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Internal and external influences on role stereotype adherence and gender dynamics on engineering design teams

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Abstract

Background Even among women who persist in the gender-imbalanced engineering fields, women on engineering design teams tend to take on non-technical roles. Understanding the mechanisms that inform this phenomenon is important for encouraging more women in STEM in order to close the gender gap. Although factors such as self-efficacy, task allocation, and occupational prestige have previously been examined through a gender-based lens, this study considers all of these factors together in order to better understand the role of internal and external effects on role stereotype adherence in engineering design teams. A survey was administered to computer science and engineering students in the United States presenting a scenario in which they are members of an engineering design team. Participants reported their interest, self-efficacy, and anticipated contribution to the project. All participants were then assigned a documentation role by a teammate and asked the same questions again after a brief reflection.

Results While all participants exhibited higher interest in a more socially impactful project, participants' interest in the project decreased significantly after they were assigned the non-technical, feminine-stereotyped role of documentation. Women reported significantly higher experience, interest, and self-efficacy levels in documentation compared to men. After being assigned the documentation role, men anticipated that their contribution to the project would be significantly lower compared to women, indicating a decrease in interest or a devaluation of their role on the team. Perceived sexism may have also played a part in how women reacted to role allocation, as it is hypothesized that reactance theory led women's interest in a mechanical design role to increase post-role allocation.

Conclusions These results support existing literature related to the likelihood of (1) women taking on non-technical roles on engineering teams and (2) society devaluing work that is stereotypically associated with feminine stereotypes. Participants' reactions to role allocation were most closely related to internal factors, such as self-efficacy and the implicit devaluation of femininity. Findings can be used to inform curriculum development in hands-on design project courses and management of design groups in industry.

Keywords Engineering education, Project-based learning, Gender stereotyping, Team dynamics, Task allocation, Self-efficacy, Social impact, Gender gap, Stereotype threat

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Introduction

In 2024, women comprised only 16.7% of the United States architecture and engineering workforce, with electrical and mechanical engineering around 11% women (U.S. Bureau of Labor Statistics, 2024). This gender disparity, while improving in recent years, remains an active area of research with room for additional interventions in pursuit of demographic parity. One particular area of concern is that women have lower self-efficacy than men even when exhibiting same levels of ability, resulting in lower perseverance and retention rates in STEM (science, technology, engineering, and mathematics) fields (Marra et al., 2013). Women also tend to perform non-technical communication-heavy roles, such as documentation or report-writing, in design teams, whereas men perform more technical roles, such as design and fabrication (Linder et al., 2010). This contributes to women's lower self-efficacy as it robs them of enactive mastery experiences, a key component to building self-efficacy (Bandura, 1977; Fowler & Su, 2018).

There are several arguments to be made for diversity in engineering. One is in the name of social justice, that offering equal opportunities to underrepresented minorities prevents reinforcement of systems that disenfranchise them. Another is that by barring a significant portion of the population from STEM fields, the world may be missing out on brilliant minds that will never get the opportunity to innovate (Intemann, 2009). Studies have shown that increased gender equity and decreased gender segregation leads to better economic outcomes, high-tech growth, innovation, and productivity (Scarborough et al., 2023). Research has also shown that intellectual diversity in student engineering teams improves complex problem-solving, learning outcomes, and long-term economic growth (Intemann, 2009; Sulik et al., 2021). On the other hand, some studies have suggested that demographic diversity may negatively impact cohesiveness or communication, and therefore productivity, preventing diverse teams from outperforming their homogeneous counterparts (Hamilton et al., 2012; Keller, 2001; Smith-Doerr et al., 2017).

This paper aims to quantitatively investigate the effects of task allocation on self-efficacy and project interest through the lens of gender. Previous work has investigated the phenomenon where men seek out technical tasks and women seek out non-technical tasks in design groups and sought to both quantitatively and qualitatively describe the nature of this phenomenon (Fowler & Su, 2018; Hirshfield, 2018; Hirshfield & Chachra, 2015; Linder et al., 2010). However, there is a gap in engineering literature separating the effects of other members on the team (external effects) and existing factors such as self-efficacy and stereotype threat within an individual (internal effects). This work will contribute to the understanding of task allocation dynamics within engineering design teams by investigating the overarching research question: *How are gender, internal/external influences, and the social impact of an engineering project related to students' role allocation preferences?* A deeper understanding of these factors will aid in the development of more effective and equitable engineering curricula and interventions.

Literature review

Task allocation on engineering teams

Understanding the dynamics at play during task allocation on engineering teams is critical because of the prevalence of team-based work in industries such as engineering and business (Paulus et al., 2012). A study of academic papers and patents over the past decades has revealed a dramatic decrease in single-authored publications, such that more than 50% of patents had multiple inventors and 80% of STEM articles had multiple authors by the mid-2000s (Wuchty et al., 2007). Although teams are more likely to produce innovative, sustainable, high-quality outcomes compared to individuals, teamwork can present a higher risk of failure and inefficient resource allocation (Sachmpazidi et al., 2021). While contributing to a collaborative goal has been found to improve academic performance for some students (Marra et al., 2016), group work in undergraduate STEM courses can also present barriers to participation and learning for neurodivergent students, highlighting the need for mindful instructor support and facilitation during group work (Salvatore et al., 2024).

As a result, research related to team size, team member ability and perceptions, and diversity has been conducted on best practices for creating effective student teams (Von Solms et al., 2018). To promote desirable team outcomes, instructors can focus on promoting shared vision, psychological safety, and team cohesion (Sachmpazidi et al., 2021). For example, teams with more balanced participation among team members perform significantly better compared to teams with unequal participation (Menekse et al., 2019). In scrum practices, one method of ensuring balanced participation and role assignment, project roles related to technical work and communication skills may be rotated by all team members throughout the course of a project (Magana et al., 2023). Although team membership and roles can be assigned by students, randomly, or by the instructor, research supports the use of instructor-assigned teaming due to its likelihood of producing more balanced teams in terms of demographic diversity as well as problem-solving approaches (Oakley et al., 2004), which are important attributes for high-performing teams (Finelli et al., 2011).

Expectancy value theory (EVT), which combines self-efficacy with the perceived value of an activity to inform students' motivation and persistence, may help explain students' motivations for their selection of roles within an engineering design team. The perceived value of a task is comprised of four factors: attainment value ("Why is it important I do well?"), intrinsic value ("Do I enjoy doing the task?"), utility value ("What do I get out of doing the task?"), and costs such as time and effort (Wigfield & Eccles, 2000). Expectancy beliefs ("How well can I do?") are discussed in further detail in the Self-efficacy subsection of this literature review.

EVT can help explain why students may choose certain roles within design teams as well as their motivations and persistence in STEM. EVT indicates that women's beliefs related to gender can shape their beliefs about their competence in various academic pursuits (Robinson et al., 2022). For women, a combination of low expectancy beliefs and high cost often overrides the attainment, intrinsic, and utility value that technical roles provide within a design group. The high costs of participating in technical roles may contribute to disparities in task allocation. Although men and women report similar levels of interest in tasks, there is often a difference in which ones they end up doing (Hirshfield & Chachra, 2015). Students in an assessment of undergraduate student design teams reported gender-based differences in the roles that men and women participated in as well as the roles that they specialized in. Women were more likely to operate in less technical, more communication-heavy roles, while men were more likely to operate in more technical roles. Students often only operated in the roles which they had taken responsibility for. Although this specialization is reflective of how professional teams operate in industry, the paper expresses concern over reduced learning outcomes. Stereotype threat and a focus on avoiding failure are presented as possible explanations for the task specialization (Linder et al., 2010).

Even when students report equal distribution of work across roles by gender, this is often not indicative of the whole truth. One mixed-gender design team in a study of a first-year engineering design course reported mostly equitable division of tasks when members quantitatively reported the time they spent on each task (Hirshfield, 2018). However, qualitative data collected by observing team meetings throughout the course of the project revealed that the men in the group were disengaged during meetings dedicated to working on the report or presentation, despite logging the meeting as time spent working on the report, leaving the responsibility for the report to the woman on the team. During technical meetings, the woman was hesitant to contribute due to low self-efficacy, and other men team members often sent her on errands instead. This case study shows that inequitable task division can be insidious and inaccurately reflected by self-reports from students (Hirshfield, 2018).

The variety of factors further discussed in the Self-efficacy section contributes to a lower sense of self-efficacy for women in an academic STEM or engineering contexts (Marra et al., 2013; Robinson et al., 2022). This results in a feedback loop that exacerbates inequitable task allocation and therefore discrepant learning outcomes. People tend to choose tasks that they are most confident in, increasing their experience and confidence, leading to them choose that same task over others in the next project. This contributes to women repeatedly taking on secretarial and documentation roles in project groups rather than participating in technical roles (Fowler & Su, 2018). Students have cited differing levels of self-efficacy and prior mastery experiences as reasons they defaulted to a role or stepped aside for a teammate to complete the role instead. Interestingly, a lack of self-efficacy was the reason for both women avoiding technical roles and men avoiding communication-heavy roles (Fowler & Su, 2018). Another study finding that there was not a gendered difference in role interest found a significant difference in the roles students self-identified with, with women relating to less-technical roles while men claimed more technical roles. Even men who reported more time spent working on non-technical tasks such as the report and presentation only self-identified with technical roles (Hirshfield & Chachra, 2015). Gender roles and socialization likely play a part in this experience, identity, and self-efficacy gap between the two roles.

In men-dominated fields, the cost of failure is higher for women than it is for men. Women are viewed as less competent following a mistake in areas that are stereotypically masculine, such as engineering, and they are often seen as unlikeable even in the case of success (Brescoll et al., 2010). Women in the financial advisory industry, also a men-dominated field, are more likely to be fired and less likely to be hired following misconduct (Egan et al., 2022). Women's failures in men-dominated fields are often attributed to a lack of ability, and their successes are attributed to luck or mere effort, while the opposite is true for men (Swim & Sanna, 1996). Women also report more negative consequences when engaging in risk-taking, a masculine-stereotyped behavior, in the workplace when compared to men (Morgenroth et al., 2022). This can discourage women from further risk-taking, such as advocating to do a more technical and less familiar task on a design team. Women are conscious of the high cost and discrimination that comes with working in a men-dominated industry. It both discourages women from pursuing leadership positions and harms women already in those positions (Fisk & Overton, 2019), contributing to the cost associated with EVT and leading to women being less likely to take the risk of volunteering for technical positions in design teams.

Self-efficacy

Self-efficacy, as first defined by Albert Bandura, is a person's belief in their own ability to succeed (Bandura, 1977). It is different from other concepts like self-confidence in that it is goal- or task-specific, rather than pertaining to generic abilities (Pajares, 1996). Those with high self-efficacy exhibit higher resilience, perseverance, and overall lower stress and depression. With higher motivation and confidence, students with high self-efficacy achieve greater academic success due to their increased willingness to seek out challenges (Pajares, 1996; van Dinther et al., 2011).

There are four main factors that contribute to self-efficacy (by order of influence): enactive mastery experiences, vicarious experiences, social persuasions, and physiological/psychological states (Bandura, 1977). The most influential factor, enactive mastery experiences, are successful hands-on experiences of the task. Vicarious experiences are seeing other people, particularly demographically representative role models, successfully complete a task (van Dinther et al., 2011). Social persuasions can include both overt social cues, such as feedback from teachers and peers, as well as subtle social cues, such as identity denial and ambivalent sexism (Chachra & Kilgore, 2009; van Dinther et al., 2011). Lastly, physiological and psychological states refers to stress reactions and internal anxiety factors such as stereotype threat (Marra et al., 2013; van Dinther et al., 2011). Various aspects of gender identity and equity have been found to influence the four factors of self-efficacy for women in engineering spaces (Schauer, Schaufel, and Fu, 2023).

i. Mastery experiences

Mastery experiences, or successful first-hand experiences with a task, are the strongest contributors to self-efficacy (van Dinther et al., 2011). As discussed previously, there exists a feedback loop where women are more likely to choose non-technical roles in design teams, leading to a loss of mastery experience opportunities. This lack of mastery experiences will in turn decrease their self-efficacy, contributing to the feedback loop (Fowler & Su, 2018). However, women report lower self-efficacy levels than men even when they display similar levels of ability, which shows that the benefits of mastery experiences may be obfuscated by confounding factors such as self-perception of skill, attribution of success to internal or external factors, or the perceived relevance of a skill/experience. As a result, men's self-efficacy beliefs tend to be more closely tied to mastery experiences, while women value vicarious experiences and verbal persuasion (Zeldin & Pajares, 2000).

ii. Vicarious experiences

Vicarious experiences, seeing others successfully perform a task, are the second largest contributors to self-efficacy. While seeing anyone complete the task can be a boost for self-efficacy, having more in common with them, such as sharing a demographic trait, can increase the effectiveness of the vicarious experience. There is a sense of "they can do it, so can I" when seeing someone similar to oneself successfully complete a task (Bandura, 1977). These vicarious experiences can even help mitigate stereotype threat, as shown in a study where women performed better on a difficult math test when told it was written by a woman, and thus seeing a role model in the domain, rather than a man (Shapiro & Williams, 2012). Because of the significant underrepresentation of women in both engineering workforces and academic faculty (National Center for Science & Engineering Statistics, 2021; U.S. Bureau of Labor Statistics, 2024), there is a lack of women role models both in academia and in engineering fields. The lack of women in leadership in men-dominated industries is not just due to lower self-efficacy in women but also due to the discrimination and high cost of failure faced by women, as discussed previously. With the lack of women role models due to the gender gap in engineering, women are severely lacking in sources of vicarious experiences to nurture their self-efficacy.

iii. Social persuasions

Social persuasions, the messages (both overt and subliminal) that society and those around us convey, play a large role in the persistent gender gap within STEM fields. Bias and disparaging messages are communicated by parents, peers, teachers, and the environment of STEM fields. Not only do women tend to rate their own self-efficacy and abilities lower than men despite similar skill levels, but external observers are prone to this bias as well (Hand et al., 2017; Muenks et al., 2020). Parents, both women and men, rate their sons as having higher overall intelligence than their daughters, especially in mathematical and spatial areas (Furnham et al., 2002). Parents continue to underestimate their daughters' intelligence in comparison to their sons' even when there is no difference in their actual spatial capabilities (Muenks et al., 2020). Spatial ability and STEM achievement are positively correlated, likely due to many STEM fields requiring visual–spatial skills (Wai et al., 2009), and the disparaging messages may discourage young girls from identifying with and pursuing these fields. Teachers also report a belief that boys perform better in STEM and girls perform better in humanities despite data showing girls actually tend to outperform boys in mathematics (Hand et al., 2017). Strangers are also more likely to express surprise when a woman in engineering reveals their major. This repeated identity denial by others communicates that women are unsuited for STEM, slowly reducing their self-efficacy and prompting them to impose more stringent expectations on themselves to "prove" they belong, or worse, quitting STEM altogether (Chachra & Kilgore, 2009).

Ambivalent Sexism Theory (AST), coined by Glick and Fiske in 1997, divides sexism into two categories: hostile and benevolent. While hostile sexism is more overtly aggressive, benevolent sexism often has much more insidious effects on women in STEM. AST defines hostile sexism with three sub-behaviors: dominative paternalism (e.g., men should control women), competitive gender differentiation (e.g., men are better than women based on gender stereotyping), and heterosexual hostility (e.g., sexual harassment) (Glick & Fiske, 1997, 2001). Benevolent sexism has three sub-behaviors: protective paternalism (e.g., assuming inferiority and offering help), complementary gender differentiation (e.g., women are warm and nurturing), and intimate heterosexuality (e.g., every man needs a woman) (Glick & Fiske, 1997, 2001).

Hostile sexism does result in various negative outcomes for women, but benevolent sexism has been shown to have greater detrimental effects on women's performance (Dardenne et al., 2007). Explicit hostile sexism is now socially unacceptable and illegal, and universities often provide additional support for recognizing, coping with, and reporting hostile sexism (Kuchynka et al., 2018). Although these measures cannot completely prevent hostile sexism—as demonstrated by one study that found that 61% of the 685 women surveyed reported experiencing STEM-related gender bias and 78% reported experiencing sexual harassment in the last year (Leaper & Starr, 2019)—it discourages some perpetrators from overt hostility and allows victims to recognize it more easily. Because hostile sexism is explicit in nature, women can attribute it as prejudice and bigotry on the offender's part rather than a personal failing. Benevolent sexism, on the other hand, is perpetuated more implicitly, leading to self-doubt, anxiety, negative intrusive thoughts occupying working-memory, and overall decrease in performance and self-efficacy (Dardenne et al., 2007; Kuchynka et al., 2018). These factors, including identity denial from parents, teachers, and peers as well as ambivalent sexism—are ways that society persuades women that they are lacking, contributing to the gender gap and low retention rates in STEM fields.

iv. Physiological and psychological states

Physiological and psychological states are the fourth contributor to self-efficacy. A person's anxieties and fears, manifested both mentally and physically, can have negative effects on their self-efficacy (Bandura, 1977; Maraj et al., 2019). A prevalent example of this for women in STEM is stereotype threat, the anxiety of fulfilling a negative stereotype within a domain (e.g., a woman "proving" women are worse than men in math by personally performing poorly on a math exam). Stereotype threat can be divided into two types: self-as-source and other-as-source. Self-as-source stereotype threat refers to fear within oneself that a negative stereotype may be true and anxiety that they might fulfill that stereotype via failure and incompetence. Other-as-source stereotype threat refers instead to fears of others perceiving oneself as fulfilling a negative stereotype, whether as a negative reflection of self or as a bad representation for the stereotyped group as a whole (Shapiro & Williams, 2012).

Stereotype threat can have tangible consequences on women's performance and perseverance in STEM fields. In one study, when women were told that performance on a math test had shown gender differences, they performed markedly worse than their men peers. When the gender differentiation information was omitted, women performed the same as men (Spencer et al., 1999). Women notice, whether consciously or subconsciously, gender imbalances and a lower sense of belonging in men-dominated areas. When shown gender-unbalanced videos of a conference, women exhibited higher heart rates, more vigilance, and lower desire to participate in comparison with a gender-balanced video (Murphy et al., 2007). Stereotype threat can result in decreased self-efficacy, and subsequently, participation, for women performing technical tasks in an engineering education context (Linder et al., 2010). On the other hand, reactance theory proposes that women who perceive that negative stereotypes are being applied to them may view the stereotype as an infringement upon their personal freedom. This may result in greater motivation to prove the stereotype wrong, causing an individual to act in opposition to the stereotype (Kalokerinos et al., 2014; Rosenberg & Siegel, 2018).

Devaluation theory

Many industries throughout history, such as banking, insurance, and medical fields (Little, 2021; Pan, 2015; Pelley & Carnes, 2020), have experienced a "tipping phenomenon" where an increase of women in fields results in a sharp decline in the number of men in the field, sometimes accompanied by a decrease in prestige and wages. One potential model to explain this phenomenon is devaluation theory, an idea where women and traditionally feminine tasks and traits are inherently devalued in Western society (Leuze & Strauß, 2016; Magnusson, 2009). Devaluation theory argues that it is this decrease in occupational prestige that results in tipping phenomenon (Pan, 2015; Pelley & Carnes, 2020). For example, the computer programming field used to be primarily a women-dominated field with low wages and low prestige. It was advertised directly to women using feminine stereotypes, such as saying the job required "patience and the ability to handle detail", in contrast with the masculine stereotypes and high pay and prestige the field sees today (Cheryan et al., 2009; Little, 2021). Devaluation theory holds up across several studies, especially when measured using wages. However, when measured using occupational prestige, findings are more complicated and unclear.

One study found that men also show much less interest in jobs advertised using feminine traits, and a high disinterest rate when the same job is titled with a feminine job title even when described in a gender-neutral way. Studies have shown that men are more steadfast in adhering to gender stereotypes compared to women, and it is seen as less socially acceptable for men to work in a gender-incongruent occupation than women (Crawley, 2014; Forsman & Barth, 2017). This is supported by a study in which men college students showed more interest in men-dominated fields rather than women-dominated fields, whereas women in the same study did not differentiate their interest based on gender (Crawley, 2014). Men tend to behave in masculinity-reaffirming ways by emphasizing their masculine traits when their masculine identity is threatened (Forsman & Barth, 2017).

Equity ethic and communal values

Underrepresented minorities (URMs) are defined by the National Science Foundation (NSF) as ethnicities with less representation in a field than their representation in the general U.S. population (National Science Foundation, 2023). Due to the previously discussed gender gap, both URMs and women are considered members of underrepresented groups (URGs) in engineering. Studies have shown that URGs value altruism and communal goals more in their STEM careers. Although both men and women value communal goals, women value communal goals significantly more than men (Boucher et al., 2017). Another study found that URM students in STEM are significantly more likely to have career goals centered around social change compared to their non-URM peers (Garibay, 2015). This phenomenon is called "equity ethic", defined by McGee and Bentley (2017) to refer to "students' principled concern for social justice and for the well-being of people who are suffering from various inequities." They found that Black and Latinx STEM students are strongly motivated by collectivist (benefiting their community) and altruistic goals in their STEM career (McGee & Bentley, 2017).

There is a correlation between social empathy and equity ethic: those that have experienced oppression first-hand, such as URGs in STEM, are more likely to attribute those struggles to structural factors and place importance upon working to improve the system (Naphan-Kingery et al., 2019). In one study exploring PhD students' motivations in pursuing academia, students from ethnic majority backgrounds tended to cite freedom to explore topics that interested them as their motivating factor. In contrast, the vast majority of URGs cited external values, such as community impact and altruism, as their motivation for pursuing academia. Even among students that decided to pursue nonacademic careers, several women of color cited their desire to make an impact as the reason they left academia (Gibbs & Griffin, 2013).

Emphasizing and nurturing equity ethic in students has been suggested by many studies as a way for STEM fields to recruit and retain more people, particularly URGs (Boucher et al., 2017; Garibay, 2015; Thoman et al., 2015). STEM fields are viewed as having less focus on communal goals than non-STEM fields, acting as a deterrent for URGs (Diekman et al., 2010; Schauer, Kohls, & Fu, 2023). Cultivating diversity has important positive effects on high-tech innovation, economic outcomes, group problem-solving capabilities, and so much more (Intemann, 2009; Scarborough et al., 2023).

Research questions and hypotheses

The overarching research question formed from the motivations and gaps in literature detailed above is:

> *How are gender, internal/external influences, and the social impact of an engineering project related to students' role allocation preferences?*

This question will seek to understand the impact of various factors on role allocation preferences. Interest and self-efficacy will be the main metrics used to understand participants' reaction to the project and role allocation. To guide data collection and analysis, this research question has been broken down into two more specific research questions that will be addressed throughout this paper:

> *RQ1: Before role allocation on a design project*

team, how does the social impact of an engineering project impact interest and self-efficacy levels for individuals?

Hypothesis 1A: Women and men are expected to have similar interest levels to each other for each of the four tasks (mechanical design, coding, fabrication, and documentation and report-writing), with lowest interest in the documentation role, which is the task that is the least directly related to their career and major choice. Compared to men, women are expected to have lower self-efficacy on the technical roles. This hypothesis aligns with existing findings that women have lower self-efficacy compared to men (Marra et al., 2013; Pajares, 1996) and further explores self-efficacy differences in various tasks related to engineering design projects.

Hypothesis 1B: It is expected that most participants, regardless of gender, will find a project with more real-world applications to be a more interesting and appealing project to work on. However, it is hypothesized that women will exhibit greater interest (McGee & Bentley, 2017) and lower self-efficacy in a project with higher perceived social impact compared to men. This hypothesis was formed based on expectancy value theory: participants exhibit lower self-efficacy in a complex task due to the higher costs of failure for a real-world application (Diekman & Steinberg, 2013; Wigfield & Eccles, 2000).

RQ2: How does role allocation on a design project team impact interest and self-efficacy levels for individuals?

Hypothesis 2A: It is expected that most participants, regardless of gender, will want to do report-writing and documentation less following the role allocation or want to do other more technical tasks more due to reactance theory, where people respond negatively in opposition to actions they perceive as infringing on their free will (Rosenberg & Siegel, 2018). This will result in lower interest in the documentation and report-writing role for all participants.

Hypothesis 2B: It is expected that women will experience a decrease in self-efficacy in technical roles due to stereotype threat and potential benevolent sexism when the task of report-writing and documentation is assigned by Jacob, a stereotypically masculine name, rather than Emily, a stereotypically feminine name. Some may experience an increased desire to perform technical roles and decreased desire to do report-writing and documentation in reactance.

Hypothesis 2C: It is expected that men will see a larger decrease in desire to do report-writing and documentation when Emily, a stereotypically feminine name, assigns the task. Literature has shown that women experience greater negative consequences when taking risks, such as assuming leadership, compared to men (Morgenroth et al., 2022), which may lead the participants to implicitly dislike "Emily" as their team leader. Additionally, men face greater backlash for violating gender stereotypes (Moss-Racusin, 2014), such as performing a feminine-stereotyped task on a technical project, which may contribute further to their lack of desire to do the documentation and report-writing task.

Methods

Data collection

Study data were obtained through a Qualtrics survey that was administered using Prolific, a subject recruitment site where participants can be compensated for completing a survey. Prolific verifies the identities of participants through ID such as a driver's license or passport. It does not verify the student status of participants, although it prompts participants often to check and update their personal information, such as education- and career-related information, that may have changed. Participants were paid $0.50 to complete the Qualtrics survey, which took an average of 2.5 min to complete. Participants were filtered by Prolific as well as a screening question at the beginning of the survey to ensure that only those currently enrolled as engineering or computer science students in the US participated in the survey.

The survey was divided into three parts: pre-role allocation, post-role allocation, and demographics. In the first section, participants were asked to imagine that they are in an undergraduate design course on a team with three other students. Participants were told that their project was either a robot meant to clean radiation from the area surrounding the Fukushima Nuclear Power Plant or a robot meant to pick up marbles off the floor. Participants were then asked to rate on a 1–5 anchored Likert scale their interest in the project, interest in each role on the project team, and how successful they expected to be in each role (to indicate their self-efficacy). The available roles listed were mechanical design, coding, fabrication, and documentation/report-writing. Finally, participants used a slider from 0 to 100% to indicate the percentage of work that they expected to contribute to the four-member team project.

In the second section, additional detail was given to the hypothetical project scenario. Participants were told that one of their teammates had assumed a leadership role and assigned them the role of documentation and report-writing. The teammate was named either Jacob or Emily, based on the most common baby boy and girl names in the US from the 2000s (U.S. Social Security Administration, 2022), the decade in which the majority of the participants were born. The participants then reported their reaction to being assigned this role as an open-ended short response. This question was followed by the same four questions from the pre-role allocation section of the survey (project interest, role interest, role self-efficacy, and anticipated contribution).

Finally, in the third section, participants provided demographic information such as their gender identity, race/ethnicity, what year they are in their university studies, and their level of prior experience in each of the aforementioned roles on an anchored 1–5 Likert scale (1—Beginner, 2—Novice, 3—Proficient, 4—Advanced, 5—Expert). A free-form space was provided at the end for any questions or comments the participants wanted to provide to the researchers.

Survey development

The duration of the survey was short in order to recruit a high number of participants and understand their initial reactions and responses. The first section, pre-role allocation, was designed as a control for the second section, post-role allocation, in order to directly compare impacts of being assigned the documentation task depending on the perceived gender of the assigner. A secondary goal of this study was to investigate differences in project interest depending on its real-world impacts and ethics. Thus, participants were provided with one of two project descriptions below.

For the Fukushima group:

> *Imagine you are in an undergraduate engineering design course. You are on a project team with 3 other students working on a robot meant to clean radiation from the area surrounding Fukushima.*

For the Marbles group:

> *Imagine you are in an undergraduate engineering design course. You are on a project team with 3 other students working on a robot meant to pick up marbles from the floor.*

In the second section, participants were assigned the task of documentation and report-writing by either Jacob or Emily:

> *Your teammate, [Jacob/Emily], has assumed the role of team leader and has assigned you the role of documentation and report-writing.*

Upon beginning the survey, participants were randomly assigned to one of four experimental conditions based on the two levels of the two independent variables (Marbles or Fukushima project topic, and Jacob or Emily as the teammate's name).

After reading the given scenario, participants were asked four questions:

1. How interested are you in this project on a scale from 1–5?
2. How interested are you in each role on a scale from 1–5:
   a. Mechanical design
   b. Coding
   c. Fabrication
   d. Documentation/report writing
3. How successful do you think you would be in each role on a scale from 1–5:
   a. Mechanical design
   b. Coding
   c. Fabrication
   d. Documentation/report writing
4. On the team of 4, what percentage of the work do you anticipate doing for this project?

Participants responded to Questions 1–3 were provided on an anchored Likert scale. For Questions 1 and 2, a scale labeled (1) extremely uninterested, (2) uninterested, (3) neutral, (4) interested, and (5) extremely interested was used. For Question 3, a scale labeled (1) unsuccessful, (2) somewhat unsuccessful, (3) neutral, (4) somewhat successful, and (5) successful was used. Question 4 utilized a sliding bar for participants to indicate a number between 0 and 100%.

Immediately after the role allocation description, a brief free response question was provided prior to Questions 1–4:

> *What is your reaction to being assigned this role?*

This free response question was included in the survey to encourage participants to briefly reflect on the situation in addition to providing qualitative data for the researchers.

Data analysis

Statistical analysis was conducted using R 4.1.2 and RStudio. Various statistical tests were used to test the between-subjects effects of participant gender, name case, and project topic on the dependent variables (interest, self-efficacy, and estimated work contribution), as well as the within-subjects effect of role allocation. Data were analyzed using analysis of variance (ANOVA) tests at a significance level of $\alpha = 0.05$ in order to consider all variables as well as their potential interactions. When a significant relationship was identified, Dunn's test was used to perform multiple pairwise comparisons (Dunn, 1964). The Kendall rank correlation coefficient (τ) was also used to check for statistically significant correlations between variables. In total, 273 different analyses were performed on this dataset (although not all of them are reported in this paper), necessitating the use of the Benjamini–Hochberg correction for false discovery rate (Benjamini & Hochberg, 1995). All reported p-values throughout this paper have been adjusted accordingly.

Demographics

The study had 475 participants who completed the survey, but 37 responses were filtered out due to failure of initial screening questions to ensure participants were currently enrolled as engineering or computer science students in university, leaving 438 participants. Of these participants, 115 were women, 301 were men, and 22 identified as non-binary or another gender. Because gender was considered an independent variable for the purposes of analysis in this study, the 22 responses from participants not identifying as women or men were removed, as statistically significant conclusions were not able to be drawn on the small sample size. Of the remaining 416 participants, 73 were graduate students and 343 were undergraduate students, with 54 undergraduate students in their first year of study, 107 second-years, 88 third-years, and 94 students in their fourth year or beyond. The majority of participants identified as White (210), followed by Asian (97), Black or African American (37), Hispanic or Latino (35), and 37 identifying as more than one race or another race. The breakdown of participants of each gender into experimental groups based on project topic and the name of the role allocator can be seen in Table 1.

Table 1 Participant demographics by experimental group, gender, and name case (416 total)

	Emily	Jacob	Total
Women			
Fukushima	29	28	57
Marbles	30	28	58
Total	59	56	115
Men			
Fukushima	69	80	149
Marbles	71	81	152
Total	140	161	301

Results and discussion

Project interest

Table 2 summarizes the interest expressed by participants in the Fukushima and Marbles projects before and after being assigned the documentation role. Participants expressed a significant preference for the Fukushima project over the Marbles project at both the pre- ($p < 0.001$) and post-role allocation ($p = 0.047$) stages of the study, as anticipated in Hypothesis 1B. After role allocation, interest in both projects decreased significantly ($p < 0.001$ for both). These trends were significant in both men and women participants, contradicting Hypothesis 1B, which predicted that women would exhibit higher interest than men in the Fukushima project due to its higher social impact.

In order to fully explore the potential impacts of equity ethic in this scenario, project interest was also assessed for other underrepresented groups in engineering. Each participant was assigned a URM (underrepresented minority) or non-URM marker based on the NSF's definition of underrepresented minorities in STEM, meaning that all non-White and non-Asian participants, regardless of gender, were categorized as URMs (National Science Foundation, 2023). Further contradicting Hypothesis 1B was the finding that underrepresented racial/ethnic minorities in STEM (URMs) did not exhibit a preference for the Fukushima project over the Marbles project pre- ($p = 0.927$) or post-role allocation ($p = 0.525$), while the non-URMs expressed higher interest in the Fukushima project compared to the Marbles project pre-role allocation ($p < 0.001$) but not post-role allocation ($p = 0.060$).

These results contrast with established literature that shows that members of underrepresented groups prioritize projects with greater altruistic or

Table 2 Mean interest (on 1–5 Likert scale) expressed toward Fukushima and Marbles projects pre- and post-role allocation overall, separated by gender, and separated by URM status

	Overall		Gender				URM status			
			Men		Women		URMs		Non-URMs	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Fukushima	4.023	3.380	4.007	3.356	4.034	3.448	3.846	3.404	4.079	3.372
Marbles	3.743	3.153	3.743	3.105	3.741	3.259	3.934	3.279	3.671	3.106

community-driven impacts as a result of equity ethic and communal goals (Diekman et al., 2010; McGee & Bentley, 2017; Murphy et al., 2007). This conflict may have resulted from confounding factors between the Fukushima and Marbles projects. Rather than emphasizing the difference in altruism and community engagement, the project choices could also be interpreted as differing in relative complexity and in their applications as a real-world vs. "traditional" school project. Additionally, the problem statement for the Marbles project ("pick up marbles from the floor") was more direct, defined, and smaller in scope compared to the problem statement for the Fukushima project ("clean radiation from the area surrounding Fukushima"). The high complexity and low specificity of the Fukushima project—and higher perceived consequences for failure—may have lowered participants' self-efficacy, offsetting any potential higher interest resulting from equity ethic. Interest and self-efficacy will be explored further in the following section of this paper.

As discussed above, there was an overall decrease in project interest after participants were assigned the role of documentation and report-writing. Neither men nor women expressed different levels of interest in the project based on whether the role was assigned to them by Jacob (mean = 3.267 for men, 3.196 for women) or Emily (mean = 3.186 for men, 3.500 for women, $p = 0.733$, 0.176, respectively). Although imagined scenarios have been found to induce similar reactions to threatening stimuli (Reddan et al., 2018), this result indicates that simply reading a hypothetical scenario in which a team member assigned a group role is insufficient to evoke stereotype threat and other phenomena of interest to this work. The text-based format likely also reduced the salience of the gender-stereotyping of the team member's name or the documentation task.

Role interest, self-efficacy, and prior experience

Analysis of participants' interest, self-efficacy, and reported experience with the four project roles will mainly focus on the gender of the participant due to the gender-stereotyping of the project roles. Participants' interest in the various project roles is summarized in Fig. 1. While there was no significant difference between genders in their interest in fabrication ($p = 0.559$) or mechanical design ($p = 0.192$), men expressed significantly higher interest in coding compared to women both pre- ($p = 0.023$) and post-role allocation ($p = 0.025$). This aligns with prior findings that women would have lower self-efficacy than men on technical group roles (Marra et al., 2013; Pajares, 1996). In contrast with Hypothesis 2A, there was no significant change

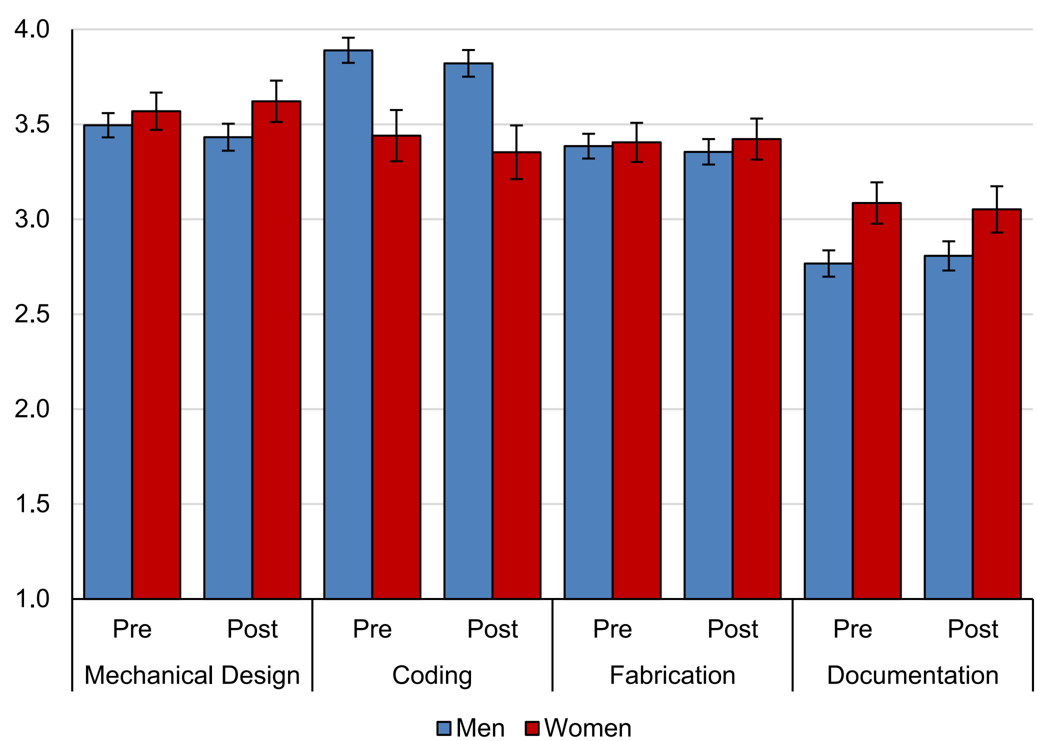

Fig. 1 Participants' interest in each role pre- and post-role allocation, separated by gender (error bars represent ± 1 SE)

in participants' interest in any of the roles post-role allocation.

Additionally, women reported significantly higher interest in documentation than men pre-role allocation ($p = 0.042$) but not post-role allocation ($p = 0.136$), although there was no statistically significant change in either men's ($p = 0.874$) or women's interest ($p = 0.960$) in documentation between pre- and post-role allocation. The lack of a significant difference in self-efficacy post-role allocation is likely due to a slight downward trend in women's interest accompanied by a slight upward trend in men's interest in documentation, resulting in the non-statistically significant gap in interest. Various confounding factors may have impacted these results. For example, women's interest in documentation may have been impacted by stereotype threat, as documentation tends to be a feminine-stereotyped role (Linder et al., 2010; Shapiro & Williams, 2012). On the other hand, men's interest in documentation may have trended upwards as being assigned the task of documentation may have been seen as "permission" to explore a role outside of masculine-stereotyped gender roles, as men often receive greater backlash for straying from their gender roles in society (Hoskin, 2020; Moss-Racusin, 2014; Rudman et al., 2012; Skočajić et al., 2020). Bandwagon effect, or the pressure to be a good "team player", may have also impacted participants' interest in the role upon being assigned it (Leibenstein, 1950).

As anticipated in Hypothesis 1A, participants' level of interest differed for the different roles. Pre-role allocation, women were significantly less interested in documentation compared to mechanical design ($p = 0.006$) and coding ($p = 0.013$). These differences persisted post-role allocation ($p = 0.002$, 0.042, respectively). Men exhibited a similar lack of interest in the documentation role, preferring all three other roles to documentation pre- and post-role allocation ($p < 0.001$ for all). Men also exhibited an unexpectedly strong interest in coding at both stages of the study, with their interest levels in coding significantly surpassing their interest in all three other roles ($p < 0.001$ for all).

The gender of the team member (Emily or Jacob) assigning the documentation task impacted women's interest in fabrication and mechanical design roles. Post-role allocation, women who were assigned documentation by Jacob (mean = 3.946) had significantly higher interest in mechanical design compared to women who were assigned the task by Emily (mean = 3.317, $p = 0.005$). Although the perceived gender of the team member did not impact women's interest in the documentation role, it is possible that being assigned a gender-stereotypical team role by a man may have caused women participants to react to perceived sexism by developing a stronger preference for a different role. This finding may be an indication of reactance theory among the women participants (Kalokerinos et al., 2014; Rosenberg & Siegel, 2018), lending partial support to Hypothesis 2B.

Role allocation did not impact participants' self-efficacies for any role, as there was no significant change in self-efficacies between pre- and post-role allocation. This indicates that stereotype threat did not significantly impact women's self-efficacy in technical roles when assigned a role by Jacob, contrary to what was expected in Hypothesis 2B. However, there were significant gender differences in self-efficacies for some roles, as shown in Fig. 2. Similar to how men expressed higher interest in the coding role than women, men also expressed higher self-efficacy in their coding abilities both pre- ($p = 0.006$) and post-role allocation ($p = 0.006$). Women also exhibited higher self-efficacy for the documentation role compared to men both pre- and post-role allocation (both $p < 0.001$). There were no significant gender differences in fabrication ($p = 0.389$) and mechanical design self-efficacies ($p = 0.169$).

Participants' reported experience in each role is displayed in Fig. 3. Women and men did not report significant differences in reported experience for mechanical design ($p = 0.282$) or fabrication ($p = 0.265$). However, women reported significantly higher prior experience with documentation than men ($p < 0.001$), and men reported significantly higher prior experience with coding than women ($p = 0.042$). The finding that women reported more prior experience with documentation aligns with the tendency of women to perform non-technical roles, such as documentation and report-writing on design teams (Hirshfield, 2018; Hirshfield & Chachra, 2015; Linder et al., 2010). Likewise, because men face increased backlash for straying from societal gender norms compared to women (Hoskin, 2020; Moss-Racusin, 2014; Rudman et al., 2012; Skočajić et al., 2020), the finding that men are less likely to report prior experience with documentation is unsurprising.

For each of the four roles, there was a significant positive correlation between participants' interest in the project role and their self-efficacy for the task at both pre- and post-role allocation stages ($p < 0.001$ for all). Similarly, there were significant positive correlations between participants' interest in a role and their and reported experience, as well as between self-efficacy and reported experience, for all four roles at both pre- and post-role allocation stages ($p < 0.001$ for all). These trends, summarized in Table 3, show that participants are more likely to be interested in a role if they report prior experience or high self-efficacy in the role, which was expected given the link between interest and

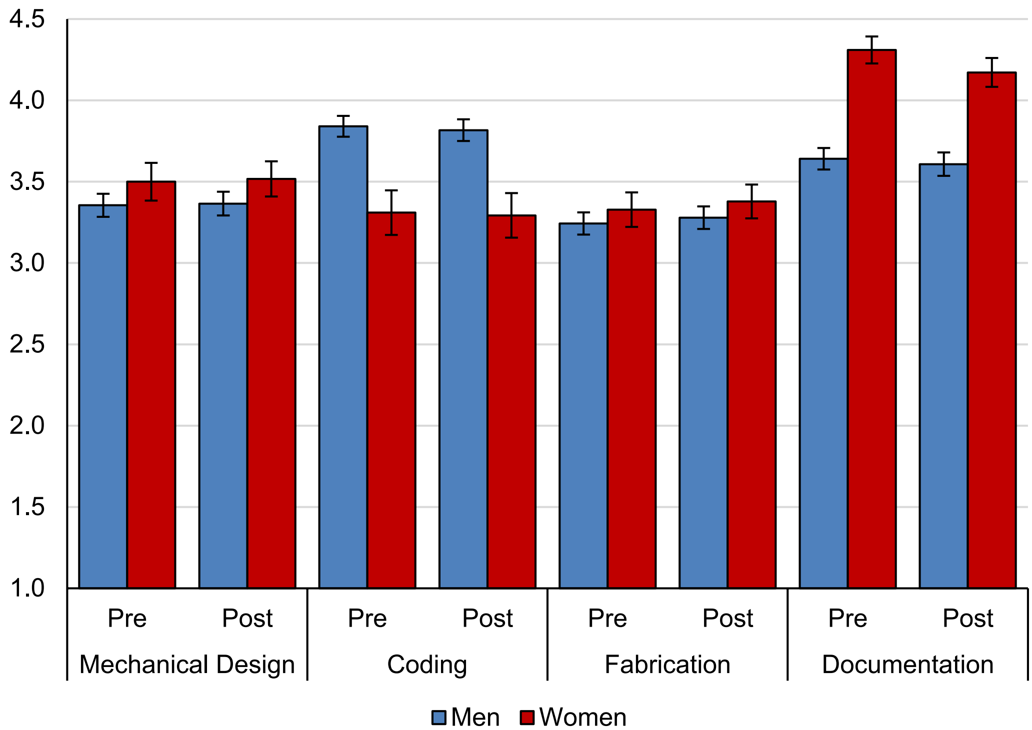

Fig. 2 Participants' self-efficacy in each role pre- and post-role allocation, separated by gender (error bars represent ± 1 SE)

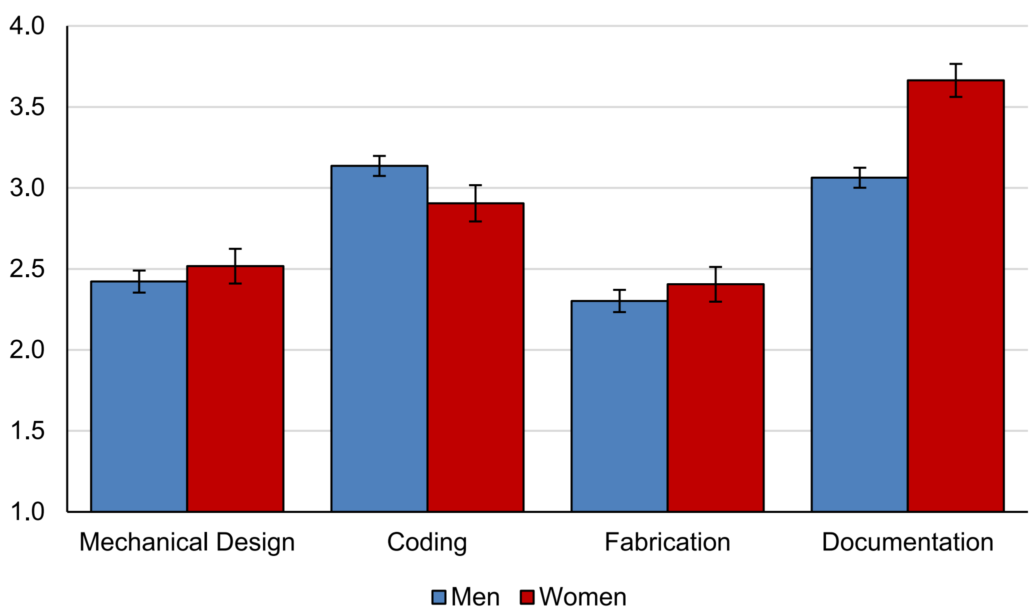

Fig. 3 Participants' reported prior experience with each role, separated by gender (error bars represent ± 1 SE)

self-efficacy (Rottinghaus et al., 2003). The finding that reported experience was positively correlated with self-efficacy aligns with Bandura's classification of mastery experiences as important contributors to self-efficacy (Bandura, 1977).

Estimated work contribution

After evaluating their interest and self-efficacy in each of the roles, participants were asked to indicate on a scale from 0–100% the percentage of the work that they anticipated doing for the project on their team

Table 3 Correlation coefficient Kendall's b-tau indicating the relationship between self-efficacy, interest, and reported prior experience for the four team roles, separated by gender and pre- or post-role allocation

	Self-efficacy vs interest		Experience vs self-efficacy		Interest vs experience	
	Pre	Post	Pre	Post	Pre	Post
Mechanical design						
Men	0.654*	0.762*	0.589*	0.599*	0.505*	0.510*
Women	0.578*	0.667*	0.617*	0.594*	0.452*	0.411*
Coding						
Men	0.669*	0.736*	0.513*	0.490*	0.468*	0.458*
Women	0.688*	0.783*	0.683*	0.679*	0.539*	0.524*
Fabrication						
Men	0.615*	0.744*	0.568*	0.555*	0.444*	0.485*
Women	0.510*	0.695*	0.545*	0.607*	0.420*	0.469*
Documentation						
Men	0.403*	0.500*	0.561*	0.501*	0.287*	0.327*
Women	0.361*	0.399*	0.484*	0.512*	0.310*	0.281*

Statistical significance at the $p = 0.050$ level is indicated by *

of four students. This metric may have been reflective of participants' interest in the project (and therefore willingness to participate and contribute) as well as their perceived value to the team. Participants' estimations of their percentage of work contribution are summarized in Fig. 4. There were no significant differences in estimated contribution based on gender (mean = 36.2% for men, mean = 36.1% for women, $p = 0.422$) or project topic (mean = 34.8% for Fukushima, mean = 37.3% for Marbles, $p = 0.081$) pre-role allocation. Examining the impact of the role allocation on estimated contribution to the project afforded insight into how taking on the role of documentation and report-writing impacted participants' perceived contribution to the project, although the name cases (Jacob, mean = 33.5%, and Emily, mean = 31.9%) did not significantly impact

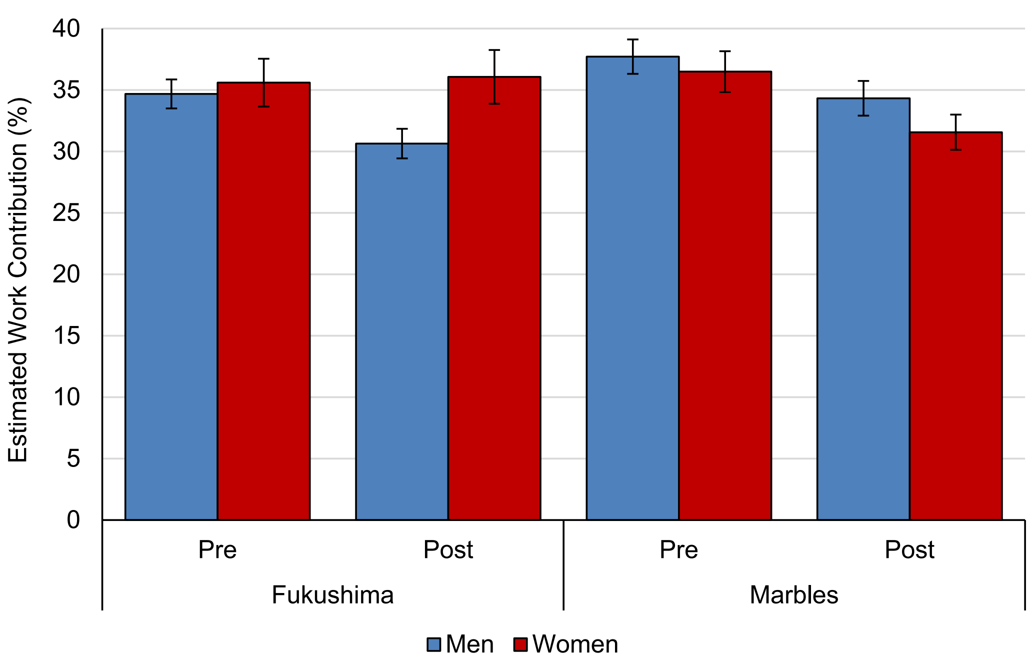

Fig. 4 Participants' estimated work contribution percentage pre- and post-role allocation, by participant gender and project topic (error bars represent ± 1 SE)

participants' estimates of their contribution ($p = 0.939$). After being assigned the documentation role, there was a significant drop in both men ($p = 0.026$) and women's expected contribution to the Marbles project ($p = 0.016$). For participants on the Fukushima project, only men exhibited a significant decrease in their expected contribution ($p = 0.001$), while women's expected contribution did not change significantly ($p = 0.854$). Although this resulted in no significant difference between men and women's expected contribution to the Marbles project ($p = 0.927$), women estimated that their contribution to the Fukushima project would be significantly higher than men's estimates ($p = 0.022$), as shown in Fig. 4. This is likely a combination of two factors. First, feminine-stereotyped roles and jobs tend to be undervalued in society compared to men-stereotyped roles (Bose & Rossi, 1983; Leuze & Strauß, 2016; Magnusson, 2009; Pelley & Carnes, 2020), resulting in men devaluing their contribution to the projects upon receiving the feminine-stereotyped role allocation. Second, women not only were less likely to undervalue the feminine-stereotyped documentation role, but their greater reported experience with documentation roles may have also resulted in a more accurate estimate of the amount of work required to complete the documentation task.

Sentiment analysis

After being told that Emily or Jacob had assigned them the documentation and report-writing role, participants provided a written response to the question, "What is your reaction to being assigned this role?" Responses to this question were analyzed using the Python Natural Language Toolkit (NLTK) version 3.8.1 (Bird et al., 2009). With NLTK, the VADER (Valence Aware Dictionary and sEntiment Reasoner (Hutto & Gilbert, 2014)) algorithm was used to classify the sentiment of each participants' response. VADER was selected due to the short nature of the participant responses and its effectiveness at gauging the sentiment of short social media posts, such as Tweets (Bonta et al., 2019; Elbagir & Yang, 2019). The algorithm assigned a score between -1 and + 1 to each response, where -1 indicates extremely negative sentiment and + 1 indicates extremely positive sentiment.

As shown in Fig. 5, women expressed more positive sentiments overall (mean = 0.139) compared to men (mean = 0.074), although this difference was not statistically significant ($p = 0.280$). Neither the project (Fukushima or Marbles) nor the gender of the role assigner (Jacob or Emily) had a statistically significant impact on the sentiments expressed by participants ($p = 0.686$, 0.872, respectively). However, there was a significant positive correlation between the sentiment of the short response and the participants'

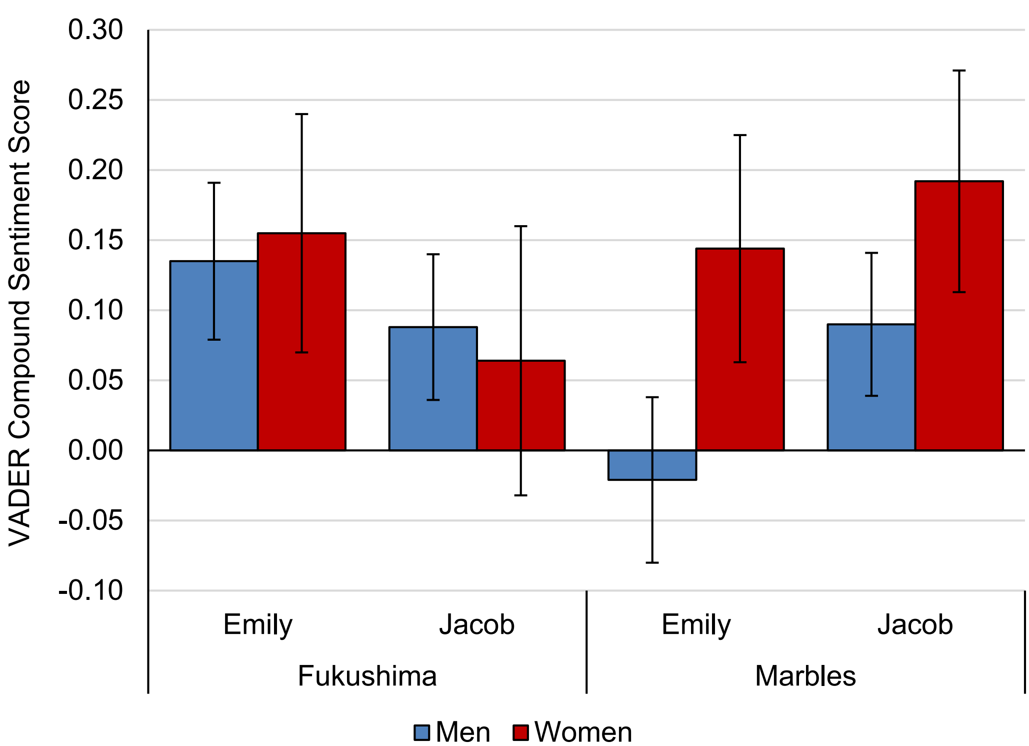

Fig. 5 Compound sentiment scores by participant gender, project topic, and role assigner name (error bars represent ± 1 SE)

interest in the project ($\tau = 0.392$, $p < 0.001$). In other words, participants who expressed more positive sentiments in their reaction to role allocation also expressed higher interest in the project. This finding is a preliminary validation of the ability of the VADER algorithm to assess sentiments expressed by study participants.

Overall, most of the participants were not happy with the role assignment. A few participants mentioned that they were willing to participate for the sake of the team, and expressed hope that their other hypothetical teammates' roles were optimally assigned in relation to their skills. A total of 42 participants stated that they would prefer another role, with a few stating that roles should be equally participated in by all team members.

There were a few standout results from the qualitative analysis. Of the 21 participants that mentioned a lack of confidence in their writing skills, 18 of them (86%) identified as men. There were 17 participants that stated the documentation role was either easy, boring, or not a "real" part of the project. This could be reflective of engineering students' general disdain for technical writing tasks (Wilson-Fetrow et al., 2023). However, out of those 17 participants devaluing the documentation role, 15 (88%) were men. These results point towards a dichotomy in which men, in comparison to women, simultaneously have low self-efficacy in the role, as shown by these responses and prior quantitative data, while devaluing the role, as suggested by literature in devaluation theory (Bose & Rossi, 1983; Leuze & Strauß, 2016; Magnusson, 2009; Pelley & Carnes, 2020). This may be an indication of "weaponized incompetence" or "strategic incompetence", a phenomenon in which people feign difficulty or inability to perform a task in order to avoid it (Leavitt, 2022). It is also possible that men experienced stereotype threat when instructed to perform the feminine-stereotyped role, leading them to distance themselves from the task by devaluing it as "easy" in order to preserve their self-esteem.

There were 8 women participants, all in the Jacob group, that mentioned gender-stereotyping sentiments, such as being unsurprised, assuming the assignment was motivated by gender stereotypes, or prior experiences with role stereotyping. While the number was low, it represented 14% of the 56 responses from women in the Jacob group, the experimental group most expected to experience stereotype threat. This gives a small glimpse into the experiences of women in STEM struggling with stereotype threat, although the format of this study was not conducive to further exploration into this phenomenon.

Conclusions

Limitations and future work

The nature of the survey methodology used in this study meant that some effects may not have the same impact as in-person interventions. Simply reading a hypothetical scenario about a team project likely did not evoke the same magnitude of stereotype threat and emotional response compared to experiencing the same phenomena in a real-world scenario, although explicitly asking participants about their views on any gender stereotypes encountered during the intervention would clarify this point and should be done in the future. Future work can be done to validate the phenomena explored in this study via an in-person study. Literature on emotional response in simulated versus real-world environments also indicates that simulated experiences on a computer (Uhr et al., 2003) or in virtual reality (Chirico & Gaggioli, 2019) can elicit similar emotional responses compared to real-world environments. The standard error of some results was also notably high among women participants. This was due to the difficulty of recruiting women participants, as the demographic breakdown of engineering students in the United States is still heavily skewed towards men.

In addition, the two project topics used in this study may have introduced more complicating factors beyond the degree of altruism and community impact. The projects topics differ in level of complexity, specificity, and real-world impact, with the Fukushima project therefore being associated with higher consequences for failure compared to the Marbles project. Further research can be done to separate these factors from the results of the different project groups in this study. Different interpretations of the metrics used in the survey may have also confounded the results. For example, participants were asked to report the percentage of the work they anticipated doing for the project. This metric was intended to assess the change in value students assigned to their project contribution after being assigned the documentation role. However, students' responses may have reflected other factors, such as a decrease in project interest and a corresponding decrease in engagement. In future work, the perceived value of a role should be more directly assessed, perhaps using Likert-scale questions similar to the ones used to assess participant interest in the roles.

Because the survey was designed to be short in order to maximize completion rate, future work should involve deeper investigation into some of the trends discussed in this work. For example, although neither men's nor women's interest in documentation changed significantly post-role allocation, a significant difference between men and women's interest pre-role allocation disappeared post-role allocation. Additional metrics could be used to assess participant interest in the project, as well as the various roles. The qualitative prompt in the survey was intended to gauge participants' "gut reaction" to the role allocation, which led to mostly short answers containing participants' feelings rather than critical thoughts on team dynamics. Although this format lent itself well to the sentiment analysis performed in this work, the longer, more detailed answers that were provided showed promise for future work. Collecting additional free-response data would permit deeper qualitative analysis investigating attitudes devaluing documentation as a role, assumptions of the role allocation being sexism-motivated, and participants' willingness to sacrifice their own preferences for the sake of team success and cohesion.

Contributions

While much research has been conducted surrounding gender differences in self-efficacy, role allocation, and occupational prestige, there is a gap in the literature exploring how these various factors cumulatively affect design team role stereotype adherence. Therefore, the main research question guiding this work was:

How are gender, internal/external influences, and the social impact of an engineering project related to students' role allocation preferences?

The primary finding and contribution of this study is that internal effects, such as self-efficacy and backlash to perceived sexism, can impact role stereotype adherence in teams in addition to biases that are externally applied to an individual. The main internal influences that were significant throughout the results were participants' self-efficacy and pre-conceived gender biases, such as devaluation theory and stereotype threat. The main external influence investigated was the effect of the perceived gender of the teammate assigning the project role. Self-efficacy was significantly correlated with participants' interest in a role, while external influence did not have a significant effect on role self-efficacy or interest. The gender differences in documentation self-efficacy also manifested as gender differences in documentation role interest, while that difference in role interest was negated by role allocation. The gender of the role allocator did not have a significant effect. Internal effects, such as devaluation theory and egocentrism, also likely played a large role in the gender differences in work contribution percentage estimations. These main findings were revealed by exploring the two more specific research questions and their hypotheses:

RQ1: Before role allocation on a design project team, how does the social impact of an engineering project impact interest and self-efficacy levels for individuals?

Regardless of the project topic, both men and women exhibited significantly lower interest in the documentation role compared to the other role options, as expected by Hypothesis 1A. Men exhibited an unexpectedly strong interest in coding compared to the other roles. As a result, men expressed higher self-efficacy in the coding role compared to women, while women expressed significantly higher self-efficacy compared to men in the documentation role. Compared to men, women did not exhibit significantly different self-efficacy toward the fabrication and mechanical design tasks, contradicting Hypothesis 1A.

Although participants exhibited significantly higher interest in the Fukushima project, the project with greater social impact, there was not a significant difference in men's and women's levels of interest in the project. Further contradicting Hypothesis 1B were the findings that underrepresented racial/ethnic minorities, or URMs, did not express a significant preference toward the Fukushima project over the less-impactful Marbles project. This result may have been due to confounding factors such as the perceived complexity, specificity, or repercussions associated with the two projects, leading participants to exhibit lower self-efficacy and therefore lower interest than expected in the Fukushima project.

RQ2: How does role allocation on a design project team impact interest and self-efficacy levels for individuals?

In contrast with Hypothesis 2A, there was no significant change in participants' interest in any of the roles post-role allocation, even for women who were assigned the documentation role by Jacob. However, both men and women exhibited significantly lower interest in the general project after being assigned a role.

Neither men nor women exhibited a significant change in self-efficacy as a result of role allocation, possibly due to the hypothetical nature of the study. However, women who were assigned the documentation role by Jacob exhibited significantly higher interest in the mechanical design role compared to women who were assigned the task by Emily, indicating that women's reaction to this scenario may have been driven by reactance theory and backlash to perceived sexism by Jacob, as predicted in Hypothesis 2B.

The gender of the team member did not significantly impact men's interest or self-efficacy in any of the project roles, contradicting Hypothesis 2C. Their interest in the documentation role was significantly lower than either their interest in the more technical roles or women's interest in the documentation role regardless of whether they were assigned the role by Jacob or Emily. However, men's anticipated contribution to the project decreased significantly after they were assigned the documentation role, aligning with their decrease in project interest and potentially indicating that men devalued their contribution to the project upon being allocated a feminine-stereotyped role.

Findings of the comparative effects of internal and external biases on role stereotype adherence can be used to inform classroom interventions, curriculum development, management methods, and policy decisions. While the primary effects motivating role stereotype adherence were internal, those internal factors, such as self-efficacy and feminine-role devaluation, are informed by external systemic societal factors. The findings surrounding participants' estimated work contributions pre- and post-role allocation also contribute to the existing literature of how women and men may view and interact with feminine-stereotyped roles on teams.

Abbreviations

AST	Ambivalent sexism theory
EVT	Expectancy value theory
NSF	National Science Foundation
STEM	Science, technology, engineering, and math
URG	Underrepresented group
URM	Underrepresented minority

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Author contributions
All authors collaborated on the experimental design and data collection methods for this study. AS completed the majority of data analysis and the writing for the manuscript. JL contributed to the writing of the manuscript and conducted the literature review, data collection, and preliminary analysis. All authors read and approved the final manuscript.

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Availability of data and materials
The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics and consent
This study was conducted under the guidance of the Institutional Review Board at the Georgia Institute of Technology as protocol H23004. Informed consent was obtained from all participants at the beginning of the survey.

Competing interests
The authors declare that they have no competing interests.

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