However, the effect sizes for all gender differences were small, ranging from 0.12 to 0.31 standard deviations. The largest gender disparity was for *tinkering*, at 0.31 standard deviations; this is nearly twice the size of the gender gap in *project management,* where female students have a slightly higher mean than male students. We also note some similarities between the genders. First, both male and female students rated *framing and solving problems* above all other affinity factors (as confirmed by paired t-tests). Additionally, as mentioned above, there was not a significant gender difference for *collaboration*.

T-tests further revealed significant differences in the dependent variable of engineering professional identity (hereafter referred to as EPI), as it was significantly higher for male students than female students (M=5.17; F=4.87). While male students do express a stronger relative identity, the effect size difference is relatively small, at 0.24 standard deviations. Moreover, the means for both groups indicate that engineering students in the sample report a moderate degree of overlap between their personal identity and the identity of an engineer (with a pooled mean of approximately 5 on a scale from 1 to 8).

4.2 Multivariate Results

To answer the second research question, whether affinities towards professional engineering practices help to explain the gender difference in identification with engineering, we now turn to a set of regression analyses (see Table 5). First, at baseline (model 1), female students have a lower EPI than male students ($b = -0.30$, $p \leq 0.001$), which is consistent with the descriptive statistics presented in Table 4. Second, with the addition of student background variables in model 2, the gender gap is still significant at a similar magnitude ($b = -0.28$, $p \leq 0.001$). We also see that BME students have a lower EPI compared to all other majors ($b = -0.13$, $p \leq 0.05$). No other student background variables were significant in model 2.

In model 3, the negative gender coefficient becomes smaller with the addition of the professional affinity variables ($b = -0.18$, $p \leq 0.001$). Each of the six professional affinity variables is significant in the model, and together they account for 19.6% of the variance in EPI. With the exception of *collaboration*, all are positive in direction. This result is likely due to the moderate correlations between the factors. In a model (not shown) including *collaboration* as a lone predictor, the results revealed that the coefficient was indeed positive. Post-hoc tests to compare coefficients revealed that among the positive affinity predictors of EPI, *tinkering* is statistically significantly different from project management ($p=0.048$), while the other variables have approximately the same magnitude. Further, post-hoc tests revealed that compared to the results in model 2, the gender gap in model 3 is significantly smaller with the inclusion of the professional affinity variables ($\chi^2=12.84$; $df = 1$; $p=0.003$).

To gain an understanding of which variables were contributing the most to the reduction in the gender coefficient, we conducted a mediation analysis following model 3. This breaks down the indirect effects of the six professional practices and the direct effect of being female on EPI. Figure 1 shows the mediation model with all six professional practices. Consistent with the descriptive statistics in Table 4, being a female student was a significant predictor of *project management* (b = 0.10, p<0.001) and *framing and solving problems* (b = 0.05, p=0.006), but was not a significant predictor of *collaboration* (b = 0.01, p=0.66). Additionally, each path from these practices to EPI was significant and had a similar magnitude (0.14 for *project management* and 0.18 for *framing and solving problems)*. Only *collaboration* was negative (-0.19). Overall, female students' engineering professional identity receives a boost from having a greater affinity than male students towards *project management* and *framing and solving problems*.

The lower portion of Figure 1 displays the practices most highly rated by male students: *analysis*, *design*, and *tinkering*. Again, consistent with Table 4, being female negatively predicts each of these practices at varying magnitudes: *analysis* (b = - 0.11, p=0.001), *design* (b = - 0.08, p=0.006), and *tinkering* (b = - 0.27, p<0.001). Furthermore, these set of practices have a greater impact on EPI than the practices preferred by female students (*project management* and *framing and solving problems)*. In other words, compared to male students, female students express lower affinity for the three engineering practices that are the strongest predictors of EPI.

Finally, to address the third research question, whether any affinities towards engineering practices differentially predict identification with engineering for male and female undergraduate engineering students, we added interactions between gender and affinity factors to the regression analyses. As seen in Table 6, there was a statistically significant interaction between gender and *framing and solving problems* (b = 0.35 $p \leq 0.05$). The interaction between gender and *tinkering* was borderline significant (b = - 0.13, p=0.06).

To illustrate these patterns, first we show the predicted values of EPI at varying values of *framing and solving problems*, holding all other variables to the mean. As seen in Figure 2, there is a gender gap of 0.36 (or about three-quarters of a standard deviation) in EPI when students' preference for *framing and solving problems* is one standard deviation below the mean. While male students' predicted values remain relatively unchanged as their affinity for *framing and solving problems* increases from one standard deviation below the mean to one standard deviation above the mean, female students' predicted level of engineering professional identity increases. Indeed, due to this differential increase for female students, the gender gap in EPI essentially closes when the value of *framing and problem solving* is one standard deviation above the mean.

Figure 3 shows the predicted values of EPI at varying values of *tinkering*. The gender interaction shown in Table 6 indicates that relative to female students, male students have higher means of EPI as values of *tinkering* increase. Thus, as shown in the figure, while both the male and female students' predicted values of EPI increase as values of *tinkering* increase, such that both genders benefit from reporting wanting to pursue a job that involves tinkering, this increase is significantly greater for men than for women. While the gender gap in EPI is quite small in magnitude when students are one standard deviation below the mean in *tinkering*, at one standard deviation above the mean, the gender gap in EPI has increased to a value of 0.31, or a little over one-third of a standard deviation.

Finally, we note that in exploratory analyses, we ran parallel models for each of the three majors to examine potential differences in gendered patterns. The results indicated that the patterns were generally similar across majors. In other words, women had significantly lower

EPI than men in all majors, the interactions described above between affinities for engineering practices and gender were also observed across majors, and there were no additional significant gender differences.

5. Limitations

As with any area of research, this study had limitations. Namely, it was conducted at a single selective institution of higher education, in which admittance to the college of engineering is also very selective. Further, our sample did not include students from all engineering fields. Therefore, we cannot claim that our findings are generalizable to a broader population of majors or institutions. For example, it is possible that students in our sample generally have a high level of engineering identification given the relatively stringent requirements to be able to enter engineering major. As such, it may be more appropriate to view this study as a case study of one selective institution, as future research at other institutional contexts might find different patterns. Relatedly, as the institution in our study is predominantly White, our sample has a very small percentage of Black students and cannot adequately speak to potential intersectional differences for Black and White females, for example. Future research at minority-serving institutions or HBCUs could help to uncover whether the gendered patterns observed here are similar or different in such contexts. Finally, we note that all our analyses are limited by the use of a binary categorization of gender, as the student survey only provided binary options for students to indicate their gender (i.e., male or female).

6. Discussion and Conclusion

This study investigated the extent to which the gender gap in engineering professional identification might be explained by six elements of affinity towards professional engineering practice, and whether any of these factors are stronger predictors of engineering professional identification for one gender or another. Our findings build on a growing body of literature relating to engineering identity as well as known disparities in the participation of women within engineering. Consistent with previous work on engineering identity using the same outcome variable, we saw male students had a significantly higher measure of identification with engineering than female students (Authors 2018b). This gendered pattern is also consistent with other research examining engineering identification as captured by measures of students' agreement with seeing themselves as an engineer (Godwin et al., 2016; Authors 2017a, Authors 2018a).

Relative to the six professional engineering practices, and in response to our first research question, we observed gendered patterns in students' expressed preferences towards different practices. Consistent with the theoretical framework of goal congruency theory, as well as related empirical research on engineering, we observed a general pattern where women expressed relatively higher preferences for practices of a more social or interpersonal nature, in alignment with feminine stereotypes, while men expressed relatively higher preferences for technical practices or those with "things" rather than "people", which aligned more with masculine stereotypes (e.g., Cech, 2013; Woodcock et al., 2013). Namely, female students had higher means on *framing and solving problems* and *project management*. An examination of the specific items composing *framing and solving problems* (see Table A.2) reveals that this factor captures students wanting to use their technical problem-solving skills to help others and improve society through learning new things from those they are working with and applying those skills to the problem. While literature often positions technical work as opposed to work that helps others, this factor appears to capture students' perceptions that these can be complementary and desirable to their future career goals, and that such perceptions are relatively more common for women than for men (Cech, 2013). This hints at a more complex relationship between women and their interest to pursue careers that are people-oriented than is often discussed in the literature.

Similarly, in reporting higher means on *project management*, female students indicate wanting a future career that involves using facts and relevant information to plan and see a project through to the end. A key aspect of project management includes interpersonal interactions, particularly communication through written and verbal reports to colleagues, clients or supervisors. As reported by The Project Management Institute, an international certification body on project management, communication is one of ten key knowledge areas. Furthermore, they define project management as the application of knowledge, skills, tools, and techniques to project activities to meet the project requirements (Project Management Institute, 2019). Thus, while female students are reporting an affinity towards using their technical skills in their future workplace, they are also indicating an affinity towards working with people; both desires are indicative of project management which is a key component of engineering practice.

The engineering practices that male students rated most highly were *analysis*, *design*, and *tinkering*. These practices can be viewed as essentially non-communal, and align with stereotypically masculine affinities such as building and using math and science skills. Specifically, *analysis* relates to math and science proficiencies and applying that knowledge to a problem. Unlike *framing and solving problems*, which involved using technical proficiencies to solve a societal problem beyond a given computational problem, our construct of *analysis* is purely a technical proficiency. One reason we may see this gender distinction is that males are often supported and encouraged via gender norms to hone this technical skill (Wang & Degol, 2017) and thus make career choices based on gender roles enacted through socialization (Correll, 2001; Eccles, 1987). In the engineering context, such processes likely result in males fostering more confidence and proficiency in their analytical skills over other skills. It is not surprising therefore that they align analytical skill as a practice desirable in their future career (Diekman et al., 2017).

Design involves using creativity, innovation, and generatively producing products and systems based on specified constraints. This is a practice most commonly associated with engineering as a profession. Yet, when considering that male students rate this practice statistically higher than female students, we should consider their socialization as a contributing factor to this outcome. Similar to *analysis*, males grow up playing with toys that involve building and often explicitly participation in design such as Legos. Relatedly, *tinkering* relates to hands-on activities in engineering that may be related to the design process or less-structured curiosity for how things work.

The only practice male and female students rated equally was *collaboration*. This was surprising given that females scored higher than their male peers on *project management*, and *framing and solving problems*. Although both male and female students rated this practice highly, it was not a positive predictor of engineering identity net of all other practices. This is consistent with some research that reports negative experiences associated with group and collaborative learning amongst engineering students (e.g., Colbeck et al., 2000; Cummings & Kiesler, 2008). However, we caution that collaboration is indeed a positive predictor of identity in baseline models that do not include the other factors. Thus, while ABET acknowledges the essential role that teamwork plays in the engineering profession, and an affinity towards collaboration does positively predict engineering professional identity among students, it does not do so independently of their affinities towards other engineering practices.

Turning to discuss results related to our second research question, we found that gendered differences in preferences for different engineering practices did account for a substantial portion of the gender gap in professional engineering identity. As seen in Table 5, with the inclusion of the variables measuring affinities for engineering practice, about one-third of the gender gap in identity was explained. Therefore, our research contributes new information to the field regarding the impact of gendered preferences for STEM outcomes, such as engineering identity. While the framework of role congruency theory has been applied to help explain why women are less likely to enter STEM fields, such as engineering, in the first place (e.g., Diekman et al., 2017), our study expands the application of this framework to important outcomes among those individuals who have already entered engineering majors.

Specifically, our results indicate that *analysis, design,* and *tinkering*, the three factors rated most highly by male students (and which were rated significantly lower by female students), were the strongest predictors of engineering professional identity. Conversely, the two factors where women had a stronger preference than men (*project management* and *framing and solving problems)* were positive, but still relatively weaker predictors of engineering identity. Therefore, there is indeed empirical evidence that gendered preferences for different engineering activities, which are consistent with gender stereotypes and socialization, contribute to the fact that female engineering majors have lower levels of identification with their chosen profession than their male peers. Put differently, our results suggest that part of the reason that women identify less with this traditionally male-dominated field is that they have lower levels of preferences for the practices that align with male stereotypes and are likewise most important for engineering identification.

Yet in addressing our third research question, we also found some evidence of gender differences in the predictive power of some preferences for engineering practices. As seen in Figures 2 and 3 respectively, men's identification with engineering is more strongly predicted by *tinkering* than is the case for women, while women's identification is more strongly predicted by *framing and solving problems* than is the case for men. This suggests a somewhat more complicated pattern, such that engineering identity appears to be somewhat constructed differently by gender, with practices that align with some feminine stereotypes being more predictive for women's engineering identity, and likewise, practices that align with some masculine stereotypes being more predictive for men. Further, regarding *framing and solving problems* in particular, for those students at one standard deviation above the mean on this variable, there is no gender gap in engineering identification. As engineering curriculums are full of various types of problem-solving activities, it is important to consider the contextual nature of problems presented to students, as well as the extent to which certain aspects of the profession are emphasized within the curricula (Knight et al., 2012), as this may have implications for substantially promoting women's engineering identity.

Finally, given the fact that the representation of women varies greatly among different engineering majors, such that, for example, they are much more likely to major in biomedical engineering than mechanical engineering, it is perhaps surprising that exploratory analyses revealed that gender gaps in engineering identity were comparable across majors, as were gender differences in affinities for different engineering practices. Further, the overall association between affinities and identity, and the gender interactions with affinities predicting identity, were also comparable across majors. This indicates that across engineering fields, both men and women exhibit preferences that align with gender stereotypes; in other words, it is not the case, for example, that women in a more male-dominated engineering field have preferences that more closely mirror their male peers when compared to women in a more gender-equitable major. As such, this suggests the strength of gender socialization processes that are at work long before men and women choose engineering specialties, resulting in aggregate gender differences that remain regardless of the specific gender composition or particular culture of an engineering field.

Moving beyond the main focus of this paper on gender disparities, we also note other patterns observed in our data. First, somewhat surprisingly, race was not a significant predictor of engineering professional identification. Given the known under-representation of minority youth in engineering and other STEM disciplines (National Center for Science and Engineering Statistics, 2019), we anticipated that they might report lower levels of engineering identification. Yet perhaps minority students who persist through engineering at the collegiate level more readily align their personal identity with the identity of an engineer. Given that our study is limited to the experiences of minority youth at one institution, our results are far from conclusive, and we believe that this is certainly an area that needs further research. Also, while it is somewhat logical that lower division students with less formal exposure to engineering would identify less with engineering as a profession, our results did not support this assumption. Null findings of this nature point to the need for continued investigations of engineering identity across a students' educational trajectory to see if their beliefs remain steady over time. Lastly, while biomedical engineers had a slightly lower identity than mechanical and civil/architectural engineers, there is limited literature in the area of differences in student attitudes related to different engineering disciplines (i.e., Potvin et al., 2013; Ro & Knight, 2016).

In closing, this study raises implications for students' engineering paths after graduation. Research should continue to examine the diversity of women's and men's experiences within engineering disciplines, and how that might affect future career choices. For instance, as students are participating in co-ops, internships, and research experiences outside of the school setting, there are certainly additional opportunities to have real-world experiences linked to professional practices, which may encourage women's increased participation and identification with engineering. Additionally, more attention can be given to earlier points in the engineering pathway, to assure that students are well informed about the particular practices associated with engineering. Future work, both rigorous quantitative and qualitative scholarship, can contribute greatly to this area of research by conducting comparative studies of students at different points in the pathway to the profession (i.e., secondary and higher education) and extended longitudinal examinations of engineering professional identity for women and men in engineering. This is especially important given our finding that female engineering students viewed the professional practices most strongly related to engineering professional identity less favorably. These are a few suggestions for areas of future research.

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References

ABET. (2016). *Criteria for Accrediting Engineering Programs, 2016–2017*. https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2016-2017/

Baenninger, M., & Newcombe, N. (1989). The Role of Experience in Spatial Test Performance: A Meta-Analysis. *Sex Roles, 20*(5-6), 327-344.

Caldera, Y. M., Huston, A. C., & O'Brien, M. (1989). Social Interactions and Play Patterns of Parents and Toddlers with Feminine, Masculine, and Neutral Toys. *Child Development, 60*(1), 70-76.

Cass, C. A. P., Hazari, Z., Cribbs, J., Sadler, P. M., & Sonnert, G. (2011). Examining the Impact of Mathematics Identity on the Choice of Engineering Careers for Male and Female Students. Frontiers in Education Conference Rapid City, SD.

Cech, E. A. (2013). Ideological Wage Inequalities? The Technical/Social Dualism and the Gender Wage Gap in Engineering. *Social Forces, 91*(4), 1147-1182.

Charles, M., & Bradley, K. (2009). Indulging Our Gendered Selves? Sex Segregation by Field of Study in 44 Countries. *American Journal of Sociology, 114*(4), 924-976.

Cherney, I. D., & London, K. (2006). Gender-Linked Differences in the Toys, Television Shows, Computer Games, and Outdoor Activities of 5-to 13-Year-Old Children. *Sex Roles, 54*(9-10), 717-726.

Cheryan, S., Ziegler, S. A., Montoya, A. K., & Jiang, L. (2017). Why Are Some Stem Fields More Gender Balanced Than Others? *Psychological Bulletin, 143*(1), 1-35.

Colbeck, C. L., Campbell, S. E., & Bjorklund, S. A. (2000). Grouping in the Dark: What College Students Learn from Group Projects. *The Journal of Higher Education, 71*(1), 60-83.

Committee on STEM Education, N. S. a. T. C. (2018). *Charting a Course for Success: America's Strategy for Stem Education*.

Patrick, A., Riegle-Crumb, C., & Borrego, M. (2021). Examining the Gender Gap in Engineering Professional Identification. *Journal of Women and Minorities in Science and Engineering,* 27(1), 31-55.

Correll, S. J. (2001). Gender and the Career Choice Process: The Role of Biased Self-Assessments. *American Journal of Sociology, 106*(6), 1691-1730.

Coyle, E. F., & Liben, L. S. (2020). Gendered Packaging of a Stem Toy Influences Children's Play, Mechanical Learning, and Mothers' Play Guidance. *Child Development, 91*(1), 43-62.

Crossley, J., & Vivekananda-Schmidt, P. (2009). The Development and Evaluation of a Professional Self Identity Questionnaire to Measure Evolving Professional Self-Identity in Health and Social Care Students. *Medical Teacher, 31*(12), e603-e607.

Cummings, J. N., & Kiesler, S. (2008). Who Collaborates Successfully?: Prior Experience Reduces Collaboration Barriers in Distributed Interdisciplinary Research. Proceedings of the 2008 ACM conference on Computer supported cooperative work,

Diekman, A. B., Brown, E. R., Johnston, A. M., & Clark, E. K. (2010). Seeking Congruity between Goals and Roles: A New Look at Why Women Opt out of Science, Technology, Engineering, and Mathematics Careers. *Psychological Science, 21*(8), 1051-1057.

Diekman, A. B., Steinberg, M., Brown, E. R., Belanger, A. L., & Clark, E. K. (2017). A Goal Congruity Model of Role Entry, Engagement, and Exit: Understanding Communal Goal Processes in Stem Gender Gaps. *Personality and Social Psychology Review, 21*(2), 142-175.

Downey, G. (2005). Are Engineers Losing Control of Technology?: From 'Problem Solving'to 'Problem Definition and Solution'in Engineering Education. *Chemical Engineering Research and Design, 83*(6), 583-595.

Eccles, J. S. (1987). Gender Roles and Women's Achievement ‐ Related Decisions. *Psychology of Women Quarterly, 11*(2), 135-172.

Eccles, J. S., Jacobs, J. E., & Harold, R. D. (1990). Gender Role Stereotypes, Expectancy Effects, and Parents' Socialization of Gender Differences. *Journal of Social Issues, 46*(2), 183-201.

Evans, C. D., & Diekman, A. B. (2009). On Motivated Role Selection: Gender Beliefs, Distant Goals, and Career Interest. *Psychology of Women Quarterly, 33*(2), 235-249.

Patrick, A., Riegle-Crumb, C., & Borrego, M. (2021). Examining the Gender Gap in Engineering Professional Identification. *Journal of Women and Minorities in Science and Engineering,* 27(1), 31-55.

Feng, J., Spence, I., & Pratt, J. (2007). Playing an Action Video Game Reduces Gender Differences in Spatial Cognition. *Psychological Science, 18*(10), 850-855.

Freeland, R. E., & Harnois, C. E. (2020). Bridging the Gender Wage Gap: Gendered Cultural Sentiments, Sex Segregation, and Occupation-Level Wages. *Social Psychology Quarterly*. https://doi.org/10.1177/0190272519875777

Frehill, L. M. (1997). Education and Occupational Sex Segregation: The Decision to Major in Engineering. *Sociological Quarterly, 38*(2), 225-249.

Grzywacz, J. G., Almeida, D. M., Neupert, S. D., & Ettner, S. L. (2004). Socioeconomic Status and Health: A Micro-Level Analysis O Exposure and Vulnerability to Daily Stressors. *Journal of Health and Social behavior, 45*(1), 1-16.

Hazari, Z., Sonnert, G., Sadler, P. M., & Shanahan, M.-C. (2010). Connecting High School Physics Experiences, Outcome Expectations, Physics Identity, and Physics Career Choice: A Gender Study. *Journal of Research in Science Teaching, 47*(8), 978-1003. https://doi.org/10.1002/tea.20363

Kline, R. B. (2015). *Principles and Practice of Structural Equation Modeling*. Guilford publications.

Knight, D., Lattuca, L. R., Yin, A., Kremer, G., York, T., & Ro, H. K. (2012). An Exploration of Gender Diversity in Engineering Programs: A Curriculum and Instruction-Based Perspective. *Journal of Women and Minorities in Science and Engineering, 18*(1), 55-78.

Lazarides, R., & Lauermann, F. (2019). Gendered Paths into Stem-Related and Language-Related Careers: Girls' and Boys' Motivational Beliefs and Career Plans in Math and Language Arts. *Frontiers in Psychology, 10*. https://doi.org/10.3389/fpsyg.2019.01243

Leaper, C., & Friedman, C. K. (2007). The Socialization of Gender. In J. E. Grusec & P. D. Hastings (Eds.), *Handbook of Socialization: Theory and Research* (pp. 561-587). Guilford Press.

Levine, S. C., Ratliff, K. R., Huttenlocher, J., & Cannon, J. (2012). Early Puzzle Play: A Predictor of Preschoolers' Spatial Transformation Skill. *Developmental Psychology, 48*(2), 530-542.

Patrick, A., Riegle-Crumb, C., & Borrego, M. (2021). Examining the Gender Gap in Engineering Professional Identification. *Journal of Women and Minorities in Science and Engineering,* 27(1), 31-55.

Marra, R. M., Rodgers, K. A., Shen, D., & Bogue, B. (2009). Women Engineering Students and Self-Efficacy: A Multi-Year, Multi-Institution Study of Women Engineering Student Self-Efficacy. *Journal of Engineering Education, 98*(1), 27-38.

Meyers, K. L., Ohland, M. W., Pawley, A. L., Sillman, S. E., & Smith, K. A. (2012). Factors Relating to Engineering Identity. *Global Journal of Engineering Education, 14*(1), 119-131.

Miller, P. H., Slawinski Blessing, J., & Schwartz, S. (2006). Gender Differences in High‐School Students' Views About Science. *International Journal of Science Education, 28*(4), 363-381. https://doi.org/10.1080/09500690500277664

Musto, M. (2019). Brilliant or Bad: The Gendered Social Construction of Exceptionalism in Early Adolescence. *American Sociological Review, 84*(3), 369-393.

National Academy of Engineering. (2008). *Changing the Conversation: Messages for Improving Public Understanding of Engineering*. National Academies Press.

National Academy of Sciences. (2007). *Rising above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*.

National Center for Science and Engineering Statistics. (2019). *Women, Minorities, and Persons with Disabilities in Science and Engineering: 2019* (Special Report NSF 19-304). , Issue. N. S. Foundation. https://www.nsf.gov/statistics/wmpd.

Oswald, D. L. (2008). Gender Stereotypes and Women's Reports of Liking and Ability in Traditionally Masculine and Feminine Occupations. *Psychology of Women Quarterly, 32*(2), 196-203.

Pierrakos, O., Beam, T., Watson, H., Thompson, E., & Anderson, R. (2010). Gender Differences in Freshman Engineering Students' Identification with Engineering. Frontiers in Education Conference Arlington, VA.

Potvin, G., Hazari, Z., Klotz, L. E., Godwin, A., Lock, R. M., Cribbs, J. D., & Barclay, N. (2013). Disciplinary Differences in Engineering Students' Aspirations and Self-Perceptions. 120th ASEE Annual Conference and Exposition,

Press, S. (2017). *Stata: Data Analysis and Statistical Software.* In *MP - Parallel Edition*

Patrick, A., Riegle-Crumb, C., & Borrego, M. (2021). Examining the Gender Gap in Engineering Professional Identification. *Journal of Women and Minorities in Science and Engineering,* 27(1), 31-55.

Project Management Institute, I. (2019). *What Is Project Management?* . https://www.pmi.org/about/learn-about-pmi/what-is-project-management

Ridgeway, C. L. (2011). *Framed by Gender: How Gender Inequality Persists in the Modern World*. Oxford University Press.

Ridgeway, C. L., & Correll, S. J. (2004). Unpacking the Gender System: A Theoretical Perspective on Gender Beliefs and Social Relations. *Gender & Society, 18*(4), 510-531.

Ridolfo, H., & Maitland, A. (2011). Factors That Influence the Accuracy of Adolescent Proxy Reporting of Parental Characteristics: A Research Note. *Journal of Adolescence, 34*(1), 95-103.

Risman, B. J. (2004). Gender as a Social Structure: Theory Wrestling with Activism. *Gender & Society, 18*(4), 429-450.

Ro, H. K., & Knight, D. B. (2016). Gender Differences in Learning Outcomes from the College Experiences of Engineering Students. *Journal of Engineering Education, 105*(3), 478-507.

Roberts, J. E., & Bell, M. A. (2000). Sex Differences on a Computerized Mental Rotation Task Disappear with Computer Familiarization. *Perceptual and Motor Skills, 91*(3 suppl), 1027-1034.

Roy, J. (2018). *Engineering by the Numbers*. American Society for Engineering Education.

Sax, L. J., Kanny, M. A., Jacobs, J. A., Whang, H., Weintraub, D. S., & Hroch, A. (2016). Understanding the Changing Dynamics of the Gender Gap in Undergraduate Engineering Majors: 1971–2011. *Research in Higher Education, 57*(5), 570-600.

Sorby, S. A. (2001). A Course in Spatial Visualization and Its Impact on the Retention of Female Engineering Students. *Journal of Women and Minorities in Science and Engineering, 7*(2), 153-172.

Sorby, S. A. (2009). Educational Research in Developing 3‐D Spatial Skills for Engineering Students. *International Journal of Science Education, 31*(3), 459-480.

Patrick, A., Riegle-Crumb, C., & Borrego, M. (2021). Examining the Gender Gap in Engineering Professional Identification. *Journal of Women and Minorities in Science and Engineering,* 27(1), 31-55.

Steinke, J., Lapinski, M. K., Crocker, N., Zietsman-Thomas, A., Williams, Y., Evergreen, S. H., & Kuchibhotla, S. (2007). Assessing Media Influences on Middle School–Aged Children's Perceptions of Women in Science Using the Draw-a-Scientist Test (Dast). *Science Communication, 29*(1), 35-64.

Su, R., Rounds, J., & Armstrong, P. I. (2009). Men and Things, Women and People: A Meta-Analysis of Sex Differences in Interests. *Psychological Bulletin, 135*(6), 859-884.

Subrahmanyam, K., & Greenfield, P. M. (1994). Effect of Video Game Practice on Spatial Skills in Girls and Boys. *Journal of Applied Developmental Psychology, 15*(1), 13-32.

Tate, E. D., & Linn, M. C. (2005). How Does Identity Shape the Experiences of Women of Color Engineering Students? *Journal of Science Education and Technology, 14*(5-6), 483-493.

Uttal, D. H., & Cohen, C. A. (2012). Spatial Thinking and Stem Education: When, Why, and How? In *Psychology of Learning and Motivation* (Vol. 57, pp. 147-181). Elsevier.

Wang, M.-T., & Degol, J. L. (2017). Gender Gap in Science, Technology, Engineering, and Mathematics (Stem): Current Knowledge, Implications for Practice, Policy, and Future Directions. *Educational Psychology Review, 29*(1), 119-140.

West, C., & Zimmerman, D. H. (1987). Doing Gender. *Gender & Society, 1*(2), 125-151.

Woodcock, A., Graziano, W. G., Branch, S. E., Habashi, M. M., Ngambeki, I., & Evangelou, D. (2013). Person and Thing Orientations: Psychological Correlates and Predictive Utility. *Social Psychological and Personality Science, 4*(1), 116-123.

Patrick, A., Riegle-Crumb, C., & Borrego, M. (2021). Examining the Gender Gap in Engineering Professional Identification. *Journal of Women and Minorities in Science and Engineering,* 27(1), 31-55.

Table 1: Descriptors of factors capturing affinities towards engineering professional practices.

Practice	**Definition**
Project Management	This factor captures the skill set individuals utilize to: organize, plan, and makes decisions needed to execute a design project as well as the wherewithal to see the plan through to the end.
Framing and Solving Problems	The factor describes an individual's application of: math and science to solving engineering problems, continuous learning, improving process and methods, and embracing curiosity in relation to addressing societal issues.
Collaboration	This factor captures the ability to: communicate and present your ideas, convince other people as to the merits of an idea, work with others, and break down a project into manageable parts.
Analysis	This factor captures the ability to: identify what you need to know to solve a problem or complete a project, and apply the appropriate math and science to solve the relevant governing equations during design and evaluation.
Design	This factor describes an individual's push to: search out innovative ideas, and to be creative and generative in the course of experimentation or prototyping in the design process. Relates specifically to an individual's ability to keep up with and apply technology to contemporary issues.
Tinkering	The factor captures the propensity an individual has to: understand how something works by taking it apart, and fix things.

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Table 2: Correlations between the dependent and independent variables

Factor	EPI	1)	2)	3)	4)	5)	6)
EPI	-						
1) Project Management	0.26	-					
2) Framing and Solving Problems	0.29	0.54	-				
3) Collaboration	0.19	0.58	0.59	-			
4) Analysis	0.35	0.52	0.48	0.47	-		
5) Design	0.39	0.55	0.63	0.51	0.60	-	
6) Tinkering	0.38	0.32	0.41	0.30	0.41	0.60	-

All significant $p<0.001$.

Table 3: Descriptive statistics for student background variables

Variable	Proportion/Mean
Gender	
Female	0.39
Male	0.61
Major	
Mechanical Engineers	0.32
Civil/Architectural Engineers	0.35
Biomedical Engineers	0.33
Semester	
Fall 2016	0.38
Fall 2017	0.18
Fall 2018	0.45
Division	
Lower (freshmen & sophomores)	0.63
Upper (juniors and seniors)	0.37
Race	
White	0.51
Hispanic	0.20
Asian	0.24
Black	0.02
American Indian/Native Hawaiian[+]	0.00
Multiracial	0.03
Mother's Education	2.88 (1.04)

[+]American Indian/Native Hawaiian is 0.001
Note: Standard deviations are included in parentheses

Table 4: Descriptive table for engineering professional identification and affinities towards engineering professional practices

Variable	**Pooled (n=2256)**	**Male (n=1365)**	**Female (n=891)**	**Effect Size**	**Sig.**
Engineering Professional Identity (EPI)	5.05 (1.26)	5.17 (1.28)	4.87 (1.21)	0.24	*
Project Management	4.26 (0.59)	4.22 (0.59)	4.32 (0.58)	-0.17	*
Framing and Solving Problems	4.50 (0.47)	4.48 (0.47)	4.53 (0.46)	-0.12	*
Collaboration	4.08 (0.59)	4.07 (0.60)	4.08 (0.58)	-0.02	n.s.
Analysis	4.03 (0.75)	4.07 (0.60)	3.96 (0.79)	0.15	*
Design	4.12 (0.63)	4.15 (0.61)	4.08 (0.66)	0.12	*
Tinkering	3.96 (0.88)	4.07 (0.86)	3.80 (0.90)	0.31	*

Significance calculated using a two-tailed t-test. Adjusted threshold for pairwise comparisons using a Bonferroni correction: *p<0.007.
n.s. = not significant
Note: EPI is on a scale of 1 to 8. All other variables are on a scale of 1 to 5.

Table 5: Regression analyses predicting engineering professional identity

	Model 1	Model 2	Model 3
Female	-0.30***	-0.28***	-0.18***
	(0.05)	(0.05)	(0.05)
Major (reference=ME)			
CAEE		-0.07	-0.08
		(0.07)	(0.06)
BME		-0.13*	-0.18**
		(0.07)	(0.06)
Semester (reference=Fall 2016)			
Fall 2017		0.15~	0.11
		(0.08)	(0.07)
Fall 2018		0.03	0.06
		(0.06)	(0.05)
Division (reference=lower)		-0.08	0.08
		(0.05)	(0.05)
Race (reference=White)			
Hispanic		0.10	0.05
		(0.07)	(0.06)
Asian		0.09	0.07
		(0.07)	(0.06)
Black		0.10	0.23
		(0.22)	(0.20)
American Indian/Native Hawaiian		1.32	0.61
		(0.89)	(0.79)
Multiracial		-0.06	-0.12
		(0.16)	(0.14)
Mother's Education		-0.03	0.02
		(0.03)	(0.02)
Flag for Missing for Mother's Education		-0.13	-0.19
		(0.20)	(0.18)
Affinity Variables			
Project Management			0.14*
			(0.06)
Framing and Solving Problems			0.21**
			(0.07)
Collaboration			-0.20***
			(0.05)
Analysis			0.25***
			(0.04)
Design			0.31***
			(0.06)
Tinkering			0.27***
			(0.03)

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Constant	5.17***	5.28***	0.99***
	(0.03)	(0.10)	(0.26)
Observations n=2256			
Adjusted R-squared	0.013	0.016	0.212

~p≤0.10; *p≤0.05, **p≤0.01, ***p≤0.001

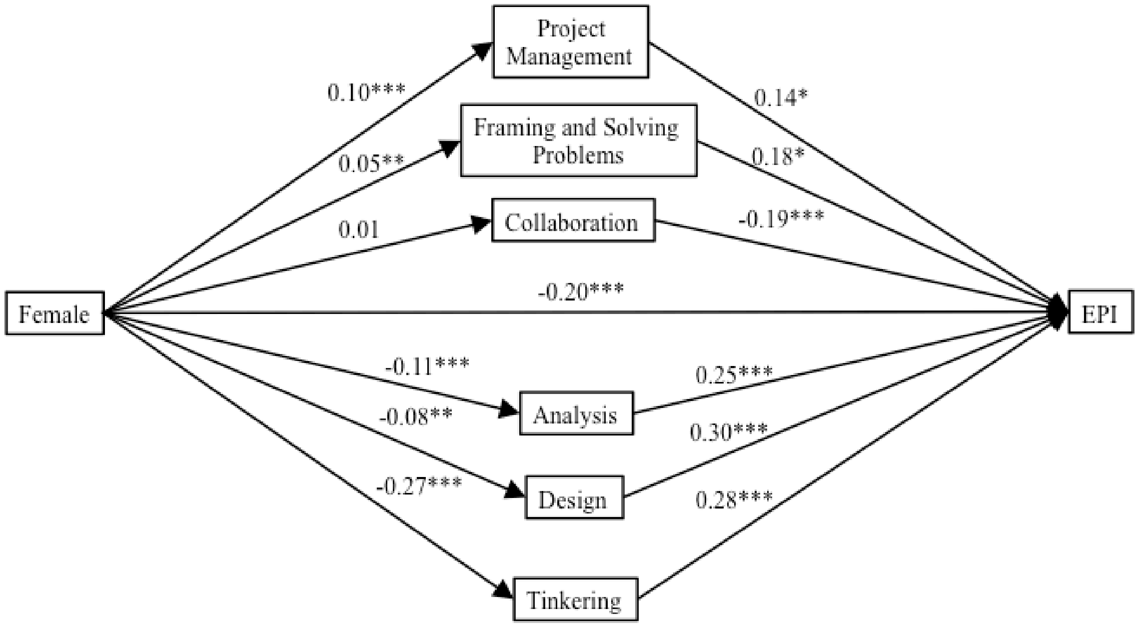

Figure 1. Unstandardized coefficients for the relationship between being a female student and engineering professional identity (EPI), as mediated by affinity towards professional practice variables. *p≤0.05, **p≤0.01, ***p≤0.001

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Table 6: Regression analyses predicting engineering professional identity with interactions between gender and affinities towards engineering practices

Gender Interactions	
Female x Project Management	0.14
	(0.11)
Female x Framing and Solving Problems	0.35*
	(0.15)
Female x Collaboration	-0.15
	(0.11)
Female x Analysis	-0.07
	(0.08)
Female x Design	-0.09
	(0.12)
Female x Tinkering	-0.13~
	(0.07)
Constant	1.13***
	(0.32)
Observations n=2256	
Adjusted R-squared	0.214

The model includes the main effect of gender, affinity variables, and student background variables (as seen in Model 3 of Table 5).
~p≤0.10; *p≤0.05, **p≤0.01, ***p≤0.001

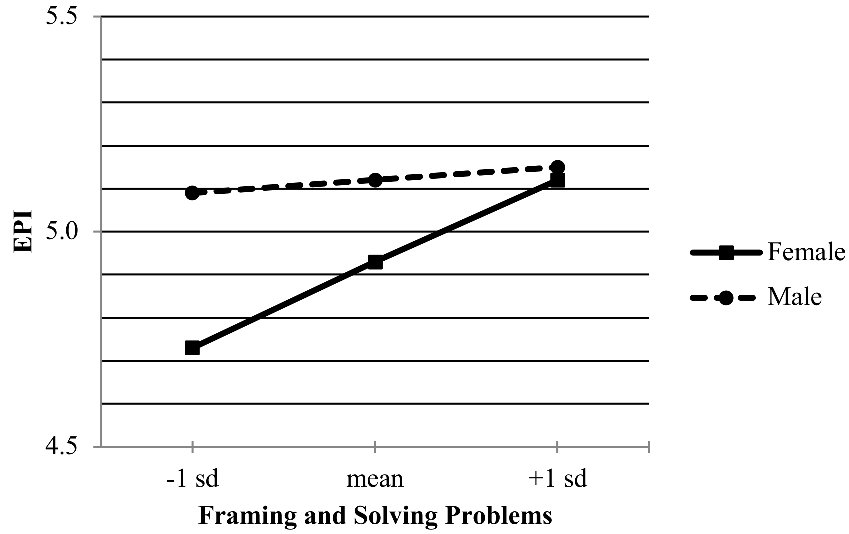

Figure 2. Predicted values of EPI at varying values of framing and solving problems.

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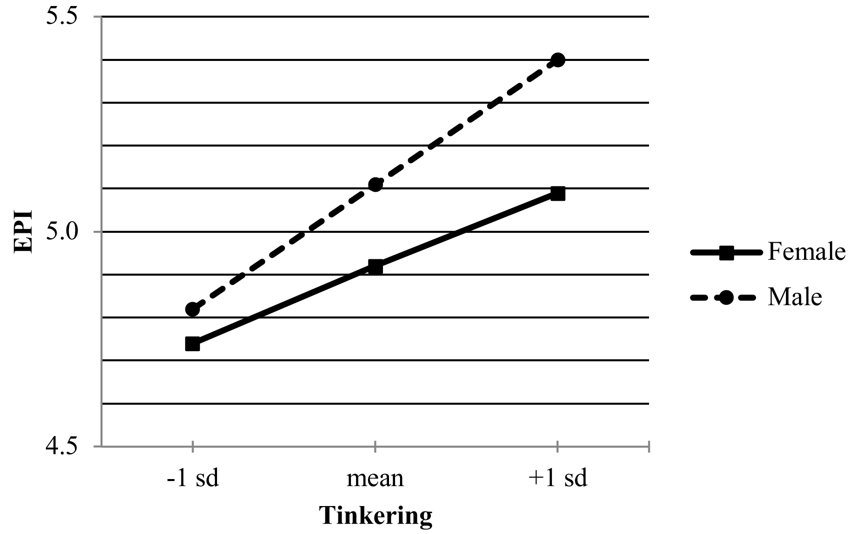


Figure 3. Predicted values of EPI at varying values of tinkering.

Appendix

Table A.1 List of engineering professional identity items

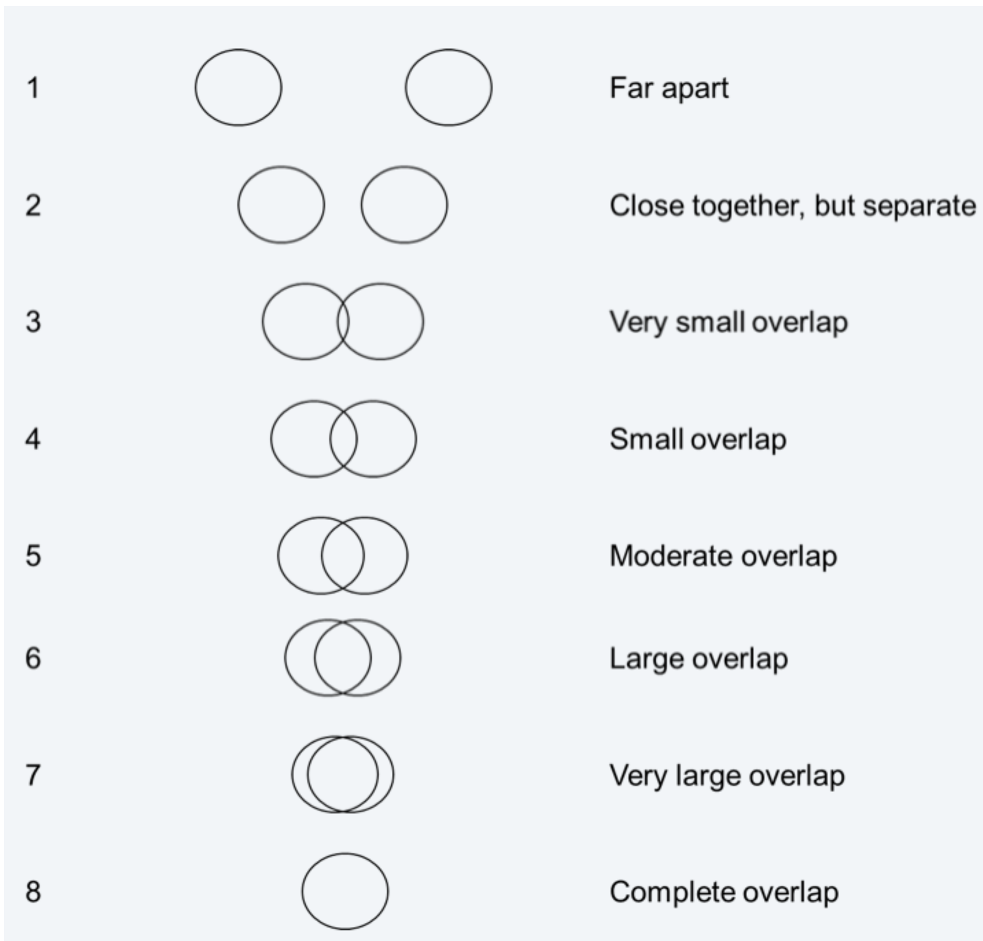
Factor	Item
Engineering Professional Identity	1) Please describe your relationship with engineering by using the following diagrams. Imagine that the circles at the left represent your own personal identity (i.e., what describes you as a unique individual), while the circles at the right represent the identity of an engineer (i.e., what describes an engineer). Which diagram best describes the level of overlap between your own identity and the identity of an engineer? 
	2) To what extent does your own sense of who you are (i.e., your personal identity) overlap with your sense of what an engineer is (i.e., the identity of an engineer)? ["1" not at all to "8" to a great extent].

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Table A.2 List of Affect Towards Engineering Professional Practices for CFA

Latent Construct	Indicator Item	Standardized Factor Loading and (S.E.)	Construct Reliability (∝)
Project Management	Planning a project and staying organized to complete it	0.60 (0.02)	0.73
	Tracking various aspects of a project to ensure that it stays on track	0.64 (0.02)	
	Using facts and information, instead of opinions, to make decisions	0.52 (0.02)	
	Seeing a project through to its end	0.57 (0.02)	
Framing and Solving Problems	Solving problems that allow me to help a lot of people	0.51 (0.02)	0.78
	Learning new things from other people I'm working with	0.58 (0.02)	
	Finding a better way of doing something	0.61 (0.02)	
	Continually learning new things	0.62 (0.02)	
	Applying my science knowledge and skills	0.64 (0.02)	
	Being curious	0.59 (0.02)	
Collaboration	Presenting my work to others	0.44 (0.02)	0.77
	Working with people with different skills and interests	0.54 (0.02)	
	Communicating verbally, for example in discussion with others	0.45 (0.02)	
	Convincing others to accept my ideas	0.43 (0.02)	
	Breaking a complicated problem into smaller parts	0.65 (0.02)	
	Working collaboratively in teams	0.46 (0.02)	
Analysis	Applying my math knowledge and skills	0.63 (0.02)	0.76
	Using calculations and equations to evaluate things	0.64 (0.02)	
	Identifying what I need to know to solve a problem or complete a project	0.80 (0.01)	

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Table A.2 List of Affect Towards Engineering Professional Practices for CFA (continued)

Design	Identifying technical solutions that are as simple as possible	0.61 (0.02)	0.83
	Designing and conducting experiments to test an idea	0.60 (0.01)	
	Searching for innovative ways to do things	0.69 (0.01)	
	Improving a design to make it more efficient (faster, better, cheaper)	0.68 (0.01)	
	Using technology to solve environmental problems	0.47 (0.02)	
	Creating prototypes to test an idea	0.64 (0.02)	
	Designing a system, a part/component of a system, or a process based on realistic constraints	0.66 (0.01)	
Tinkering	Taking something apart to see how it works	0.75 (0.02)	0.69
	Fixing things	0.70 (0.02)	

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