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Exploring career choice and retention among engineering undergraduate students and systems engineers: A gender perspective

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Abstract
The underrepresentation of women in engineering is a significant concern. This study applies the social cognitive theory and the social career cognitive theory (SCCT) to investigate gender differences in engineering career choices. We examined reasons given by 19 systems engineers and 330 undergraduate engineering students for choosing engineering and categorizing them according to SCCT themes. We compared the distribution of reasons across themes and categories by career stage and gender. For engineers, the category *self-efficacy* correlated significantly with *challenges and opportunities* and *current job suitability* categories, and women engineers cited challenges mainly with work-life balance and the gender glass ceiling. Undergraduate students cited personal reasons more frequently than environmental ones, with behavioral reasons being the least common. The extended SCCT model includes the categories *challenges and opportunities* and *current job suitability* within the behavioral theme, with the latter pertaining specifically to career retention. This research the set of provides insights into gender-dependent engineering career choice and retention by expanding the set of SCCT categories.

Keywords: social career cognitive theory, career choice, retention, engineers, undergraduate students, gender, women in STEM

INTRODUCTION

A critical concern for society in general and for science, technology, engineering, and mathematics (STEM) in particular has been gender inequality. The increasing demand for STEM careers in the labor market in developed countries contrasts with the lack of undergraduate students who pursue careers in these areas (Miller et al., 2018; Tal et al., 2024). This shortage stems from an overall decrease in interest in and selection of STEM areas in both higher education and industry (Riegle-Crumb et al., 2011; Shwartz et al., 2021; Xie & Achen, 2009). Fewer women enter STEM careers (Avargil et al., 2023, 2024; Hazari et al., 2010; Morgan et al., 2001; Sadler et al., 2012), especially in engineering fields (Gumaelius et al., 2016). During their youth, from late teenage years to late twenties, young adults make important, life-affecting decisions in many domains, including education and employment, which shape their place in society (Arnett, 2004). Young people's experiences in the various life domains and the meaning they ascribe to these experiences are important components of their investigation process and the formation of their identity (Flum & Kaplan, 2006; Michael et al., 2013). Studies on identity development and exploration processes in young adulthood tend to focus on a single life domain rather than on the range of related key domains and their interconnectedness.

Recruiting and retaining women students in engineering fields is an enduring challenge for these students and for their educators (Dzombak et al., 2016; Tal et al., 2024). Yet, girls in early adolescence experience

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Contribution to the literature

- The study extends the understanding of engineering career choices using social cognitive theory (SCT) and social career cognitive theory (SCCT). Researchers analyzed reasons given by engineers, as well as undergraduate students, identifying current job suitability as a new category within the behavioral theme.
- Despite progress, women engineers still face challenges that pertain to work-life balance and career advancement, impacting retention.
- The study extends SCCT by focusing on career choice and retention, offering insights to designing supportive environments and addressing gender gaps in STEM.

more autonomy and are in a better position than boys to make decisions about their future. Gender differences in attitude toward science vary across science disciplines (Reilly et al., 2019). Women who choose STEM careers continue to study and work in science fields such as biology, medicine, and agriculture, which have traditionally featured higher numbers of women. Conversely, men are more inclined to pursue studies in mathematics and the physical sciences, leading to professions in these areas, as well as in engineering (Kolmos et al., 2013; Sikora & Pokropek, 2012). Women are less likely to choose careers in these domains partly because they perceive themselves as less talented than men. Salmi et al. (2015) have shown that girls had more favorable attitudes toward science than boys, but boys had significantly more favorable attitudes toward engineering than girls. Suggesting that interest in science is formed at an early age, Osborne and Dillon (2008) recommended stimulating students before the age of 14 with science activities, as this shapes the course of their future career development.

Lariviere et al. (2013) noted that gender inequality in science is still prevalent, and while in many countries there are more undergraduate and graduate women than men, relatively few women are full professors, as gender inequalities persist in hiring, earnings, funding, satisfaction, and patenting. Indeed, gender inequality increases as one climbs up the STEM positions ladder. Although positive changes in the status of women in higher education and employment have occurred, some professions are still perceived as traditionally masculine (Simeon et al., 2020; Teshner, 2014). The Organization for Economic Co-operation and Development (OECD) report (Marta & Michelle, 2023) indicated that OECD countries have narrowed or closed gender gaps in education and employment. Yet, although a larger proportion of young women have attained tertiary education (43% for women vs. 35% for men in 2020), new gender gaps in STEM education are apparent. Young men are much more likely than young women to study and pursue a career in mathematics, physical sciences, and computing. Narrowing the focus to engineering at the undergraduate level, the difference between men and women is more pronounced: Men choose to study engineering 3.5 times as much as women—22% vs. 6%. In Israel, women account for about one third of the students population studying physics, mathematics, and computer science, along with engineering and architecture combined (Kuprak, 2022). This difference in STEM career choice in favor of men adversely affects the demographics within the labor market, likely lowering women's wages compared with those of men. Despite endeavors to enhance gender diversity in STEM fields, women still doubt their competences. The undergraduate phase, pivotal in shaping career trajectories, may influence women's decisions in science due to peer pressure (Bloodhart et al., 2020).

People develop professional career aspirations based on information they receive in high school about science or engineering studies and career, as well as exposure to enrichment programs (Bandura et al., 2001; Eccles, 1994; Gottfredson & Lapan, 1997; Seligman et al., 1991; Shwartz et al., 2021; Zohar & Ezer, 2023), shaping their attitudes toward these subjects (Correll, 2001; Kohen & Nitzan, 2022; Riegle-Crumb et al., 2011; Tai et al., 2006; Tan et al, 2013). Women's entrance into STEM, specifically engineering careers, and their retention are of paramount importance, mandating tackling women's decline of interest in and choice of STEM disciplines. Men's and women's STEM career choices are influenced by various factors (Archer et al., 2012; Gayles & Ampaw, 2011; Lent et al., 1994; Schneeweis & Zweimüller, 2012; Simeon et al., 2020), which sometimes negatively affect women's interest in and choice of STEM. These include traditional teaching methods, a competitive atmosphere in the classroom that often favors boys more than girls, little time that teachers dedicate to answering students' questions, and gender stereotypes in middle school science textbooks (Lindner & Makarova, 2024; Tandrayen-Ragoobur & Gokulsing, 2022). Social support in choosing a career is important for both men and women (Avargil et al., 2023). Still, while pursuing a career in systems engineering, this kind of support is likely to be more important for women than for men (Buday et al., 2012). Pleasure, self-efficacy, and achievements influence men more than women in choosing an engineering career (Jones et al., 2013; Riegle-Crumb et al., 2011; Sawtelle et al., 2012). Moreover, despite their higher grades, women who choose to study engineering tend to lose confidence in their ability to succeed more than their male colleagues (Matusovich et al., 2010; Seymour, 1995). Other studies (Buday et al.,

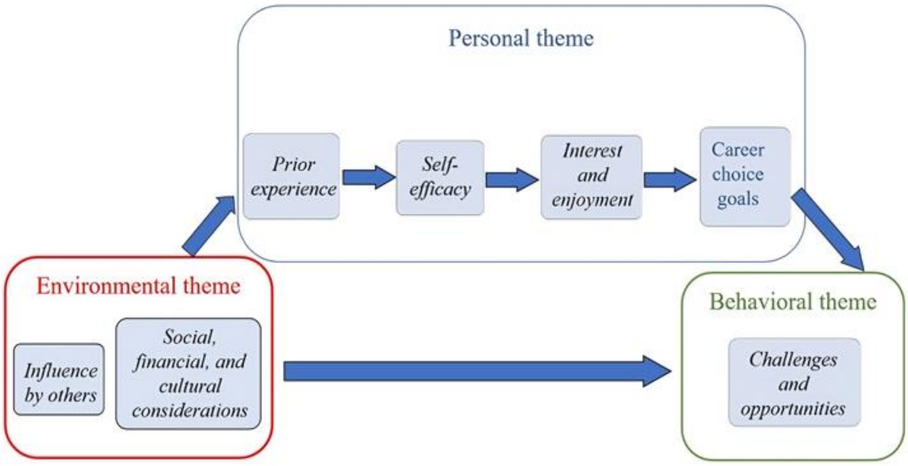

Figure 1. Model of the SCT themes and the SCCT categories within them (Source: Authors' own elaboration)

2012; Chetcuti & Kioko, 2012) indicate that girls have a lower sense of competence than boys in physics and engineering. Women have a conflict between their image and a future engineering career (Carlone et al., 2015), and they are challenged to balance their career with other social aspects. Some women even prioritize developing their husbands' careers (Avargil et al., 2023; Lent et al., 1994; Wilson & Kittleson, 2013).

The Social Cognitive Theory

People have patterns of behavior that reflect their conceptions, and experiences that individuals encounter guide their actions, causing new behavioral patterns to emerge (Bandura, 1986; Carroll & Bandura, 1987). The SCT, presented by Bandura (1986; 1997) posits that three interrelated themes affect a person's inclination and choice of learning path and future career:

(a) the personal cognitive theme, which includes knowledge, thinking skills, self-efficacy, expectations, and attitudes,

(b) the environmental theme, which refers to the social norms and physical settings, and

(c) the behavioral theme, which translates into appropriate courses of action.

In our context, the SCT behavioral theme includes three categories: choosing to study a STEM subject, retaining a STEM career, and following a role model (Avargil et al., 2023; Tal et al., 2024). As women have different experiences, they express various opinions regarding their retention in STEM, which may be attributed to one or more SCT themes. Intervention methods can alter the influence of one or more of these themes, eventually affecting the individual's behavior. For example, applying specific gender equity policies may affect an individual's learning or working environment and increase this individual's self-efficacy level, causing changes in behavior and overall attitude toward involvement in the science and engineering domains (Bandura, 1997, 1999; Crothers et al., 2008; Shekhar & Huang-Saad, 2021; Shwartz et al., 2021).

The Social Cognitive Career Theory

The social cognitive career theory (SCCT) was first suggested by Lent et al. (1994) and later modified by Brown et al. (2008, 2011). The SCCT expanded on the SCT of Bandura (1986, 1997, 1999) by connecting academic performance with the career choice process and the corresponding career decisions. The personal theme includes categories such as interest, abilities, and performance. These categories are also part of the SCCT. Similarly, the SCT environmental theme categories, such as the influence of other people (family and teachers) and contextual categories (school, enrichment program) belong to SCCT as well (Brown et al., 2008, 2011; Lent et al., 1994). Self-efficacy, beliefs, and goals can predict academic and work performance (Bandura & Locke, 2003; Husain et al., 2023; Locke & Latham, 2002; Multon et al., 1991; Stajkovic & Luthans, 1998; Sides & Cuevas, 2020). Female students exhibited elevated stress levels compared to male students, showcasing gender differences in coping mechanisms and typically resorting to emotion-centered coping strategies (Graves et al., 2021). The model in **Figure 1** presents the three SCT themes and (in italics) the SCCT categories within them, based on our interpretation of various sources, including Lent et al. (1994), Lent et al. (2000), and others (Avargil et al., 2023; Rocker Yoel & Dori, 2023). Most of these studies focused on career choice goals—a category within the personal theme. Focusing on women, our research aims to close the gap between career choice and career retention. Women face the challenge of balancing work and home with social and contextual obligations. These can influence their self-efficacy and professional outcomes (Avargil et al., 2023; Tal et al., 2024).

Retention in Engineering and Women's Career Adaptability

Retention is influenced by several SCCT key factors. High self-efficacy is crucial, as students and professionals who believe in their ability to succeed are more likely to persist through challenges (Mau, 2003).

According to the SCCT, resources such as mentoring, hands-on experience, and success stories from alumni can enhance self-efficacy and commitment (Kolmos et al., 2013). Positive outcome expectations and anticipating good job prospects strengthen retention, as individuals who believe their efforts will lead to success are more engaged (Dasgupta & Stout, 2014). Career services and internships can help shape these expectations. Aligning personal goals with engineering opportunities also fosters commitment. When individuals see their aspirations in the field fulfilled, they are more likely to retain their career. Applying SCCT to engineering retention highlights the importance of enhancing self-efficacy, fostering positive expectations, and aligning personal goals with career opportunities, enabling institutions and employers to improve retention rates and support successful engineering careers (Avargil et al., 2023; Lent et al., 2016; Tal et al., 2024).

Career adaptability is the ability of an individual to make a series of successful transitions within a labor market or an organization, which can undergo significant changes over time. Career changes can be made by seeking new challenges or by adopting new perspectives through engagement in substantive personal development (Prvulovic, 2020). The personality characteristics of a person that relate to adaptability, such as being proactive or flexible, can be regarded as prerequisites of adaptive behavior. Psycho-social self-regulatory competencies that shape career-adaptive strategies and behaviors within the labor market and work environments require self-regulation in order to accommodate employment-related change. Career trajectories differ between men and women (Godwin et al., 2016). A woman’s trajectory tends to be more influenced by predefined societal roles, relationships, and responsibilities. Traditionally, a woman’s role in society has been defined by her husband’s career, bearing and raising children, and being a primary caregiver for elderly family members. Women are therefore more likely to experience career disruptions due to these and other family responsibilities (Ackah et al., 2004; Kulik & Rae, 2019; Seymour, 1995). Women’s careers are also shaped by the masculine work culture (Godwin et al., 2016). Major men-held stereotypes that impact a woman’s career progress include the preconception of women’s roles and abilities (Clarke, 2011; Hartman & Barber, 2020; Metz, 2005), under-representation of women in higher-level positions in organizations (Schmitt et al., 2021), and senior management’s reluctance to accept accountability for women’s promotions (Choi, 2019). Due to the lack of women mentoring opportunities, mentoring of women by women peers is important (Seymour, 1995; Tal et al., 2024). Adaptability is closely linked to one’s identity development, causing variability amongst people concerning their willingness to pursue complex career trajectories rather than seeking stability (Avargil et al., 2023; Prvulovic, 2020).

Role Model

Role models are individuals that people wish to emulate or follow because of their attitudes, characteristics, behaviors, or choices (Shapiro et al., 1978). Metz et al. (2004) and Metz (2005) referred to four modeling stages: observation, interpretation, motivation, and performance. Researchers showed that men and women students are positively affected when they encounter women’s role models in science (Fox, 1981; Guthrie & Zusman, 1982; Smith & Erb, 1986). Hence, role models have long been proposed as a potentially powerful technique to influence talented young women to pursue science-related careers.

Role models have had a significant effect on educational aspirations and STEM-related career choices (Avargil et al., 2023; Buday et al., 2012; Charlesworth & Banaji, 2019; Hackett et al., 1989). Equitable representation of female mentors is needed to ensure that students fully benefit from their undergraduate research experiences. Presently, there is a lack of female role models in STEM fields, and further exploration of the of the mentor gender’s impact on the undergraduate research journey is needed (Moghe et al., 2021; Tal et al., 2024). Exposure to role models can be achieved by incorporating career education into regular instruction. Career education can, for example, include informing students about careers in science-related fields and reading stories about women in non-traditional careers (Greene et al., 1982). Early adolescent exposure to role models may help them perceive themselves as scientists or engineers (Buday et al., 2012; Chan, 2022; Smith & Hausafus, 1998). One-on-one mentoring programs for women, which provide an atmosphere of support and confidence and improve their sense of self-efficacy, positively affect their choice of an engineering career.

Why Do Students Choose a Career in STEM?

When asked to explain their engineering career choice, both men and women mentioned interest and previous experience as major reasons. However, there are some differences between the reasons men and women provided. Women were more associated with people-oriented careers and mentoring, while men were more associated with financial factors and prestige (Kolmos et al., 2013; Morgan et al., 2001). Matusovich et al. (2010) showed that more than interest, a sense of attainment influenced students to choose engineering as a career. Kolmos et al. (2013) found that parental influence on engineering career choice is low. Low or moderate interest can lead to a sense of attainment if other factors, such as financial factors, are involved. However, students with low interest, utility, and attainment values might leave engineering studies.

Female undergraduate students experience the influence of ability-related gender stereotypes, affecting the acknowledgment of women's accomplishments among peers and the retention of women in STEM fields and professions (Bloodhart et al., 2020). Despite strides towards gender balance in the U.S. workforce, a notable gender gap persists in STEM disciplines, and it is particularly noticeable in academic positions like instructors and tenure-track roles. Enhanced comprehension of the factors underlying this phenomenon can promote increased equality and inclusivity for women in academic positions within STEM fields (Galvin et al., 2024). Cultural factors, family, and organizational aspects also positively affect engineering career choice (Clarke, 2011; Hartman & Barber, 2020).

Research has focused on women and their career choices in science domains (Freedman et al., 2023; Morgan et al., 2001). However, research on women's career choices in engineering domains, especially information and systems engineering, is rare, motivating this study.

METHOD

In this section we describe the research goals, questions, settings, participants, tools, and data analysis.

Research Goals and Questions

We examined the personal, environmental, and behavioral SCT themes and identified the relevant SCCT categories within them. The goals of this study were to

(a) identify the SCCT categories based on reasons given by women and men for choosing to study engineering and

(b) determine whether the distribution of the categories differs between men and women, and if so, how.

Two research groups were examined:

(1) engineers—men and women holding senior positions in information and systems engineering in higher education and industry, all having over ten years of experience in information or systems engineering and

(2) undergraduate students—men and women undergraduate information and systems engineering students.

Two research questions were derived from the research goals:

1. What SCCT categories are involved in selecting engineering as a field of study and retaining an engineering career?
2. What differences and correlations by category and gender within each research group exist, if any?

Research Settings

Within STEM, we focus on engineering, specifically, systems engineering, hence our research population comprises systems engineering professionals and undergraduate students. Systems engineering is an interdisciplinary domain, which enables analysis of complex systems and progress in industry. It integrates various disciplines and groups, streamlining a process from concept to production while considering business and technical aspects to provide quality products (Walden et al., 2010).

Research Participants

Our research population included two groups. The participants of both groups studied or taught at the Technion, Israel Institute of Technology, a STEM research university. All participants were aged 18 or above and provided informed consent by signing.

The engineers' group included 19 systems engineers, 11 of whom were women, and the rest were men. This research group was heterogeneous with respect to gender, seniority, and positions in academia and industry. About half (43.5%) were 40 years old or younger, and the remaining (56.5%) were above 40 years old. Most had at least five years' experience as academic researchers or systems engineers in the industry, indicating their career retention. Of the participants, 90% were parents. Each member of this group was interviewed, with each interview lasting 45-60 minutes.

The students' group included 330 undergraduate engineering students who took a specification and analysis of information systems course. This is an undergraduate 5th semester course at an engineering department at the Technion. This course is essential for aspiring engineers for several reasons as they:

(1) learn to identify and analyze system requirements to ensure they meet user and business demands,

(2) gain skills to translate requirements into effective, reliable system designs,

(3) develop analytical skills to solve problems and tackle complex system design challenges,

(4) identify quality assurance issues to ensure higher quality outcomes, and

(5) gain skills valuable for systems engineering, software development, and project management careers.

About half (48.2%; N = 159) of these students were women. About half of the participants (54.2%; N = 179) had a partial undergraduate student job in parallel to their studies. The students' ages ranged from 21 to 35, averaging 25.75 years (standard deviation [SD] = 2.12). Data were collected from three undergraduate courses over three consecutive semesters. All the participants responded to a questionnaire.

Research Tools

The research tools included an ethnographic interview for the engineers' group and a closed- and open-ended questionnaire for the students' group. Both the interview and the open-ended questions in the questionnaire included the following three open-ended questions:

(a) Why did you choose to study and pursue a career in engineering? Please elaborate.

(b) Was there an event or a person who led you to choose engineering as a future career? If so, please describe this. If there was no specific event or person that affected your career choice, please describe the reasons for your career choice.

The additional questions below, presented to the engineers' group in the interviews, encouraged them to elaborate on their current status.

- What difficulties do you experience in your position?
- Besides your accomplishments, what challenges do you face or have faced while performing your profession during your career?

For the undergraduate students, the closed-ended questions in the questionnaire, each with several options to choose from, were:

- Demographic information: gender, age, employment.
- What track are you studying?
- Who influenced your career choice the most?

Finally, group 2 was presented with the following open-ended question:

Where do you see yourself 10 years from now?

Data Analysis

A mixed methods analysis was performed with exploratory sequential design (Boeije, 2002; Creswell & Creswell, 2017; Creswell & Plano Clark, 2011; Lincoln & Guba, 1985) to reveal and validate the themes and categories from both research tools. In the exploratory sequential design, there is an interaction between the quantitative and qualitative tools with priority given to the qualitative data. The participants' explanations were read and gradually analyzed from a descriptive-interpretive perspective.

Data were obtained through the transcribed interviews and the written responses to the open-ended questions. They were then divided into statements, each expressing a single specific idea. Each statement was classified into the personal, environmental, or behavioral SCT theme and then to the most relevant category within that theme. To examine and identify the SCCT categories, categories were constructed using both a top-down and bottom-up approach. In the top-down approach, SCCT categories from the literature were employed, whereas in the bottom-up approach, new categories were discovered.

The first part of the study focused on analysis that involved three types of thematic coding:

(a) open coding for discovering themes in the text,

(b) identifying links between the themes, and

(c) selective coding for finding and validating the categories.

We started the coding of the categories from the literature (top-down approach) and looked for them in our data, and later we discovered new categories (bottom-up approach). The analysis continued until no new insights occurred, reaching redundancy of themes and categories (Charmaz, 2014; Corbin & Strauss, 2008).

The first round of the analysis was done on the interview statements, and it produced the three themes and seven categories. For each category we identified several subcategories, which were extracted from the literature and served to validate the classification into the categories. Four raters, who were experts in science and engineering education, classified a sample of the interviewees' statements and further refined the names of the categories. In the next round, the raters focused on the open-ended responses to the questionnaire of the undergraduate students. The raters examined what themes and categories that emerged from the engineers' statements could be reused for the undergraduate engineering students. They concluded that all the categories could be used except those related to the *current job suitability*. To validate the classification into categories, four raters classified 10% of the responses into one of the seven categories. In inter-rater reliability analysis, using the Kappa statistic to determine the consistency among raters, the Kappa was $k = 0.952$, $p < 0.001$, indicating an almost perfect agreement (Bakeman et al., 1997; Landis & Koch, 1997).

Following is an example of the way we classified statements into categories. The response of the engineer 13.1.W13.M was:

> "I was looking for something I can relate to and understand. I have gained experience being in charge of several people as an officer … I worked with many manufacturers in various domains and managed a spare parts warehouse. I was involved in many technical areas, including quality assurance, so I obtained an overall picture and practiced my reasoning [category: prior experience]. I realized that this is the area I like the most [category: interest and enjoyment], I am best at doing this, and it will be the right thing for me to study systems engineering [category: self-efficacy]."

Table 1. Themes, SCCT categories, and subcategories

Theme	Category	Subcategory
Personal	Prior experience	Prior experience at a young age
		Prior experience before choosing engineering studies
	Interest and enjoyment	Hobby and enjoyment
		Interest in management
		Interest in STEM
	Self-efficacy	Overall self-efficacy
		STEM self-confidence
		Gender-biased self-efficacy
Environmental	Influence by others	Influence of parents
		Influence of other family members
		Influence of friends
		Influence of professionals
	Social, financial, and cultural considerations	Prestige
		Flexibility
		Financial and social class considerations
Behavioral	Challenges and opportunities	Barriers
		Challenges
		Opportunities
	Current job suitability	Job flexibility
		Interaction at work

After classifying the categories and subcategories, we conducted descriptive and inferential statistical analysis. We used the SPSS version 29 software to perform the analysis. The statistical tests that were used included frequencies, means, standard deviations, Pearson correlation, and multi-way repeated measures ANOVA. In the following we outline our hypotheses for each of the tests in detail.

- **Frequencies**
  - **H0.** There is no significant difference in the frequencies of SCCT categories by research group and gender.
  - **H1.** There is a significant difference in the frequencies of SCCT categories by research group and gender.
- **Means and SDs**
  - **H0.** The means of the number of times an engineer mentioned each theme by gender are equal.
  - **H1.** The means of the number of times an engineer mentioned each theme by gender are different.
- **Pearson correlation**
  - **H0.** There is no correlation between the seven categories for either the engineers' group or the undergraduate students' group.
  - **H1.** There is a significant correlation between at least several of the seven categories for either the engineers' group or the undergraduate students' group.
- **Multi-way Repeated Measures ANOVA**
  - **H0.** There are no main effects or interactions for the undergraduate student group regarding the three SCT themes.
  - **H1.** At least one significant main effect or interaction exists for the undergraduate student group regarding the three SCT themes.

RESULTS

We present our results as they pertain to each research question.

Results Related to Research Question 1

The first research question was: What SCCT categories are involved in selecting engineering as a field of study and retaining an engineering career?

We identified seven SCCT categories that characterize the engineering career choice process. **Table 1** presents for each theme and category, the revealed subcategories, while **Table 2** presents the personal, environmental, and behavioral SCT themes in rows that cut across the columns, dividing **Table 2** into three parts. The personal theme included three categories: *prior experience*, *interest and enjoyment*, and *self-efficacy*. The environmental theme included two categories: *influence by others* and *social, financial, and cultural considerations*.

Table 2. Themes and SCCT categories that characterize the engineering career choice process

Category	Related category or subcategory from the literature	Examples from interviews	Examples from questionnaires
Personal theme			
Prior experience	"Learning experiences" (Negrea, 2024) "College degree" (Riegle-Crumb et al., 2011) "Interactions at work" (Brown et al., 2012) "Vicarious experience" (Usher & Pajares, 2008) "Experience" (Shekhar & Huang-Saad, 2021) "Prior experience" (Shwartz et al., 2021)	Y. H. "During a year abroad with my parents … I was exposed to biomedical engineering, and I thought that's what I would do when I grew up." S. S. "During my community service, I was in the police, where I was asked to organize a database."	83.2.S13.F. "My Mom says that since I was a little girl … my hobby was to solve problems and mathematical logic puzzles." 20.3.W14.F "During the community service, in a job that I loved, I received information from various sources, I did processing, distribution, and streamlining processes in the best way."

Table 2 (Continued). Themes and SCCT categories that characterize the engineering career choice process

Category	Related category or subcategory from the literature	Examples from interviews	Examples from questionnaires
Personal theme			
Interest and enjoyment	"Want a career in science", "science enjoyment" (Riegle-Crumb et al., 2011) "Interest" (Balakrishnan & Low, 2016) "Interest" (Chan, 2022) "Career interest" (Shekhar & Huang-Saad, 2021) "Motivation for science career" (Buday et al., 2012) "Interest in STEM" (Bloodhart et al., 2020; Husain et al., 2023; Shulga et al., 2023)	N. Z. "I studied physics and computers in high school because it is of great interest to me. My father told me: 'Forget boy professions, you should study biology.' However, I insisted on choosing the domain that interested me." M. N. "For me, systems engineering is the most enjoyable and challenging thing."	2.1.W13.M. "Industrial engineers work with people and not at a computer all day. This appealed to me." 60.3.W14.M "I was more attracted to areas related to STEM."
Self-efficacy	"Self-efficacy" (Balakrishnan & Low, 2016; Usher & Pajares, 2008) "Self-efficacy" (Badmus & Jita, 2023; Chan, 2022; Sakellariou & Fang, 2021; Shekhar & Huang-Saad, 2021; Sides & Cuevas, 2020) "STEM self-efficacy" (Husain et al., 2023; Shulga et al., 2023) "Science test scores" (Riegle-Crumb et al., 2011) "Science self-confidence" (Buday et al., 2012)	D. L. "This was a very turbulent and challenging time in my life, during which I developed my professional identity and discovered how much I can stand strong in the face of significant challenges." M. N. "An [systems] engineer needs to have several significant core functions and develop an understanding of various disciplines to better recognize all the components of the system." M.N. "Seeing a woman in a job like this… raises the confidence and the feeling of self-efficacy."	1.1.W13.F. "As I knew about the profession before school, I thought it could fit my STEM abilities." 11.2.S13.M. "I began to study towards systems engineering degree, not knowing what I want to learn … I soon realized it was not for me, and industrial management sounded more general, so I thought it might suit me better."
Environmental theme			
Influence by others	"Parent education" (Badmus & Jita, 2023; Riegle-Crumb et al., 2011; Shulga et al., 2023) "Social persuasions" (Usher & Pajares, 2008) "Approval … from peers, friends and family" (Shekhar & Huang-Saad, 2021) "Influence of mentors" (Moghe et al., 2021)	M. G. "I knew from a young age that I would aim towards an academic career, mainly because my mom is a very senior Professor in the university." D. L. "My father used to say to me every night that I am the most beautiful, smartest, etc. It influenced me and shaped me".	94.3.W14.F "I got a recommendation from my big brother who studied electrical engineering at the university." 49.2.S13.M. "I consulted with engineers from different disciplines."
Social, financial, and cultural considerations	"Future personal self" (Buday et al., 2012) "Making money" (Shekhar & Huang-Saad, 2021) "Financial support" (Badmus & Jita, 2023; Galvin et al., 2024)	M. N. "I'm considering leaving the company since it is important for me to have flexibility and not work many hours."	68.1.W13.F. "I knew that this university is a serious and prestigious institution." 2.2.S13.M "I chose industrial engineering because I wanted to learn a profession that will open for me a wide range of employment opportunities."
Behavioral theme			
Challenges and Opportunities	"Barriers" (Grunert & Bodner, 2011; Rosser & Lane. 2002) "Barriers" (Shekhar & Huang-Saad, 2021) "Opportunities and challenges" (Avargil et al., 2023; Husain et al., 2023; Shekhar & Huang-Saad, 2021) "Work opportunities" (Badmus & Jita, 2023; Moghe et al., 2021)	P. R. "I knew that to pursue an academic career, I had to do a post-doctorate abroad, and it did not suit me at that time, so I went to work in the industry." M. N. "[In my previous job] There was discrimination against women. Until I was promoted, I did not feel it, everything went well. The senior positions in my organization are for men, and to be promoted, women should … confront the men."	68.3.W14.F "Industrial engineering and management was my second option with computer science (CS) being my first. I chose industrial engineering and management because I knew there was a chance I could not get accepted to CS." 56.3.W14.M. "[I chose my major] by ruling out other study programs."

Table 2 (Continued). Themes and SCCT categories that characterize the engineering career choice process

Category	Related category or subcategory from the literature	Examples from interviews	Examples from questionnaires
Current job suitability	"Interactions at work" (Brown et al., 2012) "Cooperation" (McMahon et al., 2012) "Scientific setting environment" (Buday et al., 2012)	I. R. "I was offered to continue [from M.Sc.] to a Ph.D. program. The main consideration to go for it was the flexibility of hours." Y. H. "I graduated with an honors master's degree in information management engineering and was a Lecturer in this department. I realized that my destiny is to be a researcher and lecturer, rather than going back to industry."	

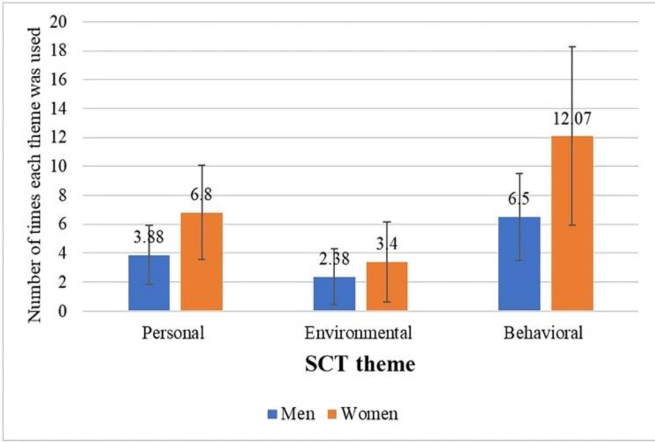

Figure 2. Means and standard deviations of the average number of times an engineer mentioned each theme by gender ($N_{engineers}$= 19, $N_{statements}$= 436) (Source: Authors' own elaboration)

Finally, the two categories within the behavioral theme were *challenges and opportunities* and *current job suitability*. Notably, *current job suitability* was a new SCCT category, which had not been identified in the literature. The *prior experience* category within the personal theme is further classified into two subcategories: *prior experience at a young age* and *prior experience before choosing engineering studies*.

The SCCT categories we identified were not necessarily defined as such in the literature, and those identified in prior studies (Shwartz et al., 2021) were not related to the SCCT in the context of engineering education and profession. The subcategories served to validate the participants' statements extracted from their responses. The second column in **Table 2**, titled ***related category or subcategory from the literature***, provides citations from research works published in peer-reviewed journals, including Eurasia Journal of Mathematics, Science and Technology Education, International Journal of Educational Research, International Journal of STEM Education, Journal of Vocational Behavior, Journal of Women and Minorities in Science and Engineering, PLoS ONE, Science Education, Science Education International and Sex Roles. These journals mentioned identical or similar categories or subcategories. The third and fourth columns in **Table 2** contain example quotations from interviews with the engineers, and the students' responses in their questionnaires, respectively.

Results Related to Research Question 2

The second research question was: What differences and correlations by category and gender within each research group exist, if any?

To answer this question, we present findings by theme for each research group. We then present findings by gender, theme, and category for both groups. Finally, correlations between categories in the engineers' group are presented. We classified the engineers' and students' statements into one of the seven categories listed in **Table 1** and **Table 2**.

Findings for the engineers' group by theme

The means and standard deviations of the number of times the engineers' group statements related to each SCT theme are presented in **Figure 2**. The total number of the engineers' group statements was 436. Women engineers tended to elaborate on their answers more than men engineers: 334 statements were from women and 102—from men. The findings suggest that the behavioral theme explains the engineers' career choice the most, while the environmental theme is the least commonly used.

Findings for the undergraduate student group by theme

The multi-way repeated measures ANOVA test for the undergraduate student group revealed a significant main effect for the three themes, $F(2, 656) = 148.97$, $p < 0.001$, $\eta^2 = 0.31$. Post hoc analysis using Bonferroni correction revealed that the undergraduate students used the personal theme (mean [M] = 1.15, SD = 0.99) to explain their career choice significantly more frequently than the environmental theme (M = 0.68, SD = 0.77). The personal and the environmental themes were used more frequently than the behavioral theme (M = 0.10, SD = 0.30). For the undergraduate students, there was neither a main effect by gender nor an interaction by theme and gender.

Table 3 presents the distribution of participants' statements classified by the seven SCCT categories, by research group, and by gender.

In the engineers' group, the statement frequency for men was different than that for women in all but one category. While 100% of the women mentioned the *prior experience* and *self-efficacy* categories, only about 60% and 50% of the men, respectively, mentioned them. The SCT

Table 3. Distribution of statements classified by SCCT categories, research group, and gender

Theme	Category	# of times mentioned	Engineers		Undergraduate students	
			% men (N = 8)	% women (N = 11)	% men (N = 171)	% women (N = 159)
Personal	*Prior experience*	0	37.5	-	76.0	69.2
		1-2	62.5	54.6	23.3	30.2
		3-4	-	45.5	0.6	0.6
		> 4	-	-	-	-
	Interest and enjoyment	0	-	18.2	35.7	39.0
		1-2	75.0	36.4	61.9	60.3
		3-4	12.5	27.3	2.3	0.6
		> 4	12.5	18.2	-	-
	Self-efficacy	0	50.0	-	88.3	89.3
		1-2	50.0	54.6	11.7	10.7
		3-4	-	36.4	-	-
		> 4	-	9.1	-	-
Environmental	*Influence by others*	0	62.5	9.1	77.2	69.8
		1-2	25.0	72.8	22.8	28.9
		3-4	12.5	9.1	-	1.3
		> 4	-	9.1	-	-
	Social, financial, and cultural considerations	0	25.0	18.2	62.6	63.5
		1-2	50.0	72.7	37.5	35.9
		3-4	25.0	9.1	-	0.6
		> 4	-	-	-	-
Behavioral	*Challenges and opportunities*	0	12.5	-	91.2	89.3
		1-2	37.5	9.1	8.8	10.7
		3-4	25.0	36.4	-	-
		> 4	25.0	54.5	-	-
	Current job suitability	0	12.5	-	100	100
		1-2	50.0	9.1	-	-
		3-4	25.0	45.5	-	-
		> 4	12.5.0	45.4	-	-

category *influence by others* was mentioned by about 90% of the women and about 40% of the men. An opposite pattern was found for the *interest and enjoyment* category: It was mentioned by 100% of the men engineers but only by about 80% of the women engineers. The pattern for the *social, financial, and cultural considerations* category was similar for the two genders (about 75%). The behavioral theme was the most mentioned one for both genders. While 88% of the statements were mentioned by men engineers in the *challenges and opportunities* and the *current job suitability* categories, 100% of the women engineers mentioned these categories.

Within the undergraduate student group, *current job suitability* was not mentioned at all since it is not relevant for the undergraduate student group. The frequency of statements mentioned at least once for each of the remaining six categories follows a pattern that is similar for the two genders: The most mentioned category was *interest and enjoyment*, with about 60% for both genders. Next was the *social, financial, and cultural considerations* category, with about 35% for both genders, followed by the categories *prior experience* and *influence by others*, with about 25% each. Finally, two categories, *self-efficacy* and *challenges and opportunities*, were mentioned only about 10% each. In what follows, we briefly discuss differences between the genders as they break down by categories within each theme.

Gender differences within each theme in the engineers' group

As **Table 3** shows, about 40% of the men did not mention in their responses anything related to the *prior experience* category, and those who did, connected it to their school or service, e.g.,

> "I studied software at high school" (X. Y.).

Most of the women described their experiences in more detail, e.g.,

> "During my community service, I was in the police, where I was asked to organize a database" (S. S.).

In the *self-efficacy* category, half of the men did not include in their responses any item that is related to self-efficacy. Women related at length to elements belonging to this category. Specifically, women emphasized their ability to engage in systems engineering more than men. Following is an example:

Table 4. Pearson correlations between categories for the engineers' group ($N_{engineers}$= 19, $N_{statements}$= 436)

	Self-efficacy	Prior experience	Interest and enjoyment	Current job suitability
Challenges and opportunities	0.46*	0.46*	0.51*	0.61**
Current job suitability	0.68**	0.55*		
Influence by others	0.50*	0.54*		

Note. **Correlation is significant at the 0.01 level (2-tailed) & *Correlation is significant at the 0.05 level (2-tailed)

> "A systems engineer needs to have a number of significant core functions and develop understanding of various disciplines to better recognize all the components of the system… Seeing a woman in a job like this … raises the confidence and the feeling of self-efficacy" (M. N.).

Within the environmental theme, about 60% of the men did not relate in their responses to the *influence by others* category, as opposed to more than 70% of the women, who did relate to this category. In the questionnaires, within the *influence by others* category, women indicated the influence of family members, schoolteachers, or work superiors as role models on their career choice as information and systems engineers:

> "My brother is the firstborn child in our family, He always was an ideal figure to be imitated. As a girl, I wanted to be like him and I was influenced by his recommendations, as well as by what I saw" (100.3.W13.F).

> "The computer science teacher, who was a woman, was a role model to all of us … and since then I wanted to be like her, and to study toward MSc …" (100.3.W13.F).

> "When I worked in a plant, each time the industrial engineer, who was a woman, visited us, I would ask her about her job" (105.3.W13.F).

In the interviews, women said:

> "I studied the same subject that my friend was studying at the same time. I did not ask myself if it was really what I wanted; I just followed him in the university" (Z. X.).

Conversely, men mentioned more than women the *social, financial, and cultural considerations* category:

> "I have to learn a profession that will make me a lot of money" (U. V.).

All the women engineers mentioned that there were challenges, opportunities, or barriers in their career path, most of which related to maintaining the balance between home, children, and work, as well as to the gender glass ceiling issue:

> "I felt that the places where I could get promotion were places in which women were in managerial positions" (U. V.).

Correlations between themes and categories within each research group

To answer the question of correlations between the three themes and the seven categories, we conducted two Pearson correlation analyses for each research group: one for the themes and the other for the categories. We found a significant correlation between the personal and behavioral themes for the entire engineers' group, $r(19) = 0.77$, $p < 0.01$. We found no significant correlations between the environmental theme and the personal theme nor between the environmental theme and the behavioral theme. This was true for both research groups. A Pearson correlation test applied to the seven categories for each group, revealed significant correlations between the categories for the engineers' group, as presented in **Table 4**. No significant correlations were found between themes and categories among the undergraduate students.

For the engineers' group, we found significant correlations between the categories *prior experience* and *challenges and opportunities*, as well as between the categories *self-efficacy* and *current job suitability*. These are the sources of the significant correlations between the personal and behavioral themes, respectively. We also found a significant correlation between the categories *self-efficacy* and *influence by others*, as specified in **Table 4**.

DISCUSSION

Both gender and social class influence career choice and persistence in STEM fields (Wilson & Kittleson, 2013). We found that women indicated *self-efficacy* as an important category in their engineering career choice, pointing to the importance that women attribute to self-efficacy for maintaining an engineering career (Avargil et al., 2023; Bloodhart et al., 2020). Among the students, we found no significant difference between the three themes for explaining their engineering career choice. The personal and environmental themes were mentioned at about the same frequency, and the behavioral theme was the least mentioned.

Women engineers differed from men engineers in the frequency of categories mentioned, while for the undergraduate students, the gender differences were much smaller. This difference can be attributed to the fact that the engineers' group participants belong to an older generation, in which gender differences were more pronounced than in the younger generation (McMahon et al., 2012). This is encouraging, because if this trend continues, we expect to see even smaller gender differences in the future.

Gender and social class influence persistence in STEM fields (Wilson & Kittleson, 2013). Our research has investigated causes for the pressing problem of women's underrepresentation in engineering professions in general, and information and systems engineering in particular. One important finding of our research was the categories in which differences between men and women in the engineers' group had the most influence on their career choice: women indicated that *influence by others* affected them more than men, while *social, financial, and cultural considerations* had a stronger effect on men than on women.

The finding that women are more influenced than men by others is in line with the literature, which indicates that women tend to be influenced by mentors or role models (Kolmos et al., 2013; Rocker Yoel & Dori, 2023; Tal et al., 2024), while men are influenced by financial and cultural factors (Kolmos et al., 2013; Morgan et al., 2001). Role models may help early adolescents identify themselves as future practicing scientists, engineers, or mathematicians (Smith & Hausafus, 1998), so exposing women to role models may positively influence their attitudes toward choosing a career in engineering (Hackett et al., 1989; Tal et al., 2024). Women mentioned that role models influenced them at a young age to pursue science and engineering careers (Avargil et al., 2023; Fox et al., 1977; Seymour, 1995; Smith & Erb, 1986), and women need encouragement to pursue their STEM trajectories (Kohen & Nitzan, 2022; Tan et al, 2013). We also found that female students indicated role models within the *influence by others* category as a motivation for choosing a career in information and systems engineering. Our research emphasizes the importance of mentors and role models for women in engineering, examining the impact of social, financial, and cultural factors on their career decisions.

Within the undergraduate students' group, the behavioral theme is almost absent. This makes sense, because the undergraduate students are still studying and do not have a career, so the behavioral theme in general, and its *current job suitability* in particular, does not yet exist, so it cannot be expressed. This is one "sanity check" that indicates the validity of our findings.

According to SCT (Bandura, 1999), the personal and environmental themes influence each other, while behavior is a more independent factor. In our research, we found a correlation between the personal and behavioral themes within the engineers' group. The source of the correlation between these two themes is the women in this group.

This finding is in line with Matusovich et al. (2010), who showed that attainments influence students' choice of an engineering career more than interest, and women value an engineering career less than men. Low or moderate interest can lead to a sense of attainment if more factors, such as financial ones, are involved. Riegle-Crumb et al. (2011) have shown that self-efficacy and achievements influence boys more than girls in choosing a career in engineering. Yet, we found a correlation among the entire engineers' group between *self-efficacy* and *influence by others*. This correlation makes sense since the positive feedback that mentors or role models provide strengthens one's self-efficacy. This feedback is especially important for women, as they typically do not elect to pursue STEM disciplines and in particular engineering (Gumaelius et al., 2016). In their SCCT approach, Lent et al. (1994) noted that self-efficacy is linked to interest and performance in school and work, which in turn influence career choice.

Our study showed that an important category that led women to choose a STEM career was *prior experience* with STEM topics. High self-efficacy and positive experience lead students to aim high at challenging goals (Sides & Cuevas, 2020). In line with our findings, recent studies (Avargil et al., 2023; Balakrishnan & Low, 2016; Dzombak et al., 2016; Tal et al., 2024) indicate that prior learning experience correlates with career choice in engineering among women students, while *social, financial, and cultural considerations* have a strong correlation to career choice in the engineering domain among men students, implying that certain strategies are needed to encourage girls to choose engineering for their studies and future careers. Dzombak et al. (2016) examined the entrepreneurial experience of five women, and Shekhar and Huang-Saad (2021) examined 20 undergraduate engineering students who participated in entrepreneurship education programs based on the theory of planned behavior. Based on the SCCT, we examined 330 university engineering students and 19 engineering professionals in academia and industry. Our research adds a layer of knowledge on engineering career choice in undergraduate studies and advanced career stages, focusing on the retention of engineers, especially women.

Limitations and Future Studies

A limitation of this research is that the participants were from one STEM-oriented research university. To overcome this limitation, we recommend that future research employs the tools developed in this study to examine larger research groups from different countries to generalize our findings. Comparing the status of women who choose a career in science vs. those who choose engineering is beyond the scope of this paper and

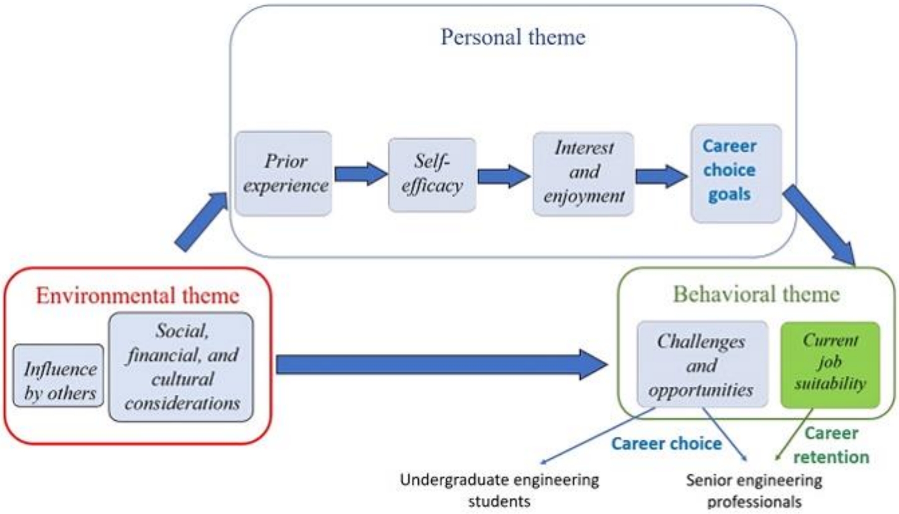

Figure 3. The SCCT model, in which career choice is extended with retention (Source: Authors' own elaboration)

is suggested, as follow-up research. One additional limitation is that our sample was drawn from a single engineering discipline—systems engineering, making it difficult to generalize the findings to other engineering disciplines. It is therefore recommended to extend the research using the tools developed here to other engineering disciplines.

CONCLUSIONS

STEM career choice and retention are crucial in developed countries as they lead to global advancements in new scientific and engineering innovations and development. The world is suffering from an ongoing shortage of engineers, and the situation can be improved if more women would choose and retain an engineering career (Miller et al., 2018; Riegle-Crumb et al., 2011; Shwartz et al., 2021; Xie & Achen, 2009). We investigated the SCCT categories that affect women's and men's choice of STEM studies and careers, especially in information and systems engineering. We analyzed the transcript of interviews of women and men holding engineering positions in information and systems engineering professions. We also analyzed the responses of information and systems engineering undergraduate students to closed- and open-ended questions.

Among the engineers, the behavioral theme was mentioned the most, while the environmental theme was the least mentioned. We identified seven SCCT categories, presented in **Figure 3**, which are classified into the three SCT themes, as follows. In the personal theme, we found three categories: *prior experience*, *interest and enjoyment*, and *self-efficacy*. The environmental theme included two categories: *influence by others* and *social, financial, and cultural considerations*. In the behavioral theme, two categories were identified: *challenges and opportunities* and *current job suitability*. The latter category is new; it emerged in this study from the interviews with the engineers. Not previously mentioned in the literature, the *current job suitability* category, marked in green in **Figure 3**, strengthens and elaborates on the SCCT in that it covers not just career choice goals (Ackah & Heaton, 2004) but also career retention. Previous studies highlighted the importance of SCCT categories, such as self-efficacy, role model, and positive expectations, to improve retention rates (Dasgupta & Stout, 2014; Kolmos et al., 2013; Lent et al., 2016; Tal et al., 2024), while the new category, *current job suitability*, suggests an additional way to improve retention. The thick blue arrows in **Figure 3** represent the relationships between the personal, environmental, and behavioral themes: The environmental theme influences the personal theme, which influences the behavioral theme, and the environmental theme influences also the behavioral theme. The thin blue arrows within the *challenges and opportunities* category indicate contribution to career choices of both undergraduate engineering students and senior engineering professionals.

Among the engineers, all the male engineers explained their career choice based on *interest and enjoyment*, and over 60% of them did not indicate *influence by others*. In contrast, all the women engineers explained their career choices based on *prior experience*, *challenges and opportunities*, and *current job suitability*. Among the students, the distribution of the various categories for men and women was similar.

Women expressed more statements related to *influence by others*, while men expressed more statements that were classified as *social, financial, and cultural considerations*. In the *challenges and opportunities* category, all the women indicated that there had been challenges, opportunities, or barriers in their career path. Opportunities and barriers were related to promotion in the engineering profession. Most of the challenges related to the balance between home, children, and work, as well as to the glass ceiling effect. Indeed, according to several researchers (Ackah & Heaton, 2004; Rocker Yoel & Dori, 2023; Seymour, 1995; Tal et al., 2024), women tend to be influenced by predefined societal roles, relationships, and family responsibilities more than men.

Contributions

Our findings contribute to the theory of engineering career choice by advancing the SCCT and expanding the categories in this theory. The research findings shed light on the relationships between gender and career choice by exploring gender differences in themes and categories in the engineering domain. The extended SCCT model in **Figure 3** includes within the behavioral theme two new categories: *challenges and opportunities* and *current job suitability*. As **Figure 3** shows, the former relates to both the undergraduate engineering students and the engineering professionals (the blue arrow), while the latter, which pertains to career retention (the green arrow), is relevant only to the engineers.

The research can provide a basis for encouraging women to advance their engineering careers by emphasizing the *challenges and opportunities* and *current job suitability* categories, which women engineers mentioned more than men engineers. Interestingly, the *challenges and opportunities* category was found also for women in chemistry at the academia (Avargil et al., 2023), while the new category *current job suitability* is unique to this research.

Regarding the personal theme, since self-efficacy is a strong predictor of academic and work performance (Multon et al, 1991; Stajkovic & Luthans, 1998) and goals (Bandura & Locke, 2003; Locke & Latham, 2002), strengthening young women's self-efficacy is likely to encourage them to set up high goals for themselves and later pursue a STEM career (Freedman et al., 2023; Shekhar & Huang-Saad, 2021). As **Figure 3** clearly shows, the three categories—*challenges and opportunities*, *current job suitability*, and *self-efficacy*—are most strongly correlated for the entire engineers' group.

The study provides two methodological contributions. One is the questionnaire, which can be administered to undergraduate engineering students in different cultures to understand their reasoning for choosing an engineering career. The other is the method for analyzing the engineers' interviews and determining the strength of the correlations between the categories.

Practically, the study can contribute to designing environments that foster women's engineering career choices, alleviating the acute shortage in STEM professions. Finally, the research provides insights into gender-dependent engineering career choice and retention categories, potentially contributing to researchers interested in investigating undergraduate students in general and women in particular who choose and retain STEM careers.

Author contributions: YJD, HR-M, NW, SRY, & DD: conceptualization & writing–original draft; **YJD, HR-M, & NW:** methodology; **YJD, SRY, & DD:** writing–review & editing; **YJD & DD:** project administration & supervision; **HR-M & NW:** data curation & formal analysis; & *SRY:* visualization.

Author notes: This research is dedicated to the memory of Dr. Hagit Refaeli Mishkin, a valued colleague and the second author of this paper, who tragically lost her life on October 7, 2023. Dr. Refaeli Mishkin graduated from the Technion in 2016. Her Ph.D. research focused on motivation and gender factors influencing career choices in engineering. She later led TESFA (hope in Amharic), at the MOFET National Institute for Research and Development in teacher education, supporting Ethiopian-descended pre-service and novice teachers. In addition to her professional achievements, she served as treasurer for Midburn Israel. Dr. Refaeli Mishkin is survived by her three children, Noa, Uri, and Ido, and is deeply missed by all who knew her.

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