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Gendered Elective Track Choice in Engineering Undergraduate Education: Antecedents and Career Path Implications

Dr. Teresa Cardador, University of Illinois at Urbana - Champaign

Teresa Cardador is an Associate Professor in the School of Labor and Employment Relations at the University of Illinois Urbana-Champaign. Her research centers on how occupations, organizations, and personal orientations toward work (e.g., callings) affect how individuals make sense of, and experience meaningfulness in, work. She is particularly interested in these issues as they relate to the job and career experiences of individuals in sex-segregated occupations, such as engineering, medicine, nursing, and policing. Her research has been published in a number of outlets including the Academy of Management Journal, Organization Science, Journal of Organizational Behavior, Journal of Vocational Behavior, and Harvard Business Review, and she has given over 50 invited or referred talks to academic and business audiences.

Dr. Karin Jensen, University of Illinois at Urbana - Champaign

Karin Jensen, Ph.D. is a Teaching Assistant Professor in bioengineering at the University of Illinois Urbana-Champaign. Her research interests include student mental health and wellness, engineering student career pathways, and engagement of engineering faculty in engineering education research. She was awarded a CAREER award from the National Science Foundation for her research on undergraduate mental health in engineering programs. Before joining UIUC she completed a post-doctoral fellowship at Sanofi Oncology in Cambridge, MA. She earned a bachelor's degree in biological engineering from Cornell University and a Ph.D. in biomedical engineering from the University of Virginia.

Dr. Kelly J. Cross, University of Nevada, Reno

Dr. Cross is currently an Assistant Professor in the Chemical and Materials Engineering Department at the University Nevada Reno. After completing her PhD in Engineering Education at Virginia Tech in 2015, Dr. Cross worked as a post-doctoral researcher with the Illinois Foundry for Innovation in Engineering Education and in the Department of Bioengineering with the Revolutionizing Engineering Departments (RED) grant at the University of Illinois at Urbana-Champaign. Dr. Cross' scholarship investigated student teams in engineering, faculty communities of practice, and the intersectionality of multiple identity dimensions. Her research interests include diversity and inclusion in STEM, intersectionality, teamwork and communication skills, assessment, and identity construction. Her teaching philosophy focuses on student centered approaches such as culturally relevant pedagogy. Dr. Cross' complimentary professional activities promote inclusive excellence through collaboration.

Ms. Grisel Lopez-Alvarez, University of Illinois at Urbana - Champaign
Andrea J. Kunze, University of Illinois at Urbana - Champaign

Andrea Kunze is a PhD student at the University of Illinois at Urbana-Champaign in the Department of Educational Psychology. Prior to coming to UIUC, she completed a MS in Educational Psychology at NC State University, and a BS in Human Learning & Development at Georgia State University. Her research currently focuses on utilizing qualitative and mixed methodologies to explore people's perceptions and experiences of the social environment in which they learn or work, and how it impacts their engagement and success.

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Introduction

With support from the NSF Improving Undergraduate STEM Education (IUSE) Program, this Institutional and Community Transformation project aims to serve the national interest of broadening participation by improving the representation of women in more technically-oriented roles and career paths within engineering. Research has shown that women who pursue engineering careers are more likely than their male counterparts to be in less technical roles and careers paths, and these gendered career patterns increase attrition risk for female engineers [1-3]. This project focuses on female engineering students' elective track choices and perceptions of different career paths in engineering as potential "upstream" predictor of gendered career patterns. We investigate the driving forces behind elective track choices and career path decisions for female engineering students. The findings will inform faculty development and other administrative efforts in order to achieve gender balance within technical elective tracks and, ultimately, technically-oriented careers.

The study is grounded in intra-occupational sex segregation and social cognitive career theories, and is a longitudinal, multi-method, multi-case study. We are systematically exploring elective track choices among aspiring engineers in three engineering majors—Bioengineering, Computer Science, and Electrical Engineering. Each major represents a single case with which we will conduct within- and between-case analysis. We are using this methodology to systematically examine how and why elective track choices become gendered during undergraduate engineering education, and what the career implications might be for women. In particular, we are collecting multi-year, and multi-level (institutional, educator, and student) archival, survey, and interview data relevant to educational tracks and track selection as well as career attitudes and decisions during undergraduate engineering education. We are examining how personal factors (e.g., interests and beliefs), relational factors (e.g., peer) and structural factors (e.g., advising, program climate, instruction and extra-curricular activities) impact elective track choices, and exploring whether and how these specialization track selections shape career-relevant outcomes. As this project is ongoing, we present preliminary results based two waves of engineering student interviews and one wave of survey data collection.

Insights gained from this research will help inform theory and practice related to improving the diversity of students participating in the more technically-oriented roles and career paths within engineering. Moreover, shedding light on factors related to women's elective track and career path decisions will allow us to suggest institutional changes to enhance gender equality in engineering education curricula in order to better prepare women to enter technical roles in the workforce.

Project background and theoretical framework

Existing research shows that men and women in gender-typed occupations – such as engineering – often experience their professional roles differently [4-6]. In a recent study [7] found that as compared to men's professional identity, women's professional identities were less likely to emphasize dominant and valued traits in engineering such as technical leadership and concurrently, more likely to emphasize typically marginalized traits (e.g., social consciousness; [7]. Further, these gender differences in engineering identity traits were linked to gender differences in persistence in engineering education [8] and wage gaps [3]. Others have noted the tendency among engineers to define "real" engineers in terms of technical "nuts and bolts" and scientific and mathematical expertise or rigor [9], thereby locating the less technical (i.e., social; [10]) aspects outside of what it means to be a "real" engineer [11]. Godfrey found that there is a devaluing of content or subject areas that were seen as "easy" or "soft" [12]. This extant research suggests that "real engineering" is often positioned as technical, and that women are less likely to adopt or perform the most celebrated (i.e., technical) engineering roles, with implications for greater risk of attrition [1, 2, 7]. Some previous scholars have considered the technical social dualism in engineering (e.g. [10, 12, 13], however, our understanding of the role of major and within major track selection linked to career choices in engineering is understudied. To address this gap, the current project seeks to shed light on early career stage (i.e., "upstream") antecedents of gendered career patterns and their downstream career path/role choice. We use two complementary theoretical lenses to inform our investigation – intra-occupational sex segregation (IOSS), and social cognitive career theory (SCCT).

Intra-occupational sex segregation in engineering

As noted in the Introduction, while scholars are beginning to recognize forms of IOSS in engineering—whereby women and men pursue different career paths and roles within the profession—and to acknowledge that they may have important negative consequences for women's professional retention in engineering, there is a paucity of research examining how and why these gendered career patterns begin to emerge. Research on the technical/social dualism in engineering provides some insights, suggesting that women gravitate toward or are mentored toward managerial roles because these roles are considered to be more aligned with the "social" or "people side" of engineering [4, 5]. While there is limited research on the antecedents IOSS in engineering, some research has shown that engineers' choice of managerial roles is predicted by advanced career stage and desire for promotion, while choice of technical roles is predicted by identification with the engineering profession [14].

What is not well understood, however, is when female engineers' decisions about engineering roles and career path begin to formulate and how factors present in their undergraduate educational environment may influence their later decisions to consider, or conversely gravitate away from, the most technical roles in their engineering major and sub-field. Accordingly, the purpose of this research is to examine how and why elective track choice—a factor significant to the formation, socialization, and preparation of engineers for the workforce—may become gendered during undergraduate education, and what the implications might be for downstream career decisions and attitudes. Moreover, we explore engineering undergraduate perceptions of career paths in engineering and track these perceptions over three years.

Social cognitive career theory

SCCT has been used to explain the formation of career-relevant interests, choice, and attainment of career-related goals, and emphasizes the role of self-efficacy and outcome expectations (e.g., [15, 16]). The theory posits that self-efficacy and outcome expectation beliefs are impacted by personal accomplishments, and contextual factors present in academic and career-development environments which impact personal behavior and choice [15]. In a "virtuous cycle" of sorts, self-efficacy (confidence) in one's abilities in the domain prompts positive initiation and expectations in career-related endeavors and interests are increased for those areas in which one feels efficacious [16]. This theory also suggests that contextual factors can service as structural enablers or impediments such that personal preferences and contextual factors interact to influence career-relevant decisions.

This prior research suggests that SCCT is a valuable lens through which to examine how female engineering students make career-critical, elective track and career path decisions during their undergraduate education, and the personal and structural (i.e., contextual) factors that may affect these decisions via positive technical outcome expectations. Accordingly, our study pays attention to the role of these factors of contributing to female engineers' elective track decisions and subsequent implications.

Methods

This is a three-year project with three waves of both survey and interview data collection. Thus far, we have conducted the wave 1 and wave 2 interviews (with 30 and 24 female undergraduates, respectively), and have completed the wave 1 survey (N = 94 engineering undergraduates). Data collected also include 9 interviews of faculty and staff from each of the three majors in our wave 1 interviewing. We believe that our sample sizes for the wave 2 student interviews and wave 1 student survey were reduced due to student survey fatigue, and perhaps general fatigue, to the Covid-19 pandemic. Our interviews and survey data included engineers from three engineering majors – Bioengineering, Computer Science, and Electrical Engineering. These three majors were selected based on the gender balance in each major – high (Bioengineering; 51.4% female), medium (Computer science; 27.5% female) and low (Electrical Engineering; 14.2% female) at the focal institution.

Qualitative interview design

Interview protocols. The interview protocol for wave 1 (N = 30) included three main sections. Table 1 includes example questions. After all the questions were asked, participants were offered the opportunity to share any additional information or thoughts not covered in the interview. The interview protocol for the wave 2 interview mirrored that of wave 1.

Table 1. Example questions from interview protocol

Protocol Section	Example Questions
Section 1. Students were asked about their major selection and influences on deciding on that major.	1. In thinking about how you selected your major, who, if anyone, contributed to your choice? What courses, if any, prepared you for your major? 2. What factors/characteristics are required for success in your major? 3. How important are technical in your major? Professional skills?
Section 2. Participants were asked about their specialization or elective track within their major.	1. What elective track/specialization have you selected/plan to select within your major? Why? 2. What factors/characteristics are required for success in your area of specialization? 3. What are the ways, outside of coursework, in which students can specialize within you major? 4. How important are technical skills in your elective track/specialization area? Professional skills?
Section 3. Participants were asked questions about their post-graduation plans.	1. What are your plans for internships or career development in the near future? 2. What are your career plans post-graduation? 3. What career path do you envision taking? Do you see yourself as taking a more technical or managerial role. Explain why.

Data collection. Interview data were collected in Fall 2019 (wave 1) and Fall 2020 (wave 2) semesters under IRB approval. Participants were recruited by email from advisors of the Electrical and Computer Engineering, Bioengineering, and Computer Science departments. Participants were eligible if they identified as female, were in their second year of undergraduate education, and were currently enrolled in one of the three focal majors. Participants were informed in the recruitment email that they would receive $20 for their participation. All wave 1 interviews were held face-to-face in a private office on the engineering quad. All wave 2 interviews were held via Zoom due to the Covid-19 pandemic. Interviews in both years were conducted by one of four project team interviewers. The interviews were audio recorded and transcribed verbatim. Wave 2 participants included the 24 of the 30 we interviewed in the prior wave. We were not able to obtain the other six because two participants were no longer in the program and the remaining four did not respond to multiple invitation emails.

Data analysis. Wave 1 interview transcripts were cleaned to remove identifying information, and then imported into MAXQDA2020 for the researchers to analyze the interviews using a thematic analysis approach [17-19]. During the first phase of coding, two of the researchers each read through 10 of the same transcripts (distributed across the three majors) and began generating initial codes (i.e., “open coding”). The two researchers then engaged in a collaborative process of re-categorizing or combining common codes. These codes were then used to develop a codebook for use in coding the remaining interviews. Additional collaborative meetings between the entire team took place to further define and name themes and discuss relationships among them as presented in our findings. Wave 2 data analysis is just beginning.

Quantitative survey design

Data collection. We sampled male and female engineering students in their second year. All participants were students at the same large, public university. The survey included questions about technical, professional and engineering identity, identification with engineering students, peer and program influences on their confidence and motivation to continue with engineering, field-specific ability beliefs, technical professional ability beliefs, elective track/specialization choice, outcome expectations associated with elective track/specialization choice, post-graduation career plans and career path preferences, perceived prestige of the technical and managerial paths, and demographics (gender, GPA, race, SES). The survey had an approximate 16% response rate.

Data analysis. We are just beginning data analysis and plan to use non-parametric analyses in SPSS, such as Spearman correlations to look at associations between variables and Kruskal-Wallis tests to examine potential differences across majors and between men and women.

Preliminary results

Results from interview data[1]

We have analyzed the data from the wave 1 interviews and have two key sets of findings. These findings are summarized in Table 2. The first relates to second-year female student interests in managerial versus technical career paths in engineering, as well as how the students in our sample characterize the merits and limitations of each career path. Findings, theoretically informed by literature on IOSS in engineering and SCCT, highlight majority interest in managerial versus technical career paths in engineering and highlight that students interested in the managerial path have a "leadership orientation" toward engineering work and those interested in the technical path have a "discovery orientation" toward engineering. These findings are important because they shed light on patterns of IOSS in engineering by showing that women's preferences for managerial versus technical career paths are formed early in their education and socialization into engineering. Moreover, our findings detail the reasons why women may show preferences for managerial career paths in engineering. While we are exploring this link in future waves of data collection, we believe that technical versus managerial interests are likely to influence female students track/specialization choice as those interested in the technical career path will be more likely to choose the most technical specialization areas, and those interested in the managerial path will gravitate to less technically focused specialization areas.

[1] Early results from the first year of the study were presented at ASEE 2020 [20].

Table 2. First set of key preliminary findings from wave 1 qualitative study

Topic Area	Key Finding	Finding Significance
Student interests in managerial vs. technical career paths in engineering.	1. The majority of students expressed interest in managerial versus technical career paths in engineering. 2. Majors with higher (lower) percentages of women, were the most (least) likely to express interest in the managerial path.	Even before most have had any work experience, female students across all three majors show strong interests in managerial career paths. Interests in managerial path appears correlated with gender representation in the major.
How students in our sample characterize the merits and limitations of each career path.	1. Students associated the managerial path with work that is collaborative and holistic, the application of both technical and professional skills and opportunities for customer and organizational impact. 2. Students associated the technical path with work that is intellectually stimulating and hands-on, application of specialized technical skill and technological impact through innovation.	The relationships among our themes highlight that students interested in the managerial path have a "leadership orientation" toward engineering work and those interested in the technical path have a "discovery orientation" toward engineering.

The second set of findings emerging from the wave 1 student interviews relate to the structural and contextual factors that shape second year female engineering students' elective track/specialization decisions. We are developing a conceptual model which highlights three sets of influential factors: top-down vs. bottom-up specialization structure, availability and timing of courses, and perceived difficulty of courses. Table 3 summarizes these themes. These findings are important because while the assumption is generally made that students choose specializations based on interests, we show that programmatic factors (i.e., program structure, timing of courses, difficulty of courses) may be at least as, or perhaps more influential in student choice of specialization than interests. Moreover, to the extent that female students are more likely than male students to attach low self-efficacy perceptions to course performance [21], these factors may encourage female engineering students to choose specialization areas not out of interest but rather to maximize the chances of good performance.

Table 3. Second set of key preliminary findings from wave 1 qualitative study

Topic Area	Key Finding	Finding Significance
Factors that shape second year female engineering students' elective track/specialization decisions.	1. "Top down" vs. "bottom up" specialization structure. Whether the structure of the major encourages students to pick tracks/ courses based on the link to a specific career path or whether they are encouraged to explore courses to identify a career path. 2. Availability and timing of courses. Ability to fulfill specialization pre-requisites and/or the anticipated ability to access the courses related to a particular specialization. 3. Perceived difficulty of courses. Influential, particularly for some groups (i.e. those that are highly concerned with GPA such as those planning to go to medical school or graduate school in engineering), but also for those concerned about their overall performance.	Findings highlight that programmatic factors (i.e., program structure, timing of courses, difficulty of courses) may be at least as, or perhaps more influential in student choice of specialization than interests.

Results from survey data

Survey analysis is currently in progress. We plan to test the following in our data: (1) the relationship between peer support and program support and students' interest and confidence in engineering; (2) the relationship between technical identity, professionalism identity, engineering identity and specialization choice and outcome expectations from their track/specialization area; (3) the relationship between peer and program support, as well as identity (technical, professionalism, engineering) and career path plans; and (4) differences in these relationships by gender and by major.

Discussion and future work

Our project aims to better understand potential upstream antecedents to the patterns of IOSS found in the engineering profession, as well as to longitudinally track the career-related choices, attitudes and preferences of engineering students. To date, we have collected half of the total data we plan to collect for the project and are actively engaging in analysis and writing up study results for publication. So far, our research has (1) uncovered female engineering student preferences for the managerial versus technical path in engineering and explored student characterizations of these two career paths, and (2) identified structural (programmatic) influence on female engineers' elective track/specialization decisions with potential implications for career development. In addition to the cross-sectional studies currently underway, once all data is collected, we will engage in analysis of the longitudinal data to understand patterns of change over time as well as their implications.

Taken together, results from our qualitative analyses to date reveal important insights about the track/specialization decision factors and career path plans of engineering students.

With respect to insights about track/specialization choice, findings highlight the role of structural program features (e.g., advising, timing, availability and difficulty of courses), With respect to insights about career plans, our findings show majority interest in the managerial career path among our qualitative sample, and highlight that female students have path preferences and have formed opinions about what each path entails as early as the first semester of their second year. Taken together, these insights provide shed light on women's specialization decisions within the engineering major and career path plans post-graduation.

These findings carry with them several implications. First, to the extent that the structural features of engineering programs including institutional context play a role in shaping engineering student track/specialization decisions, engineering education programs need to work to remove these structural barriers so that students are freer to follow their specializations interests with fewer structural constraints. Second, as it is clear that engineering students form perceptions about career paths in engineering and their intended career plans early in their education tenure, engineering education programs could provide students with more comprehensive career counseling about career options to ensure that students have the most accurate information to inform their preferences. This could take the form of inviting engineering alumni in different roles to give guest lectures, building education about career roles into courses, creating a video series on career paths in engineering, or ensuring that counselors are equipped to educate students are career path in addition to course options.

Our next steps are as follows. First, analyze the wave 2 interview data and the wave 1 survey data. Second, based on analyses of these data, develop a theoretical model that describes (1) personal and structural influences on elective track selection and career path interests, (2) whether and how interests and career path preferences change over time (from wave 1 to wave 2), and (3) possible career implications. Third, this model will form the basis for development of a wave 2 survey questionnaire (that will be administered in Fall 2021), as well as our wave 3 interview protocol for interview data (of the same participants interviewed in waves 1 and 2) that will be collected in Winter 2021).

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