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Exploring the Influence of Gender and Prior Experience on Career Perceptions in Remotely Operated Vehicle Operations: A Social Cognitive Career Theory Perspective

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Abstract

This complete paper uses Social Cognitive Career Theory (SCCT) as a guiding framework to investigate the intersection of demographics, prior experiences, and career perceptions in Remotely Operated Vehicle (ROV) operations. Given the unique attributes and evolving nature of ROV operations as an emerging career, new vocational psychology research is needed to meet workforce needs more systematically and equitably. SCCT provides a comprehensive framework for examining the interplay among personal, contextual, and psychological constructs, making it a valuable tool for understanding the career development process. Using a cross-sectional survey design with a sample of 156 first-year engineering students, the research examines how personal and contextual factors (i.e., gender, ethnicity, academic major, career awareness, gaming, and robotics experiences) relate with the core SCCT constructs of self-efficacy, outcome expectations, career interest, and intention to pursue a career in ROV operations. The findings reveal that male students report higher career awareness, gaming, and robotics experiences than female students, though no significant gender differences emerged in the core SCCT constructs. Notably, robotics experience exhibited a gender-specific pattern, primarily associated with female students' lack of career awareness but demonstrating broader links with self-efficacy, career interest, and career intention for male students. Moreover, gaming experience contributed to career awareness among male students but had minimal influence on core SCCT constructs for both genders. Despite these differences, the comparable levels of core SCCT constructs across genders suggest that female students, while underrepresented in STEM, have equivalent cognitive foundations for pursuing ROV-related careers. However, gender-specific differences in the influence of prior experiences highlight potential mediating factors not examined in this study, warranting further research. These findings emphasize the importance of inclusive learning strategies, particularly in robotics activities, to foster equitable engagement and support for developing self-efficacy, interest, and intentions in engineering-related careers among all students.

Introduction

Remotely Operated Vehicles (ROVs) are critical tools in modern engineering, playing a pivotal role in subsea exploration, maintenance, and inspection. By extending human capabilities in challenging environments, ROVs drive innovation and create a growing demand for skilled professionals in ROV teleoperation. However, limited research exists on how individuals, particularly first-year engineering students, develop interest and perceptions about careers in this emerging field. Understanding these early career perceptions is essential, as they significantly

influence students' academic and professional trajectories, particularly in emerging technological domains like ROV operations.

The lack of sufficient data on first-year students' backgrounds and career interests for emerging engineering-related careers, such as ROV operations, poses a challenge for educational institutions that aim to design effective programs. Without these insights, institutions may miss opportunities to engage and inspire future professionals at a formative stage in their academic journey. Importantly, addressing this gap requires a theoretically grounded career development approach that considers the interplay between individual experiences, demographic factors, and career development constructs.

Social Cognitive Career Theory (SCCT) provides a robust framework for investigating individual-level career development processes, offering a nuanced understanding of how self-efficacy, outcome expectations, career interest, and career intention interact as central constructs [1], [2]. Brown and Lent's framework [3] also emphasizes the role of personal factors, including personality traits, prior experiences, gender, and race/ethnicity, alongside contextual factors, such as socioeconomic status and prior education, in shaping career and educational outcomes. These elements interact to shape self-efficacy beliefs, outcome expectations, and career interests, highlighting the complex influences that guide career development.

In particular, Brown and Lent [3] highlight the critical role of gender in career outcomes, often mediated through social learning experiences. Gender-specific opportunities, shaped by societal norms and educational structures, affect access to learning environments and, in turn, influence self-efficacy beliefs and career aspirations. For instance, traditional gendered learning experiences, such as being assigned supporting roles, having fewer opportunities to practice, or not having role models [4], [5], may reinforce conventional occupational pathways, whereas broader exposure can expand career possibilities. Given the persistent underrepresentation of women in engineering [6], failing to account for these gendered experiences risks reinforcing disparities and barriers that hinder women's participation in this field.

Extending this discussion, prior research in STEM education has shown that gaming experiences can foster transferable skills and enhance interest in related fields, both of which are positively associated with career success [7], [8], [9]. Similarly, participation in robotics activities has been linked to increased self-efficacy and heightened interest in STEM careers [10]–[12]. Despite these benefits, disparities in access to and engagement with such activities are also well-documented, particularly across gender and ethnic groups in engineering fields [13], [14]. These disparities may influence career intentions and levels of engagement, underscoring the importance of addressing such inequities to foster more inclusive pathways to STEM and engineering careers.

To address these gaps within the context of ROV operations, this study adopts a quantitative approach to investigate three critical areas: (1) the extent to which personal characteristics, such as gender, ethnicity, and academic major, are associated with variations in contextual factors, including ROV career awareness, gaming experience, and robotics experience; (2) how these personal characteristics are related to differences in the core SCCT constructs of self-efficacy, outcome expectations, career interest, and career intention; and (3) the correlations between the contextual factors and the core SCCT constructs. By examining these areas, this study aims to assess the utility of SCCT in the emerging field of ROV operations and provide insights for developing strategies to engage and attract a diverse pool of future professionals to this rapidly expanding field. For the context of ROV operations at a large research-intensive university in the Southeastern United States, this study sought to address the following research questions:

- RQ1. Are there statistically significant differences in career awareness, gaming experience, and robot experience based on gender, ethnicity, and major?
- RQ2. Are there statistically significant differences in the core SCCT constructs of self-efficacy, outcome expectations, career interest, and career intention based on gender, ethnicity, and major?
- RQ3: What are the significant relationships among career awareness, gaming experience, robot experience, and the core SCCT constructs, and how do these relationships differ across gender groups?

Methods

Research Design and Participants

This study employed a quantitative cross-sectional survey design to investigate the research questions. With approval from the university's Institutional Review Board (IRB) (ET00043771), data were collected from an introductory engineering design course at a large research-intensive university in the Southeastern United States. The course, designed for first-year students, introduces the human-centered design process, emphasizing engineering prototyping, teamwork, and communication to tackle societal challenges through multidisciplinary approaches.

A total of 414 students were enrolled in the course, divided into nine sections. Four sections, comprising 196 students, were invited to participate in the survey. The survey was administered online through the university's learning management system as an optional extra-credit opportunity to encourage participation. Of those invited, 188 students responded, provided informed consent, and became participants. Following data cleaning, 32 responses (17%) were excluded due to consistent response patterns, non-engineering majors, or consistent random answers to open-ended questions. The final dataset included 156 participants (83%) representing diverse engineering majors, including computer science (37%), mechanical engineering (17%), electrical engineering (16%), aerospace engineering (6%), and industrial engineering (6%). The

focus on first-year students provided valuable insights into their early career perceptions and the factors influencing them.

Instruments

Two sets of survey instruments were utilized to address the research questions. The first set collected personal data (i.e., gender, ethnicity, and academic major) alongside contextual factors (i.e., career awareness, gaming experience, and robotics experience). To ensure standardized participant comparisons, contextual factors were measured on a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree).

The second set, adapted from Chiu et al. [1], assessed the core constructs of SCCT: self-efficacy, outcome expectations, career interest, and career intention. Each construct was measured using four items on a 5-point Likert scale. To align the survey with the context of ROV teleoperation, items from Chiu et al. [1] were tailored to this domain. For example, participants responded to items such as, "I will be competent in acquiring the technical knowledge required for ROV operation (self-efficacy)," "If I were to pursue this profession, I would have a sufficient or satisfactory income as an ROV operator (outcome expectation)," "I would like to join more training or courses related to ROV operation (career interest)," and "ROV teleoperation is my career aspiration (career intention)."

To ensure that participants' career awareness responses were based on their prior experience rather than influenced by the study materials, the survey began with a single 5-point Likert-scale item: “How aware are you of jobs that involve operating an underwater ROV?” This item was presented before any additional information on ROV careers. Following this, participants watched two brief introductory videos (lasting two and four minutes) illustrating ROV-related work, required competencies, and job requirements. These videos provided foundational knowledge about the field, ensuring that all participants had a comparable understanding of ROV operations before responding to the remaining survey items. After viewing the videos, participants completed the rest of the survey. A reliability analysis using Cronbach’s alpha yielded a value of 0.927, indicating a high internal consistency within the survey items in measuring constructs related to ROV career perceptions.

Table 1. Cronbach’s alpha for career perception survey

Scale	Cronbach’s alpha	Number of items
All	0.927	16
Self-Efficacy	0.918	4
Outcome Expectation	0.828	4
Career Interest	0.928	4
Career Intention	0.897	4

Data Analysis

To answer the research questions, a series of statistical analyses were conducted:
For RQ1 and RQ2, independent sample t-tests and one-way Analysis of Variance (ANOVA) were used to examine group differences. T-tests were applied to compare means between genders, while ANOVA assessed differences across ethnic and academic major groups. Correlation analysis was used to investigate correlations among variables for RQ3. Correlation analysis quantified the strength of associations between career awareness and prior experiences (e.g., gaming and robotics) and the core SCCT constructs. The total sample size (n = 156) surpassed the minimum required sample of 84, which was calculated using G*Power for a two-tailed correlation analysis with 80% power and a medium effect size (r = 0.03) [15]. Using these statistical techniques, the study ensured a quantitative analysis of the relationships among demographic factors, prior experiences, and the core SCCT constructs. This approach facilitated a nuanced understanding of the potential factors that may influence career perceptions for ROV teleoperation.

Results

To ensure clarity and alignment, the results are presented in the order of the research question. First, we examine differences in career awareness, gaming experience, and robotics experience across gender, ethnicity, and academic major (RQ1). Next, we analyze variations in the core SCCT constructs of self-efficacy, outcome expectations, career interest, and career intention based on personal factors (RQ2). Finally, we investigate the relationships among career awareness, gaming experience, robotics experience, and the core SCCT constructs, with a particular focus on gender-specific patterns in these associations (RQ3).

RQ1. Differences in Career Awareness, Gaming Experience, and Robotics Experience
The descriptive analysis revealed that students demonstrated relatively low overall scores in career awareness (M = 2.06, SD = 1.04), gaming experience (M = 2.38, SD = 1.27), and robotics experience (M = 2.19, SD = 1.28) on a 5-point scale, indicating limited exposure or engagement with these domains among the first-year engineering students surveyed. Male students consistently reported higher mean scores across all three domains than their female counterparts, suggesting a disparity in ROV career awareness and gaming and robotics experiences.

Independent t-tests further revealed significant gender-based differences across all three domains (Table 2 and Figure 1). Male students reported higher levels of career awareness (M = 2.22, SD = 1.06) compared to female students (M = 1.74, SD = 0.86), with a medium effect size (t (145) = 2.442, p = 0.016, d = 0.478). This indicates that men are potentially more familiar with or exposed to ROV-related career opportunities, though awareness levels for both genders remain low overall. Similarly, gaming experience showed an even larger disparity (t (145) = 2.966, p = 0.004, d = 0.580), where males (M = 2.54, SD = 1.28) scored significantly higher than females (M = 1.82, SD = 1.06). This reflects gender differences often observed in engagement with

gaming activities. The disparity in robotics experience, with males reporting higher engagement (M = 2.30, SD = 1.29) than females (M = 1.74, SD = 1.02), highlights the persistent underrepresentation of women in robotics-related activities (t (145) = 2.345, p = 0.02, d = 0.459).

Table 2. Gender differences in career awareness, gaming experience, and robot experiences

Domain	*M (SD)*			*t*	*df*	*p*	Cohen's d
	All (n=156)	Male (n=113)	Female (n=34)				
1. Career Awareness	2.06 (1.04)	2.22 (1.06)	1.74 (0.86)	2.442	145	0.016	0.478
2. Gaming Experiences	2.38 (1.27)	2.54 (1.28)	1.82 (1.06)	2.966	145	0.004	0.58
3. Robot Experiences	2.19 (1.28)	2.30 (1.29)	1.74 (1.02)	2.345	145	0.02	0.459

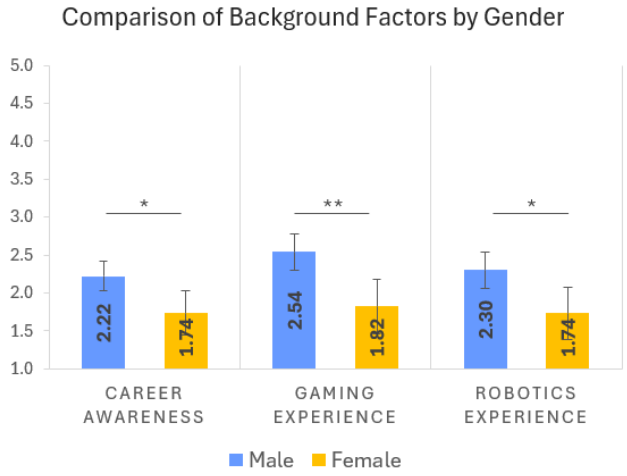

Figure 1. Gender-Related Differences in Career Awareness, Gaming Experience, and Robotics Experience. Note: * indicates p < 0.05. ** indicates p < 0.01.

Next, ANOVA revealed significant differences in career awareness among ethnic groups (F(4, 145) = 4.604, p = 0.002, η^2 =0.111) (Table 3). Asian students reported the highest career awareness (M = 2.58, SD = 1.10), while students with multiple ethnicities reported the lowest (M = 1.44, SD = 0.79). However, no significant differences were observed in gaming experience (F(4, 145) = 0.395, p = 0.812, η^2 =0.011) or robotics experience (F(4, 145) = 0.478, p = 0.752, η^2 =0.013) across ethnic groups. Post hoc analyses of gaming experience using LSD tests further identified significant differences between students identifying as multiple ethnicities and both White (p = 0.013) and Asian (p = 0.001) students, with multiple-ethnicity students reporting lower levels of career awareness. No other pairwise comparisons reached statistical significance, underscoring the relatively consistent levels of gaming engagement across most ethnic groups.

Table 3. Ethnicity-related differences in career awareness, gaming experience, and robot experiences

Domain	Sum of Squares	*df*	Mean Square	*F*	*p*	η^2
1. Career Awareness	18.154	4	4.538	4.604	0.002	0.111
2. Gaming Experiences	2.532	4	0.633	0.395	0.812	0.011
3. Robot Experiences	3.043	4	0.761	0.478	0.752	0.013

Moreover, Gaming experience varied significantly across engineering majors ($F(4, 145) = 3.429$, $p = 0.011$, $\eta^2 = 0.100$ (Table 4). Computer science and engineering students reported the highest gaming experience ($M = 2.75$, $SD = 1.33$), while those in industrial and systems engineering scored the lowest ($M = 1.70$, $SD = 1.25$). Post hoc analyses revealed a significant difference between mechanical engineering and computer science and engineering students ($p = 0.027$), with the latter demonstrating higher gaming engagement. Other pairwise comparisons, including those involving aerospace and electrical engineering students, did not yield significant differences. No significant differences were observed in career awareness ($F(4, 145) = 0.133$, $p = 0.970$, $\eta^2 = 0.004$) or robotics experience ($F(4, 145) = 0.320$, $p = 0.864$, $\eta^2 = 0.01$) across majors, indicating that these domains are not strongly tied to students' chosen disciplines.

Table 4. Engineering major-related differences in career awareness, gaming experience, and robot experiences

Domain	Sum of Squares	*df*	Mean Square	*F*	*p*	η^2
1. Career Awareness	0.607	4	0.152	0.133	0.970	0.004
2. Gaming Experiences	20.925	4	5.231	3.429	0.011	0.1
3. Robot Experiences	2.138	4	0.534	0.32	0.864	0.01

RQ2. Differences in core SCCT Constructs

Independent t-test revealed no significant gender-based differences in any of the core SCCT constructs, including self-efficacy, outcome expectations, career interest, and career intention (Table 5). Male and female students reported similar levels of self-efficacy ($t(145) = 0.537$, $p = 0.592$), outcome expectations ($t(145) = -0.643$, $p = 0.521$), career interest ($t(145) = 0.481$, $p = 0.631$), and career intention ($t(145) = 0.664$, $p = 0.508$).

These findings suggest that despite significant gender differences in prior experiences such as gaming and robotics (reported in earlier analyses), perceptions of career readiness and expectations within the framework of SCCT remain consistent across genders. This consistency indicates that the core SCCT constructs may serve as robust predictors of career interest, regardless of gender-based disparities in experiential exposure.

Table 5. Gender differences in the core SCCT constructs

Domain	*M (SD)*			*t*	*df*	*p*	Cohen's *d*
	All (*n*=156)	Male (*n*=113)	Female (*n*=34)				
1. Self-efficacy	3.69 (0.87)	3.72 (0.87)	3.63 (0.89)	0.537	145	0.592	0.105
2. Outcome Expectations	3.64 (0.79)	3.61 (0.81)	3.71 (0.77)	-0.643	145	0.521	-0.126
3. Interests in a Career	2.94 (1.03)	2.99 (1.03)	2.89 (1.02)	0.481	145	0.631	0.094
4. Career intention	2.63 (0.96)	2.68 (0.96)	2.55 (0.99)	0.664	145	0.508	0.13

ANOVA results also indicated no significant differences in core SCCT constructs across ethnic groups (Table 6). For self-efficacy, scores ranged from 3.62 (multiple ethnicities) to 3.73 (white), but these differences were not statistically significant ($F(4, 145) = 0.107$, $p = 0.980$, $\eta^2 = 0.003$). Similarly, outcome expectations ($F(4, 145) = 0.888$, $p = 0.473$, $\eta^2 = 0.024$), career interest ($F(4, 145) = 0.337$, $p = 0.853$, $\eta^2 = 0.009$), and career intention ($F(4, 145) = 1.400$, $p = 0.237$, $\eta^2 = 0.037$) did not exhibit significant variation by ethnicity. Post hoc analyses further confirmed the absence of significant differences in pairwise comparisons for any of the constructs.

Table 6. Ethnicity-related differences in core SCCT constructs

Domain	Sum of Squares	*df*	Mean Square	*F*	*p*	η^2
1. Self-efficacy	0.336	4	0.084	0.107	0.980	0.003
2. Outcome Expectations	2.231	4	0.558	0.888	0.473	0.024
3. Interests in a Career	1.449	4	0.362	0.337	0.853	0.009
4. Career intention	5.078	4	1.269	1.400	0.237	0.037

Similarly, no significant differences in core SCCT constructs were observed across engineering majors (Table 7). For self-efficacy, scores were marginally higher for electrical engineering ($M = 3.90$, $SD = 0.84$) and aerospace engineering students ($M = 3.93$, $SD = 0.84$), but these differences did not reach statistical significance ($F(4, 145) = 1.105$, $p = 0.357$, $\eta^2 = 0.034$). Outcome expectations, career interest, and career intention were also consistent across majors, with no statistically significant differences detected. Post hoc analyses using LSD confirmed the lack of significant pairwise differences in any of these constructs. For instance, the largest observed mean difference in self-efficacy (0.425) between aerospace engineering and computer science students failed to achieve significance after adjustment for multiple comparisons ($p = 0.649$).

Table 7. Engineering major-related differences in core SCCT constructs

Domain	Sum of Squares	df	Mean Square	F	p	η^2

1. Self-efficacy	3.631	4	0.908	1.105	0.357	0.034
2. Outcome Expectations	2.633	4	0.658	0.96	0.432	0.030
3. Interests in a Career	3.671	4	0.918	0.841	0.502	0.026
4. Career intention	7.78	4	1.945	2.086	0.087	0.063

RQ3. Relationships Among Career Awareness, Gaming Experience, Robotics Experience, and core SCCT Constructs

The correlation analysis revealed significant relationships among career awareness (CA), gaming experience (GE), robotics experience (RE), and the core SCCT constructs of self-efficacy (SE), outcome expectations (OE), career interest (CI), and intention to pursue a career (IPC) (Table 8). Robotics experience showed a significant positive association with self-efficacy ($r = 0.231$, $p < 0.01$) and career interest ($r = 0.229$, $p < 0.01$), indicating that hands-on robotics activities contribute to students' confidence and engagement in ROV-related career pathways. Additionally, robotics experience was also moderately correlated with career awareness ($r = 0.211$, $p < 0.05$), suggesting that exposure to robotics can enhance awareness of career opportunities in related fields.

Furthermore, the core SCCT constructs demonstrated significant intercorrelations, supporting the theoretical rigor of the model. For instance, self-efficacy exhibited a strong positive correlation with outcome expectations ($r = 0.515$, $p < 0.01$), career interest ($r = 0.426$, $p < 0.001$), and career intention ($r = 0.36$, $p < 0.001$). These relationships highlight the cohesive nature of SCCT in explaining how confidence in abilities and positive career expectations drive students' interest and career intentions.

In contrast, gaming experience showed weaker and largely nonsignificant correlations with core SCCT constructs. While gaming may provide exposure to technological skills, its limited influence on key variables such as self-efficacy and career interest suggests that gaming alone may not be a sufficient driver of career development in ROV-related fields. These findings emphasize the differential impact of prior experiences, with robotics exposure emerging as a more robust predictor of core SCCT constructs and career readiness.

Table 8. Correlations for Study Variables (All)

Variable	n	M	SD	CA	GE	RE	SE	OE	CI	IPC
CA	156	2.058	1.036							
GE	156	2.378	1.272	0.213*						
RE	156	2.186	1.279	**0.211***	0.198*					
SE	156	3.688	0.874	0.082	0.091	**0.231****				
OE	156	3.638	0.794	0.004	-0.007	0.11	**0.515****			
CI	156	2.942	1.027	0.141	0.051	**0.229****	**0.426*****	0.478***		
IPC	156	2.631	0.962	0.198*	0.02	0.145	**0.36*****	0.355***	0.813***	

*$p < .05$. **$p < .01$. ***$p < .001$.

Gender-specific analyses revealed distinct patterns in the relationships between prior experiences and core SCCT constructs, underscoring the need for tailored approaches to understanding and fostering career engagement. Among female students, robotics experience exhibited a strong positive correlation with career awareness in ROV-related fields ($r = 0.638$, $p < 0.001$) (Table 9 and Figure 2). However, career awareness did not significantly correlate with the core SCCT constructs, which suggests that while robotics exposure raises career awareness, it does not necessarily translate into increased confidence or motivation to pursue ROV-related careers. Furthermore, the core SCCT constructs demonstrated strong interrelationships, with all constructs significantly correlated. These findings suggest that while robotics experiences indirectly shape career development through career awareness, the core SCCT constructs operate as a cohesive framework, reinforcing each other in female students' perceptions and career decision-making processes.

Table 9. Correlations Between Study Variables (Female)

Variable	n	M	SD	CA	GE	RE	SE	OE	CI	IPC
CA	34	1.735	0.864							
GE	34	1.824	1.058	0.179						
RE	34	1.735	1.024	**0.638*** **	0.263					
SE	34	3.625	0.89	0.054	-0.193	0.137				
OE	34	3.713	0.767	0.156	-0.083	0.19	0.792***			
CI	34	2.89	1.017	0.259	0.08	0.16	0.53**	0.609***		
IPC	34	2.551	0.986	0.132	0.096	-0.159	0.398*	0.433*	0.846***	

$^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

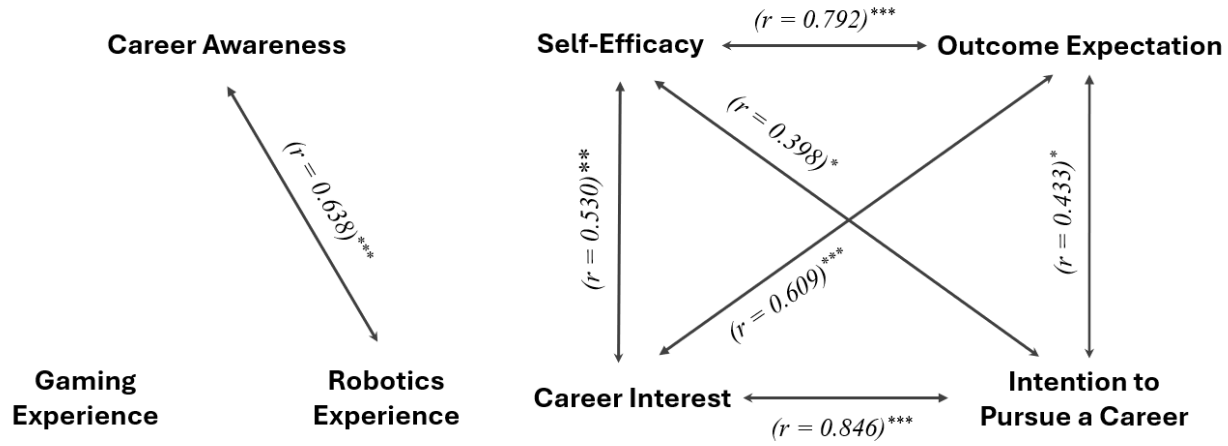

Figure 2. Correlations Between Study Variables (Female). Note: * indicates p < 0.05. ** indicates p < 0.01. * indicates p < 0.001.**

In contrast, male students demonstrated a different set of relationships. Gaming experience exhibited a significant positive correlation with career awareness ($r = 0.201$, $p < 0.05$), suggesting that gaming is more central in raising career awareness among males. However,

career awareness did not significantly correlate with the core SCCT constructs similar to the female group, highlighting its limited direct influence on male students' confidence or motivation to pursue careers in ROV-related fields. Robotics experience, however, showed significant positive correlations with self-efficacy ($r = 0.218$, $p < 0.05$), career interest ($r = 0.281$, $p < 0.01$), and career intention ($r = 0.243$, $p < 0.01$) (Table 10 and Figure 3). These findings suggest that hands-on robotics engagement fosters male students' confidence in their competencies and strengthens their interest and commitment to ROV-related careers. The core SCCT constructs also demonstrated strong interrelationships for male students as well. This highlights the cohesive nature of SCCT in shaping male students' career-related motivations and perceptions.

Table 10. Correlations for Study Variables (Male)

Variable	n	M	SD	CA	GE	RE	SE	OE	CI	IPC
CA	113	2.221	1.058							
GE	113	2.54	1.282	**0.201***						
RE	113	2.301	1.288	0.147	0.128					
SE	113	3.717	0.87	0.069	0.118	**0.218***				
OE	113	3.613	0.808	-0.022	-0.042	0.079	0.426***			
CI	113	2.987	1.034	0.072	0.054	**0.281****	0.416***	0.48***		
IPC	113	2.677	0.961	0.174	0.009	**0.243****	0.371***	0.37***	0.799***	

$^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

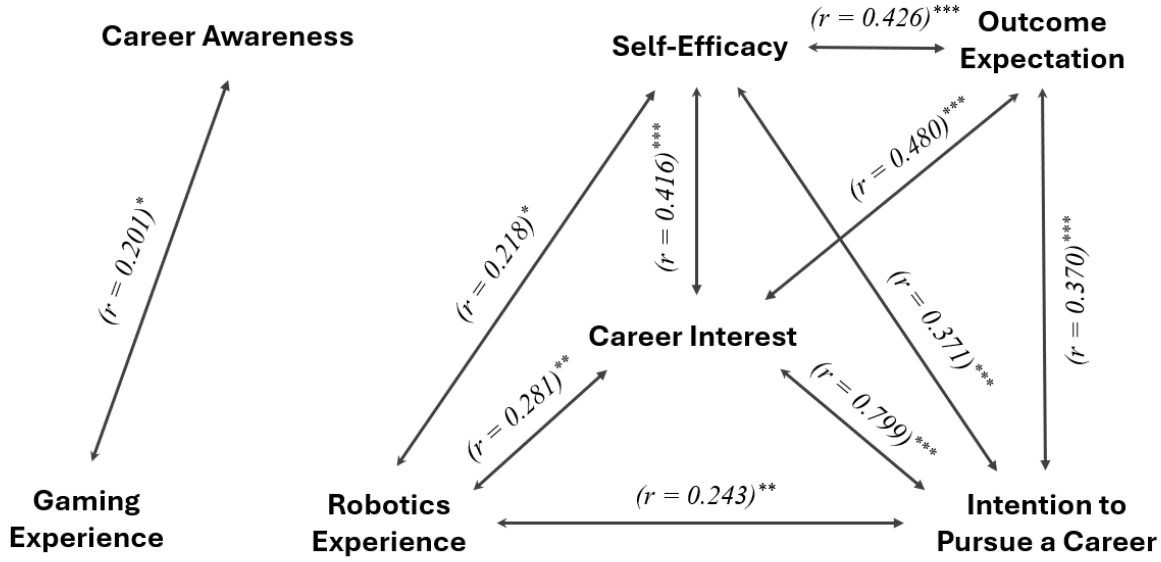

Figure 3. Correlations Between Study Variables (Male). Note: * indicates p < 0.05. ** indicates p < 0.01. * indicates p < 0.001.**

Discussion

This study employed a cross-sectional survey design to explore how personal factors, including gender, ethnicity, and academic major, along with contextual characteristics such as career awareness and prior experiences in gaming and robotics, influence core constructs of SCCT within the context of ROV-related careers. The findings validate the application of SCCT in understanding career development processes within this emerging field, reinforcing its theoretical robustness in explaining how personal and contextual factors shape career trajectories. Additionally, the results provide valuable insights into the interplay of these factors, underscoring the need for targeted interventions to foster equitable engagement in ROV-related career pathways.

RQ1. Demographic Differences in Career Awareness, Gaming Experience, and Robotics Experience

First, the findings revealed significant demographic differences in career awareness, gaming experience, and robotics experience. Specifically, ethnicity-related differences were observed in career awareness, with Asian students reporting the highest levels and students identifying as multiple ethnicities exhibiting the lowest. However, gaming and robotics experience did not significantly vary across ethnic groups. This suggests that factors other than ethnicity influence access to these activities more strongly. Regarding academic disciplines, computer science and engineering students reported significantly higher gaming experience than other majors. In contrast, career awareness and robotics experience appeared less connected to students' majors. This finding shows that career awareness and robotics experience may not be directly shaped by students' academic disciplines but could instead be influenced by broader factors, such as extracurricular activities or personal interests.

Notably, gender-based disparities were pronounced across all three contextual factors, with female students reporting significantly lower levels than their male counterparts. Particularly, female students reported lower engagement in robotics, aligning with previous studies documenting their reduced confidence and interest in robotics compared to male students [10]. Similarly, Rajpal et al. [16] reported that female students experience disproportionately negative outcomes in robotics participation and are underrepresented in robotics-related activities, comprising only 31% of participants in their study. The persistence of such disparities across educational levels underscores systemic challenges in fostering equitable engagement in robotics among female students. These findings emphasize the ongoing need to address barriers to participation and improve the inclusivity of robotics-related activities.

Addressing these challenges, practical strategies identified in a systematic literature review conducted by Pederson and Weigelin on educational robotics [17] can guide the development of gender-specific experiences. For example, integrating technologies such as humanoid or animal-like robots and embedding social contexts that emphasize helping humans or animals have been shown to resonate with female students, enhancing their interest and engagement. Additionally,

fostering collaborative learning environments instead of competitive ones and incorporating relatable mentors or role models into robotics programs have demonstrated positive effects on female students' confidence, interest, and self-efficacy. Implementing such targeted approaches is expected to help mitigate gender disparities, creating more equitable opportunities for all students in STEM fields.

RQ2. Gender-Based Comparisons of SCCT Constructs

Despite differences in contextual factors, the study revealed comparable levels of core SCCT constructs across genders, including self-efficacy, outcome expectations, career interest, and career intention. This finding contrasts prior research indicating significant gender disparities in such constructs [18], [19], suggesting a promising shift. In this study, female students, often underrepresented in STEM [20], exhibited similar career perceptions as their male counterparts, highlighting their potential to contribute to ROV operations. This finding highlights the need to foster equitable access and participation, as such efforts can empower educational and workforce development initiatives to support female students effectively. By doing so, these initiatives can strengthen and diversify the talent pool for ROV-related careers, equitably addressing the growing workforce demands in this field.

RQ3. Gender-Specific Patterns in the Influence of Prior Experiences on Career Development

The study's findings further showed gender-specific patterns in the correlations between prior experiences and core SCCT constructs. Particularly, robotics experience emerged as a significant factor for both male and female students, though its impact varied by gender. Among male students, robotics experience demonstrated broader associations, significantly correlating with self-efficacy, career interest, and career intention. This suggests that hands-on robotics activities are integrated in building male students' confidence and engagement in ROV-related career pathways. These findings align with prior research linking robotics participation to positive perceptions of STEM fields, including improved attitudes, heightened interest, and increased self-efficacy [10]–[12], supporting the value of robotics as a key avenue for fostering confidence and engagement in STEM-related career pathways.

In contrast, the lack of significant correlations between robotics experience and core SCCT constructs among female students is a critical finding that requires further examination. Among female students, robotics experience strongly correlated with career awareness, suggesting its importance in increasing awareness of ROV-related careers. However, it did not demonstrate significant relationships with core SCCT constructs such as self-efficacy or career interest. The absence of similar effects for female students suggests that additional factors may mediate the connection between robotics experience and core SCCT constructs for female students, pointing to distinct pathways in how career-related constructs are shaped by gender, even when the overall SCCT construct levels remain comparable.

Building on this perspective, prior research provides insights into these dynamics, suggesting that negative experiences with robotics among female students [6] or the indirect influence of past performance on self-efficacy beliefs and outcome expectations [3] may undermine the benefits of robotics participation among female students. These challenges might hinder the development of confidence and engagement, potentially limiting the positive effects typically associated with robotics exposure. Such findings underscore the need for further investigation into potential factors influencing the career development of female students in STEM fields, particularly in relation to robotics activities.

To address these disparities, gender-specific strategies are considered to be essential for fostering engagement in ROV-related careers. For female students, increasing access to robotics activities through inclusive and supportive initiatives may enhance career awareness, providing a foundation for further engagement [17]. However, improving access alone may not be sufficient. Interventions must also address the quality of robotics experiences to mitigate potential negative effects and foster positive perceptions of STEM careers. By contrast, for male students, hands-on robotics activities directly strengthen their confidence, interest, and career intentions, suggesting that experiential robotics learning may play a more straightforward role in their career development.

Lastly, gaming experience also exhibited gender-specific patterns. Among male students, gaming experience was significantly correlated with career awareness, indicating it may be an entry point for introducing students to ROV-related careers. However, it did not show meaningful relationships with core SCCT constructs for both genders. This demonstrates that while gaming activities may raise awareness of ROV-related careers, they are insufficient for shaping core SCCT constructs. To address this limitation, supplementing gaming activities with additional experiential opportunities, such as robotics or project-based learning, is suggested to provide a more comprehensive foundation for career development.

Although this study identified gender-specific differences in the influence of robotics and gaming experiences, it failed to uncover factors influencing the core SCCT constructs among female students. Future studies should investigate additional variables, such as the quality of prior experiences [10] or cultural influences [21], that may influence the development of female students' self-efficacy, outcome expectations, career interest, and career intention. Understanding these factors is crucial for designing targeted interventions that not only address gender disparities but also enhance female students' engagement with ROV-related careers. Such efforts could offer actionable insights to create more inclusive and supportive pathways that empower female students to realize their full potential in STEM and ROV-related fields.

Conclusion

This study highlights the complex interplay of demographics, prior experiences, and core SCCT constructs in shaping career development related to ROV operations, an emerging engineering-related career. By examining first-year engineering students, the findings underscore significant gender differences in how robotics and gaming experiences influence career awareness, self-efficacy, and career interest. For female students, robotics experience was strongly associated with career awareness, suggesting its potential to raise awareness of ROV-related career opportunities. However, it showed limited impact on core SCCT constructs of self-efficacy and career interest, indicating the need for further research to identify mediating factors that can bridge this gap. In contrast, for male students, robotics experience demonstrated broader associations, significantly correlating with self-efficacy, career interest, and career intention, underscoring the straightforward benefits of hands-on engagement. Gaming experience, while contributing to career awareness for male students, had limited influence on core SCCT constructs across both genders.

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References

[1] H.-Y. Chiu *et al.*, "Development of a social cognitive career theory scale for measuring the intention to select surgery as a career.," *Heliyon*, vol. 9, no. 11, p. e21685, Nov. 2023, doi: 10.1016/j.heliyon.2023.e21685.

[2] R. W. Lent, S. D. Brown, and G. Hackett, "Social Cognitive Career Theory," in *Career Choice and Development*, Wiley, 2002, pp. 255–311.

[3] S. D. Brown and R. W. Lent, "Social cognitive career theory.," in *Career psychology: Models, concepts, and counseling for meaningful employment.*, W. B. Walsh, L. Y. Flores, P. J. Hartung, and F. T. L. Leong, Eds. Washington: American Psychological Association, 2023, pp. 37–57.

[4] C. Seron, S. S. Silbey, E. Cech, and B. Rubineau, "Persistence Is Cultural: Professional Socialization and the Reproduction of Sex Segregation," *Work Occup.*, vol. 43, no. 2, pp. 178–214, May 2016, doi: 10.1177/0730888415618728.

[5] M. M. Fifolt and G. Abbott, "Differential experiences of women and minority engineering students in a cooperative education program," *J. Women Minor. Sci. Eng.*, vol. 14, no. 3, pp. 253–267, 2008, doi: 10.1615/JWomenMinorScienEng.v14.i3.20.

[6] L. J. Sax, M. Allison Kanny, J. A. Jacobs, H. Whang, D. S. Weintraub, and A. Hroch, "Understanding the changing dynamics of the gender gap in undergraduate engineering majors: 1971–2011," *Res. High. Educ.*, vol. 57, no. 5, pp. 570–600, Aug. 2016, doi: 10.1007/s11162-015-9396-5.

[7] C. Sapp, "Enhanced ROV performance using AR/VR huds," presented at the Offshore Technology Conference, Apr. 2023, doi: 10.4043/32554-MS.

[8] D. W. Vinson, A. Kass, L. Takayama, and K. Weatherwax, "Humans, Robots, Teaming, and the Future of Work," Accenture Labs, 2020. Accessed: Jul. 20, 2023. [Online]. Available: https://davevinson.com/pubs/Vinson_Kass_etal_collaborating-with-robots_20.pdf.

[9] E. A. Giammarco, T. J. Schneider, J. J. Carswell, and W. S. Knipe, "Video game preferences and their relation to career interests," *Pers. Individ. Dif.*, vol. 73, pp. 98–104, Jan. 2015, doi: 10.1016/j.paid.2014.09.036.

[10] S. Kucuk and B. Sisman, "Students' attitudes towards robotics and STEM: Differences based on gender and robotics experience," *International Journal of Child-Computer Interaction*, vol. 23–24, p. 100167, Jun. 2020, doi: 10.1016/j.ijcci.2020.100167.

[11] G. Nugent, B. Barker, N. Grandgenett, and V. I. Adamchuk, "Impact of robotics and geospatial technology interventions on youth STEM learning and attitudes," *Journal of Research on Technology in Education*, vol. 42, no. 4, pp. 391–408, Jun. 2010, doi: 10.1080/15391523.2010.10782557.

[12] Y. Chen and C.-C. Chang, "The Impact of an Integrated Robotics STEM Course with a Sailboat Topic on High School Students' Perceptions of Integrative STEM, Interest, and Career Orientation," *EURASIA J. Math, Sci & Tech Ed*, vol. 14, no. 12, Aug. 2018, doi: 10.29333/ejmste/94314.

[13] A. Moran, "A different approach to recruiting girls in engineering," *JOM*, vol. 60, no. 1, pp. 80–80, Jan. 2008, doi: 10.1007/s11837-008-0011-5.

[14] S. M. Lord, R. A. Layton, and M. W. Ohland, "Trajectories of electrical engineering and computer engineering students by race and gender," *IEEE Trans. Educ.*, vol. 54, no. 4, pp. 610–618, Nov. 2011, doi: 10.1109/TE.2010.2100398.

[15] F. Faul, E. Erdfelder, A. Buchner, and A.-G. Lang, "Statistical power analyses using G*Power 3.1: Tests for correlation and regression analyses," *Behav. Res. Methods*, vol. 41, no. 4, pp. 1149–1160, Nov. 2009, doi: 10.3758/BRM.41.4.1149.

[16] R. Rajpal, K. Sample, and E. Torraca, "Analyzing gender differences in the FIRST® robotics challenge by FIRST® robotics," *J. Stud. Res.*, vol. 11, no. 3, Aug. 2022, doi: 10.47611/jsrhs.v11i3.3186.

[17] B. Pedersen and B. C. Weigelin, "Using educational robotics to foster girls' interest in STEM: A systematic review," 2021.

[18] S. N. C. Rundgren, Y. Sun, and A. Jidesjö, “Examining Gender Differences in Students’ Entrance into and Persistence in STEM Programs in Swedish Higher Education.,” *European Journal of Educational …*, 2019.

[19] E. T. Iskander, P. A. Gore, C. Furse, and A. Bergerson, “Gender Differences in Expressed Interests in Engineering-Related Fields ACT 30-Year Data Analysis Identified Trends and Suggested Avenues to Reverse Trends,” *J. Career Assess.*, vol. 21, no. 4, pp. 599–613, Nov. 2013, doi: 10.1177/1069072712475290.

[20] B. J. Casad *et al.*, “Gender inequality in academia: Problems and solutions for women faculty in STEM.,” *J. Neurosci. Res.*, vol. 99, no. 1, pp. 13–23, Jan. 2021, doi: 10.1002/jnr.24631.

[21] M. El-Hout, A. Garr-Schultz, and S. Cheryan, “Beyond biology: The importance of cultural factors in explaining gender disparities in STEM preferences,” *Eur. J. Pers.*, vol. 35, no. 1, pp. 45–50, Jan. 2021, doi: 10.1177/0890207020980934.