AN EXAMINATION OF PSYCHOSOCIAL ACADEMIC CHALLENGES FOR ENGINEERING AND DESIGN POST-SECONDARY STUDENTS DURING COVID-19

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ABSTRACT

The COVID-19 pandemic has forced post-secondary students to hastily transition to online learning environments. Engineering students report the highest subclinical symptoms for depression, anxiety, and stress during online learning compared to their peers from other faculties. Moreover, female engineering students report facing more severe academic challenges compared to their male counterparts. Numerous studies have examined the subsets of variables considered in the current study. However, few have examined them among engineering students in the context of forced online learning as a result of the pandemic. As such, the current exploratory study examined nine psychosocial variables that have been empirically linked to academic achievement and perceived stress. Participants were 624 engineering and design students from Carleton University who completed surveys asking them to rate statements relating to their engineering programs and online learning experiences. The findings revealed that females reported significantly lower coping efficacy and held less stereotypical views of female engineers compared to their male counterparts. Further, when managing heavy course loads, males perceived themselves to have better coping abilities than females. Implications for different demographic groups and potential interventions are discussed.

Keywords: engineering students; COVID-19; academic achievement; STEM.

UN EXAMEN DES FACTEURS PSYCHOCIAUX DU SUCCÈS CHEZ LES ÉTUDIANTS POST-SECONDAIRES EN INGÉNIERIE ET EN CONCEPTION PENDANT LE COVID-19

RÉSUMÉ

La pandémie COVID-19 a forcé les étudiants de niveau postsecondaire à passer à la hâte d'un environnement d'apprentissage en classe à un environnement d'apprentissage en ligne. Les étudiants en génie présentent les symptômes subcliniques les plus élevés de dépression, d'anxiété et de stress lors de l'apprentissage en ligne par rapport à leurs pairs d'autres facultés. De plus, les étudiantes en génie déclarent être confrontées à des défis académiques plus graves que leurs homologues masculins. De nombreuses études ont examiné la variable dans la présente étude. Cependant, peu d'études les ont examinées chez les étudiants en génie dans le contexte de l'apprentissage forcé en ligne à la suite de la pandémie. À ce titre, la présente étude exploratoire examine neuf variables psychosociales qui ont été empiriquement liées au rendement scolaire et au stress perçu. Les participants, 624 étudiants en génie et en design de l'Université Carleton, ont répondu à des sondages leur demandant d'évaluer les énoncés relatifs à leurs programmes d'ingénierie et à leurs expériences d'apprentissage en ligne. Les résultats révèlent que les femmes ont signalé une efficacité d'adaptation significativement plus faible et ont des visions moins stéréotypées des femmes ingénieures que des hommes. En outre, lorsqu'ils gérent de lourdes charges de cours, les hommes se percoivent comme ayant de meilleures capacités d'adaptation que les femmes. Les implications sur les différents groupes démographiques et les programmes susceptibles de bénéficier des interventions sont discutées.

Mots-clés : étudiants ingénieurs ; COVID-19 ; réussite scolaire ; STEM.

1. INTRODUCTION

The emergence of Coronavirus Disease (COVID-19) in 2019 has caused debilitating consequences for educational institutions worldwide. By June of 2020, a total of approximately 6.6 million students were impacted by sudden, forced school closures in Canada [1]. Of these, 1.6 million were post-secondary students attending Canadian universities or colleges. In response to the growing concerns of the spread of COVID-19, the Canadian government has implemented strategies to mitigate the risk of transmission, including physical distancing measures and restrictions on group gatherings [2]. In addition, universities and colleges have shifted to an online learning delivery system in lieu of face-to-face learning; extracurriculars and on-campus activities were terminated; students involved in hands-on and experiential learning faced additional restrictions and, in some cases, were forced to give up those learning components. Further, a new set of challenges have emerged during the unexpected and forced transition to remote learning.

A few notable challenges for students include unreliable or inaccessible internet connection, technological and digital incompetence, decreased interactivity, lack of financial and economic resources, and heavy workloads [3]. Inspite of such new challenges that have emerged on the forefront, students are constantly expected to do well in their studies [4]. Such difficulties have created ambiguous and uncertain situations for students as they worry about when and how these circumstances will progress [4].

These challenges have undoubtedly translated into psychosocial difficulties for many students from a wide range of programs. However, engineering and design students have been particularly impacted. One study found that engineering and design students reported the highest subclinical symptoms for depression, anxiety, and stress during online learning when compared to their peers from the social sciences, health sciences, and arts and humanities faculties [5]. More specifically, compared to their male counterparts, female engineering and design students have reported unique negative circumstances relating to their academic life that have put them at a disadvantage. For instance, Mozahem et al. (2019) [6] interviewed female engineering students, and found that they reported low familial and societal support for their choices to pursue STEM (science, technology, engineering, and mathematics) studies. Additionally, STEM programs tend to be male dominated, with female students viewed in negatively stereotypical ways [7]. Hence, the current study examined nine psychosocial variables that are associated with student achievement, and the extent to which male and female engineering students experience them during the pandemic. To our knowledge, this research is the first to examine these variables in the context of the pandemic, and specifically among engineering students.

2. PSYCHOLOGICAL AND SOCIAL FACTORS AND ACADEMIC OUTCOMES

Student success is multifaceted. Research has outlined various factors that are associated with academic outcomes such as interest in program, gender stereotypes, social support, and sense of belonging can impact student motivation, performance, and persistence in their studies. Since students' academic experiences and learning environments shifted as a result of the pandemic, students may be experiencing new types, or varying levels, of existing barriers compared to their learning environments prior to the pandemic. Encouragingly, existing research outlined at least nine variables which can impact student achievement. Students' interest in their programs is examined as the first variable.

2.1. Interest in Program

Garris and Fleck (2020) [8] examined students' experiences during the transition to online learning as a result of the pandemic and found that students were not as interested in their courses. Students who are not interested in their courses may experience negative emotional states and lower achievement. For instance, Pekrun et al. (2014) [9] concluded that a lack of interest can trigger feelings of boredom, which was associated with lower performance and further boredom. Boredom has been negatively associated with task effort, intrinsic motivation, and attention [10]. As such, students who lack interest in their programs or courses may have lower motivation and persistence in their studies. On the other hand, it was found in [11] that students who were interested in the subject at hand were more satisfied with their online courses. As such, an examination of students' interest in their programs is relevant in understanding student retention [12]. More importantly, it is crucial to examine this variable in light of the changing learning environments during COVID-19.

2.2. Online Learning Experiences

Remote learning has been an option for students for a long time. However, since the pandemic, students have engaged in online learning as a compulsory platform. In March 2020, mid-semester, during forced COVID-19 restructuring, students were asked in [8] to report on their online transition experiences. Overall, students reported decreased quality of learning. Moreover, across genders and courses, students expressed that their courses were not as interesting, that they felt less motivated to put in effort, and that it had become harder to pay attention since the transition. Additionally, even though they felt that their courses were more flexible, students reported a decrease in perceived learning value. In another study, engineering students reported especially low satisfaction with the quality and quantity of student-instructor online communication [13]. Notably, students had little choice in the transition and were forced into remote learning environments, which they generally experienced as being negative. Students who are forced into learning environments that do not suit their preferences, such as online learning during the pandemic, are likely to adopt negative attitudes towards their courses [14]. Nonetheless, integrating aspects of the classroom environment such as active learning (e.g., group work, peer collaboration) in online contexts is associated with improved learning outcomes, better class engagement, and higher perceived self-efficacy [15, 16], which are all important factors in student achievement.

2.3. Perceived Self-Efficacy

In 1977, Psychologist Albert Bandura defined *self-efficacy* as one's beliefs in his or her own abilities to achieve. Moreover, self-efficacy has been found to predict coping, effort, and persistence on tasks [17]. Numerous studies examined self-efficacy as it related to performance, whereby higher self-efficacy beliefs predicted better academic outcomes [14, 18–20]. Notably, gender differences in self-efficacy among engineering students have been a focus in research. Concannon & Barrow [21] found that female engineering students reported lower self-efficacy in certain domains, such as coping and career outcomes efficacy (i.e., expectations as to what they hope to achieve in an engineering career), compared to their male counterparts. During active learning, students may face new challenges that can affect their self-efficacy. For instance, Yokoyama (2019) reviewed six studies that have investigated self-efficacy during remote learning and found positive associations between self-efficacy and academic performance on average [22]. However, the researcher described that online learning environments are characterized by unique aspects, such as unfamiliarity with online learning, which may lead to lower self-efficacy and academic achievement. Although the research on the association between self-efficacy and student achievement during in-person learning is consistent, an investigation of self-efficacy during new online learning circumstances is strongly warranted.

2.4. Perceived Academic Coping Efficacy

Coping efficacy is a domain of self-efficacy that can be tailored to a range of life aspects. The concept refers to one's beliefs that they can apply strategies to alleviate or manage stressors [23]. In academics, a relevant example is managing a difficult assignment using problem-solving strategies. Devonport and Lane [24] argued that students who improved their coping abilities were likely to increase their coping efficacy, which will further increase their outcome efficacy (i.e., belief that a course of action will lead to specific outcome). Notably, females in engineering majors report lower beliefs about their abilities to cope with their academic challenges [21, 25]. In the face of new challenges, students may doubt their abilities to cope. As such, coping self-efficacy is examined in the current study as a potential barrier to success for engineering students. Additionally, the gender differences among males and females were examined. Of note, students who perceived stress to have impacted their lives reported lower coping efficacy [26].

2.5. Perceived Academic Stress

Post-secondary students have reported stress as the most common barrier to their academic achievement [26]. For engineering students, discrimination, stereotypes, heavy course loads, high performance expectations, and time pressures have been described as sources of stress [27]. Further, in [28] it was found that engineering students perceived that the psychological costs (e.g., program demands, not being able to engage in other activities) of their studies increased within the first two years of post-secondary education. The researchers postulated that students who experienced such stressors may reconsider their possibility for success and program value, which can impact their motivation to persist. Notably, female students in STEM fields have reported higher stress compared to males [26] which has been linked to differences in their academic experiences. For instance, it was found that women in stereotypical STEM environments reported higher emotional exhaustion and academic detachment compared to those in less hostile environments [29]. Additionally, female engineering students reported higher stress levels and burnout (a response to chronic stress, characterized by physical, emotional, and mental symptoms like fatigue, hopelessness, and irritability) [30]. Further, female students were deemed at higher risk for depression, anxiety, and stress compared to their male engineering peers [31]. Combined with the existing academic stressors, the pandemic has introduced new sources of stress for students. For instance, students are relying on email communication during remote learning. A high number of emails has been associated with email stress, regardless of how individuals manage these emails [32]. New sources of stress and changing environments can impede student learning as it becomes harder to manage the demands of their engineering studies. Thus, stress as experienced between male and female students is a significant factor to consider in student achievement during the pandemic. For female engineering students, negative stereotypes held by male peers is a unique source of stress.

2.6. Gender Stereotypes

Engineering programs tend to be male dominated [33]. As a result, female students make up a minority of the student population. Numerous studies found that female engineering students expressed anxiety and psychological threat because of the negative stereotypes held by male peers about their engineering performance and abilities [33–35]. First coined by psychologists Steele & Aronson in 1995 [36], *stereotype threat* refers to the perceived threat that a negative stereotype (e.g., gendered stereotype of math abilities) may threaten the treatment or group identity of an individual in a relevant environment (e.g., females in an engineering program). In another study, university mission statements were analyzed and it was concluded that successful engineering students were illustrated as holding masculine traits, like dominance, rather than feminine traits [37]. They suggested that engineering programs have established "a culture of masculinity", which can deter female students from applying to these programs. When female students pursued STEM studies, reoccurring, and long-term stereotype threat led them to disidentify with their domains [38]. With the shift to remote learning environments, female students may be less directly exposed to the classroom culture and potential stereotypical attitudes. Thus, they may perceive, experience, and be impacted by negative stereotypes differently compared to before the pandemic. Whether students are learning in class or online, negative stereotypes can create unwelcoming environments making students feel like they do not belong to their programs.

2.7. Sense of Belonging

Goodenow & Grady [39] (1993) first defined *sense of belonging* as feeling "personally accepted, respected, included, and supported by others" in one's environment. Sense of belonging is positively associated with action-based coping strategies, life satisfaction [40], task persistence [41], and mental health [41, 42]. Additionally, belonging to a school environment is significantly linked to students' expectations of success, motivation, and reported effort [39]. Although a sense of belonging is important for both males and females, research supports that men in STEM fields feel like they belong more to their academic environments compared to female students [43]. Notably, negative stereotypes of females in math domains can lead to a diminished sense of belonging for females [44], which is predictive of their desire to persist in their mathematical studies [43]. Based on their literature review, Cheryan et al. (2015) [45] suggested that diversifying engineering program environments to represent student diversity and shift the engineering culture may increase females' sense of belonging. The learning environments for students have inevitably shifted during the pandemic, with less in-class and physical contact between students and faculty members since the transition. Such changes can hinder student performance. For instance, it has recently been found that individuals who received cues of social connectedness, even from unfamiliar people, reported higher performance motivation and persistence [46]. Thus, an examination of the extent to which students feel like that belong to their online learning environments is important in understanding student performance. Notably, instructor support is positively associated with students' sense of belonging [47].

2.8. Perceived Faculty Support

It is imperative to distinguish between objective and subjective measures of social support, which measure the actual received social support and one's own perceptions of how much social support they have, respectively. In this study, we focus on students' perceived social support from faculty members and instructors. Generally, perceiving support from instructors is linked to academic engagement [48], motivation, resilience [49], and better grades [50, 51]. However, the shift to online learning environments has negatively impacted students' perceptions of instructor support. In one study, researchers asked students to write reflective essays on their online learning experiences during the pandemic [52]. They found that a lack of instructor support was a reoccurring theme in students' reflections. In another study, students in out-of-class learning settings reported receiving less feedback and less teacher support in general [53]. Importantly, students also felt that they had better relationships with their teachers during in-class learning prior to the pandemic. Notably, student perceptions of faculty support seem to be understudied during the pandemic. Few published articles examine this variable in the context of COVID-19, and no studies were done on engineering student samples. Thus, it is included in the current study and examined across male and female engineering students. Of note, while teachers can be one source of student support, family and friends are another.

2.9. Perceived Social Support

A 2013 study found that students pursuing STEM studies who perceived higher social support from friends, instructors, and families reported higher perceived self-efficacy in math and science [54]. Additionally, higher perceived social support is negatively correlated with perceived stress [55]. However, a gender gap exists between males' and females' perceptions of social support as it relates to their STEM fields. In one study, men perceived increasing social support during their first academic semester of pursing a STEM field compared to no significant increases for women [25]. In a more recent study, female engineering students reported low familial and societal support for pursing STEM studies [6]. In the context of the pandemic, perceived social support can predict better online learning engagement [56]. Further, perceived social support is predictive of belonging, motivation, and a sense of security for women in non-traditional fields [57]. Nonetheless, with students not being able to learn in-class with their peers and faculty members, student perceptions of social support may have changed.

3. THE CURRENT STUDY

The purpose of the current exploratory study was to examine students' experiences on nine variables during online learning, as a result of COVID-19. To our knowledge, there is extensive research on each of the psychosocial factors examined in this study, but no published research that explores them during the pandemic and split across biological sex lines among engineering and design post-secondary students. Considering the novelty of the pandemic and the limited published research on its implications for students' academic success, the current research is strongly warranted. The primary goal was to gain insights into the subjective experiences and differences among male and female undergraduate engineering and design students during novel, but forced, online learning environments. Further, our results provide preliminary evidence for future hypothesis testing and experimental research.

3.1. Methodology: Sample

To be eligible to participate, participants must have been enrolled in an engineering or design program at Carleton University, an undergraduate student, and registered in at least one online course at the time of the study. At the end of the fall 2020 semester, a total of n = 624 Faculty of Engineering and Design (FED) students were recruited. n =130 (21%) participants were removed from the dataset due to some form of participant non-compliance, such as: completing less than 70% of the questionnaire (n = 101); spending less than 2 minutes completing the questionnaire (n = 21); not making their biological sex clear to the researchers (n = 5); failing to correctly respond to both attention check questions (n = 3). Although this number seems like a high attrition rate for a short survey, it is not particularly high considering participation was not compensated. Participants were eliminated on a more liberal basis due to the fact that Exploratory Factor Analysis (EFA) required the missing data be inputted using the series mean (i.e., the average of the rest of the responses on that item). All subsequent analyses were conducted on the remaining n = 494 participants (i.e., 79.17% of the initial data set). Participants were 292 males and 202 females with mean values of $M_{\text{age}} = 20.16$ years, $SD_{\text{age}} = 2.376$, $n = 494$ (see Appendix A, Table 1). Participants analyzed were in their first (32%), second (26%), third (22%), or fourth (19%) year of their undergraduate degree $M = 2.28$, $SD = 1.109$, $n = 488$ (see Appendix A, Fig. 1). Students were enrolled in at least 22 different engineering and design programs (see Appendix A, Table 2). Participants were registered in two to seven online courses $M = 5.77$, $SD = 1.109$, $n = 494$ (see Appendix A, Fig. 2). Participants were Caucasian (63%), Asian (15%), Middle Eastern (12%), African American (5%), Hispanic (2%), First Nations (0.4%), and other (0.6%). Seven participants did not provide information about their ethnicity (1%) (see Appendix A, Table 3).

3.2. Methodology: Recruitment

Participants were recruited using Facebook, Instagram, and Snapchat social media platforms. In addition, mass emails were sent out by the FED at Carleton University for all students registered as undergraduates in the faculty. FED faculty members were additionally asked to post the study invitation and survey link on their course websites to broadcast the invitation to FED students (see Appendix B for invitation forms).

3.3. Methodology: Measures

We created a survey asking participants to rate items relating to nine variables (*Interest in program, online learning experiences, perceived self-efficacy, perceived academic coping efficacy, perceived academic stress, gender stereotypes, sense of belonging, perceived faculty support, and perceived social support*). Each variable had a couple of statements that asked about aspects of the variables (see Appendix C, Table 1 for complete survey). Participants rated a total of 61 statements on the Likert scale (1 = Strongly Disagree, 7 = Strongly Agree). Each variable had instructions for participants to rate the statements as they related to their programs and online learning experiences.

3.4. Methodology: Procedure

After providing informed consent, participants accessed an online survey through Qualtrics (see Appendix D for consent form). Participants first provided demographic information, including age, program and year of study, biological sex and gender identification, and ethnicity. Since no personal identifiers were collected, the responses remained anonymous. Next, participants read statements and rated each statement on the Likert scale. At the end of the survey, participants were provided with a debriefing form explaining the purpose of the study. Qualtrics software access limits were imposed to disable multiple survey submissions, hence participants were only able to submit one survey. They were not compensated for their participation.

4. RESULTS

All analyses were done using SPSS (Version 27), which is a statistical computing software common amongst Experimental Psychologists. First, EFA was conducted to specify the number of factors (i.e., variables) in the model. Then, composite variables were created in light of these empirically-based factors. Then, two multivariate analyses of covariance (MANVOCA) were conducted to examine the influence of students' program information (i.e., FED Program, Year of Study, and Number of Courses) and self-reported demographics (i.e., Biological Sex and Ethnicity) on the surveyed factors (e.g., Stress Toward Online Learning). These surveyed factors were used to operationally define their experience within their first academic semester during COVID-19 restrictions.

4.1. Results: Data Cleaning

After accounting for attrition, all analyses were conducted on the remaining n = 494 participants (i.e., 79.17% of the initial data set). Next, the Likert scale questions were checked for participant string responding and none was found. Finally, 63 missing values were replaced, which comprised 0.22 percent of the data set (excluding the two attention check questions). To run an EFA leading to meaningful results each array of data must contain n elements. There are many useful ways to "replace" missing data. In this case the series mean value, the average for all participants on that variable containing missing values, was used.

4.2. Results: Exploratory Factor Analysis (EFA)

EFA was conducted to create empirically-based variables that represented the different facets of this present survey (see Appendix C, Table 1). This dataset was demonstrated to be a good candidate for EFA, as the Kaiser-Meyer-Olkin (KMO) statistic was 0.898, which is considered good. The KMO statistic represents the ratio between bivariate and partial correlations and varies from 0 to 1, whereby a value close to 1 indicates low partial correlations compared to bivariate correlations, demonstrating good candidacy for EFA. Additionally, the communalities ranged from 0.349 to 0.796, with most of the values above 0.600. Thus, EFA was deemed appropriate for this present study.

4.2.1. Results: Number of Factors

The Kaiser-Guttman Rule (i.e., the number of factors retained should be no more than the number whereby factors' eigenvalues are greater than 1) resulted in the maximum number of factors retained to be 13. Then, a Scree Plot demonstrated that retaining between 4 to 12 factors was appropriate. However, the most prominent bend in the plot appears around 9 factors (see Appendix E, Fig. 1). This is in-line with the theoretical notions that assisted in constructing the survey items. Thus, 9 factors were retained. Cronbach's alpha was used to gauge overall reliability for the factors (see Appendix C, Table 1)

4.2.2. Results: Factor Loadings

Next, a Direct Oblim rotation was conducted, with 9 factors, to determine which items loaded onto which factors. The Factor Correlation Matrix demonstrated that the factors were not correlated. So, a Varimax rotation was used, as it is more interpretable, but only appropriate when the factors are orthogonal. Two items did not load onto any factor, which were SelfEff6 (i.e., "I give up in the face of challenges") and Stress4 (i.e., "in general, I am not stressed during my academic studies"). Therefore, they were no longer included in the model. One item was considered cross-loaded, which was OL1 (i.e., "overall, online learning has been a positive experience for me"), but there were clear theoretical indications as to where it should load.

4.2.3. Results: Composite Variables

Then, marker variables (i.e., variables with the strongest loading) were identified for each of the 9 factors (they are denoted in Appendix C, Table 1). This helped to create names for the composite variables: Perceived Faculty Support, Interest in Program, Connectedness Among Colleagues, Self-Efficacy, Coping Efficacy, Preference for Online Learning, Social Support, Positive Attitude Toward Female Engineers, and Stress Toward Online Learning.

Then, outliers were identified for six of the nine factors. For each variable, a transformation was done to eliminate (or, in some cases, reduce) outliers. Factors 2, 4, 7, and 9 were reflected, log transformed, and reflected back. Afterwards, they were identified as approximately normally distributed. Factor 6 was positively skewed, which meant it did not need to be reflected. A square root transformation was used to gain normality. Finally, no transformations increased the normality for Factor 8. Therefore, it was Windsorized to remove the vast majority of outliers. Fifteen outliers remained for Factor 8.

	Male		Female		
	M	*SD*	*M*	*SD*	*t*-test
Faculty support	3.97	1.38	4.19	1.33	-1.73
(F) Interest in program	1.43	0.19	1.46	0.18	-1.63
Connectedness among colleagues	4.75	0.19	4.82	1.23	-0.55
(F) Self-Efficacy	1.39	0.18	1.37	0.15	1.56
Coping Efficacy	4.60	1.14	4.25	1.07	3.42*
(*t*) Online Learning Preference	1.78	0.31	1.84	0.29	-1.90
(F) Social Support	1.47	0.17	1.49	0.19	-0.99
(T) Positive Att. Toward Female Eng.	6.60	0.50	6.74	0.40	-3.39*
(F) Stress Toward Online Learning	1.43	0.18	1.45	0.18	-1.16

$*p < 0.001$

Table 1. Means, standard deviations, and significance levels for all variables across males and females.

4.3. Results: FED Program Differences

A multivariate analysis of variance (MANOVA) was conducted on all nine factors with FED Program as the independent variable. Significant main effects were found for Perceived Faculty Support, $F(19,473) = 3.24$, $p < 0.001$, where F is the F-ratio associated with an analysis of variance (ANOVA), and p is, in this context, the significance level whereby $p < 0.05$ is considered *significant*; Interest in Program, $F(19,473) = 2.29$, $p = 0.002$; Connectedness Among Colleagues, $F(19,473) = 1.94$, $p = 0.01$; Self-Efficacy, $F(19,473) = 1.89$, $p = 0.01$; Preference for Online Learning, $F(19,473) = 2.52$, $p < 0.001$;

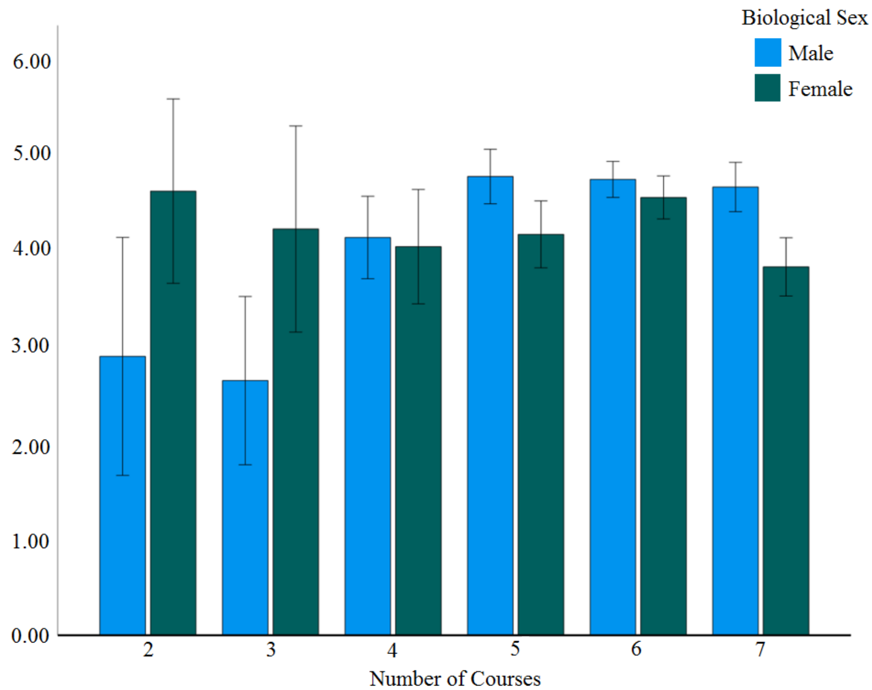

Fig. 1. A bar chart depicting the interaction between biological sex and number of courses for coping efficacy. Error bars represent 2 standard errors from the mean.

Positive Attitude Toward Female Engineers, $F(19,473) = 1.78$, $p = 0.02$; and Stress Toward Online Learning, $F(19,473) = 1.76$, $p = 0.03$ (see Appendix F, Fig.s 2-8 for graphed results).

Next, a multivariate analysis of covariance (MANCOVA) was conducted on all nine factors with Age as a covariate and FED Program and Biological Sex as independent variables. Age did not have an effect on the model. A significant interaction was found for Connectedness Among Colleagues. However, this was likely due to high variability in the data. A significant interaction was found for Self-Efficacy, F(18, 454) = 0.45, $p = 0.03$ (see Appendix E, Fig. 9). Two main effects for Biological Sex reached significance; that is, for Coping Efficacy, $F(18,454) = 16.82$, $p < 0.001$ and Positive Attitude Toward Female Engineers, $F(18,454) = 9.33$, $p = 0.002$.

For Coping Efficacy, the difference between males ($M = 4.60$, $SD = 1.14$) and females ($M = 4.25$, $SD = 1.07$) was significant, $t(492) = 3.42$, $p = 0.001$. For Positive Attitude Toward Female Engineers, the difference between males ($M = 6.60$, $SD = 0.50$) and females ($M = 6.74$, $SD = 0.40$) was significant, $t(483.97) = 3.39$, $p = 0.001$ (see Table 1 for all variables).

4.4. Results: Demographics that Influence Students' Academic Experiences

Another MANCOVA was conducted on all nine factors with Age as the covariate and the following independent variables: Biological Sex, Ethnicity, Number of Courses, and Study Year. Age did not have an impact on the model. The four-way interaction for Self-Efficacy was found to be significant, $F(4,364) = 0.32$, $p = 0.02$. A significant interaction between Biological Sex and Number of Courses was found to be significant for Coping Efficacy, $F(5,446) = 16.82$, $p = 0.01$. The results demonstrated that when course load increases, males have a tendency to perceive better coping efficacy compared to females (see Fig. 1). However, results of the significant interaction between Biological Sex and Number of Courses on Preference

Toward Online Learning demonstrating that females tend to prefer online learning more so than males (see Appendix E, Fig. 10). However, once course-load becomes too heavy, this difference is non-existent.

An interaction was also found for Study Year and Biological Sex for Connectedness Among Colleagues, $F(3,446) = 29.52$, $p < 0.001$. That is, first-year females felt more connected to their colleagues compared to their male counterparts. However, for upper-year students, the trend was that males felt more connected (Appendix E, Fig. 11).

Unsurprisingly, there was a significant main effect for Number of Courses on Stress Toward Online Learning, $F(5,446) = 0.49$, $p = 0.01$. It seems as though, as course-load increases, so does Stress Toward Online Learning. Interestingly the difference between 4 through 7 courses is non-significant. In terms of Perceived Faculty Support, two significant main effects were found. The first was for Ethnicity, $F(7,446) = 61.85$, $p < 0.001$. Students with Middle Eastern and First Nations origins perceived less support from Faculty compared to other ethnicities (see Appendix E, Fig 12). The second was for Study Year, $F(3,446) = 17.03$, $p = 0.01$. That is, first- and fourth-year students perceived to have more support than their second- and third-year peers (see Appendix E, Fig. 13).

5. DISCUSSION

The current study examined nine psychosocial variables that have been empirically associated with student achievement. The purpose of the study was to better understand the academic experiences of engineering students during online learning. The results demonstrated that females and males rated their abilities and academic experience during online learning differently. More specially, our major findings is that females perceived themselves to have lower coping efficacy than males. Further, males endorsed less positive attitudes towards female engineering students compared to females. Additionally, demographic variables such as year of study and number of courses showed significant relationships with certain variables.

The significant findings of biological sex differences in coping efficacy have been supported in previous studies [21,25], where female engineering students also reported lower perceptions of their coping abilities compared to males' reports. One mechanism that may explain this finding relates to women's awareness of the negative stereotypes in engineering domains. Cadaret et al. [58] found that females' awareness of the stigma they face in male-dominated engineering fields was associated with lower self-efficacy, with coping efficacy moderating this relationship [58]. Further, Concannon & Barrow [21] suggested that women recognized the gendered discrimination in the field and were more negatively affected by failure than their male peers, which may be related to females' lower coping efficacy perceptions [21].

Our finding that female students endorsed more positive attitudes towards females in engineering fields support these arguments. This finding is consistent with results reported in [59], where it was also found that male engineering students held more negative gender stereotypes of females' math abilities compared to female engineering students. In light of these findings, and the fact that females recognize the existence of such serotypes, female students are likely to experience stereotype threat. That is, females may feel psychologically threatened that such negative attitudes may impact the way they are treated or their group identity in engineering programs [36]. Effects of gender stereotypes has been implicated in a previous study that concluded that gender stereotypes in STEM fields are associated with less favourable academic self-concepts (self-evaluations of one's abilities and confidence in their domain) for females [60].

Despite the significant findings relating to gender stereotypes, this variable presented with the most outliers that had to be removed from data analysis. Most participants had ratings of 4 and 5 (4 = Neutral, 5 = Slightly Agree) and few (other than removed outliers) rated statements relating to gender stereotypes along the extreme dimensions of the scale (1 = Strongly Disagree, 7 = Strongly Agree). This pattern in responding might be a direct function of social desirability bias. This bias occurs when, for instance, respondents consciously reportd untruthful answers to portray themselves in a positive light by denying that negative characteristics are in line with one's self, e.g., disagreeing with "females should not be in engineering and design programs" even when one agrees [61]. Social desirability bias may therefore impact the accuracy of collected data when undetected, and in more extreme cases, the true effects of a variable.

As for perceived stress, perhaps not surprisingly, increases in course loads were associated with increases in perceived stress. However, being registered in more than 4 to 7 courses during the term did not seem to further increase stress. This pattern reveals that students' course loads may not have a cumulative effect on their stress levels, and that there might be a threshold where stress does not continue to increase. More research is needed to understand the type of relationship between these factors.

Furthermore, student's ethnicity in relation to their perceptions of faculty support was significant. The findings reveal that Middle Eastern and First Nations perceived significantly less faculty support than students from other ethnic groups. Notably, previous research demonstrated that student ethnicity has a role in how students perceive and rate certain aspects relating to their engineering programs. For instance, student minorities (specifically Asian males and African American females) rated their skills relating to engineering studies lower than the majority Caucasian students [62]. Importantly, our finding should be interpreted with caution as the sample sizes for Middle Eastern ($n = 60$) and First Nations ($n = 2$) were not sufficient to detect true differences of ethnicity. However, we cannot neglect the role of ethnicity in how students experience variables and the paths in which they influence their academic outcomes.

5.1. Limitations and Future Directions

The current study is not without its limitations. First, this study provides a basis regarding engineering students' academic experiences during the pandemic. Although existing research provides good support for the inclusion of the variables, the present findings should be interpreted cautiously. That is, since this study is exploratory in nature, no causal interpretations can be made between any of the variables and academic success. Nonetheless, our study provides a basis for future researchers to generate hypotheses in experimental study designs.

Additionally, considering the novelty of the pandemic and the unexpected transition from in-person to online learning, researchers are not able to study every aspect of the pandemic and publish many studies. We therefore do not have research that examines similar constructs (and on a similar sample and context) with which to compare our results. We primarily relied on research published prior to the pandemic to compare our findings. Although the older research examined variables under different circumstances (i.e., in-class learning), it can provide insights as to how students' experiences may have changed across time (e.g., did students have higher self-efficacy levels before- compared to during the pandemic?).

Further, there are some methodological considerations to discuss. First, our study relies on subjective measures (i.e., self-report) to examine students' experiences. However, we did not collect data to understand whether the current variables have a true effect on student achievement. For instance, Grade Point Average (GPA) can function as an objective measure to see whether specific experiences are predictive of academic success [34]. Our recommendation is that future researchers employ both subjective and objective measures in examining variables relating to academic achievement.

We also encourage future researchers to expand our current examination of biological sex (male and female) to include individuals of nonbinary identification. Furthermore, researchers can follow-up our findings that students generally reported negative experiences of remote learning by examining the specific aspects of online learning environments that make them undesirable. We recommend that future studies and conceptual replications of the present study are done across time (e.g., academic year) to ensure that the present trends are consistent and not one-time findings. Finally, it happens to be that no mechanical engineering students participated in this study. Researchers may wish to examine between-group differences by comparing various subfields of engineering to detect potential experiences that may be present in one group but not the other.

5.2. Implications

The current study carries various theoretical and practical implications. First, researchers may wish to examine the current variables in a theoretical model that may predict academic success. That is, through a closer examination, building a model that describes relationships between variables, including potential mediators that may illustrate the mechanisms in which variables influence academic success. As for practical implications, the current findings shed light into potential areas where engineering programs and students may benefit from interventions. For instance, in light of the findings that males hold more stereotypical views of females in engineering fields, a potential intervention is educational sessions to raise awareness about such issues. Of course, further research is needed to determine which interventions to apply and when and on whom they work best. Another practical application relates to online learning contexts. Since students tend to prefer in-class learning overall, instructors can work to incorporate elements of in-class learning (e.g., group work) in online learning contexts.

6. CONCLUSIONS

The COVID-19 pandemic has impacted students in various ways, not the least of which is a forced, sudden transition in their learning environments. Both male and female engineering students experience a range of academic challenges, which may impact their success. However, females, being a minority in engineering programs, experience these challenges in different, and at times, more severe ways. The current findings provide evidence of such biological sex differences during remote learning as a result of the pandemic, a context which has not yet been thoroughly examined. These findings carry important implications for future researchers and practical uses for engineering programs, students, and faculty members.

REFERENCES

1. Accessed Jan. 30, 2020.
   URL `https://en.unesco.org/covid19/educationresponse`
2. Accessed Jan. 30, 2020.
   URL `https://www.canada.ca/en/public-health/services/diseases`
3. Adedoyin, O.B. and Soykan, E. "COVID-19 pandemic and online learning: The challenges and opportunities." *Interactive Learning Environments,* doi: 10.1080/10494820.2020.1813180, 2020.
4. Besser, A., Flett, G.L. and Zeigler-Hill, V. "Adaptability to a sudden transition to online learning during the COVID-19 pandemic: Understanding the challenges for students." *Scholarship of Teaching and Learning in Psychology,* Advance online publication, 2020.
5. Odriozola-González, P., Planchuelo-Gómez, Á., Irurtia, M.J. and de Luis-García, R. "Psychological effects of the COVID-19 outbreak and lockdown among students and workers of a Spanish university." *Psychiatry Research,* Online, Vol. 290, No. 8, 2020.
6. Mozahem, N.A., Ghanem, C.M., Hamieh, F.K. and Shoujaa, R.E. "Women in engineering: A qualitative investigation of the contextual support and barriers to their career choice." *Women's Studies International Forum*, Vol. 74, pp. 127–136, 2019.
7. Rincón, B.E. and George-Jackson, C. "Examining department climate for women in engineering: The role of STEM interventions." *Journal of College Student Development*, Vol. 57, No. 6, pp. 742–747, 2016.
8. Garris, C.P. and Fleck, B. "Student evaluations of transitioned-online courses during the COVID-19 pandemic." *Scholarship of Teaching and Learning in Psychology,* Advance online publication, 2020.
9. Pekrun, R., Hall, N.C., Goetz, T. and Perry, R.P. "Boredom and academic achievement: Testing a model of reciprocal causation." *Journal of Educational Psychology*, Vol. 106, No. 3, pp. 696–710, 2014.
10. Pekrun, R., Goetz, T., Daniels, L.M., Stupnisky, R.H. and Perry, R.P. "Boredom in achievement settings: Exploring control–value antecedents and performance outcomes of a neglected emotion." *Journal of Educational Psychology*, Vol. 102, No. 3, pp. 531–549, 2010.
11. Leong, P. "Role of social presence and cognitive absorption in online learning environments." *Distance Education*, Vol. 32, No. 1, pp. 5–28, 2011.

12. Leuwerke, W.C., Robbins, S., Sawyer, R. and Hovland, M. "Predicting engineering major status from mathematics achievement and interest congruence." *Journal of Career Assessment*, Vol. 12, No. 2, pp. 135–149, 2004.
13. Tang, T., Abuhmaid, A.M., Olaimat, M., Oudat, D.M., Aldhaeebi, M. and Bamanger, E. "Efficiency of flipped classroom with online-based teaching under COVID-19." *Interactive Learning Environments,* Online, 2020.
14. Gurung, R.A.R. and Stone, A.M. "You can't always get what you want and it hurts: Learning during the pandemic." *Scholarship of Teaching and Learning in Psychology,* Online, 2020.
15. Bolliger, D.U. and Des Armier Jr., D. "Active learning in the online environment: The integration of student-generated audio files." *Active Learning in Higher Education*, Vol. 14, No. 3, pp. 201–211, 2013.
16. Campbell, L.O., Heller, S. and Pulse, L. "Student-created video: An active learning approach in online environments." *Interactive Learning Environments,* doi: 10.1080/10494820.2020.1711777, 2020.
17. Bandura, A. "Self-efficacy: Toward a unifying theory of behavioral change." *Psychological Review*, Vol. 84, No. 2, pp. 191–215, 1977.
18. Agustiani, H., Cahyad, S. and Musa, M. "Self-efficacy and self-regulated learning as predictors of students academic performance." *The Open Psychology Journal*, Vol. 9, doi: 10.2174/18743501016090100001, 2016.
19. Lane, J., Lane, A.M. and Kyprianou, A. "Self-efficacy, self-esteem and their impact on academic performance." *Social Behavior and Personality*, Vol. 32, No. 3, pp. 247–256, 2004.
20. Salazar, L.R. and Hayward, S.L. "An examination of college students' problem-solving self-efficacy, academic self-efficacy, motivation, test performance, and expected grade in introductory-level economics courses." *Decision Sciences Journal of Innovative Education,* Online, Vol. 16, No. 3, 2018.
21. Concannon, J.P. and Barrow, L.H. "A reanalysis of engineering majors' self-efficacy beliefs." *Journal of Science Education and Technology*, Vol. 21, No. 6, pp. 742–753, 2012.
22. Yokoyama, S. "Academic self-efficacy and academic performance in online learning: A mini review." *Frontiers in Psychology,* Online, Vol. 9, No. 4, 2019.
23. Watson, J.C. and Watson, A.A. "Coping self-efficacy and academic stress among Hispanic first-year college students: The moderating role of emotional intelligence." *Journal of College Counseling*, Vol. 19, No. 3, pp. 218–230, 2016.
24. Devonport, T.J. and Lane, A.M. "Relationships between self-efficacy, coping and student retention." *Social Behavior and Personality*, Vol. 34, No. 2, pp. 127–138, 2006.
25. Hardin, E.E. and Longhurst, M.O. "Understanding the gender gap: Social cognitive changes during an introductory STEM course." *Journal of Counseling Psychology*, Vol. 63, No. 2, pp. 233–239, 2020.
26. Frazier, P., Gabriel, A., Merians, A. and Lust, K. "Understanding stress as an impediment to academic performance." *Journal of American College Health*, Vol. 67, No. 6, pp. 562–570, 2019.
27. Garriott, P.O., Navarro, R.L., Flores, L.Y., Lee, H., Carrero-Pinedo, A., Slivensky, D. and Lee, B.H. "Surviving and thriving: Voices of Latino engineering students at a Hispanic serving institution." *Journal of Counseling Psychology*, Vol. 66, No. 4, pp. 437–448, 2019.
28. Robinson, K.A., Lee, Y., Bovee, E.A., Perez, T., Walton, S.P., Briedis, D. and Linnenbrink-Garcia, L. "Motivation in transition: Development and roles of expectancy, task values, and costs in early college engineering." *Journal of Educational Psychology*, Vol. 111, No. 6, pp. 1081–1102, 2019.
29. Jensen, L.E. and Deemer, E.D. "Identity, campus climate, and burnout among undergraduate women in STEM fields." *The Career Development Quarterly*, Vol. 67, No. 2, pp. 96–109, 2019.
30. Hall, W.M., Schmader, T. and Croft, E. "Engineering exchanges: Daily social identity threat predicts burnout among female engineers." *Social Psychological and Personality Science*, Vol. 6, No. 5, 2015.
31. Negi, A.S., Khanna, A. and Aggarwal, R. "Psychological health, stressors and coping mechanisms of engineering students." *International Journal of Adolescence and Youth,* Online, Vol. 24, No. 4, 2019.
32. Jerejian, A.C.M., Reid, C. and Rees, C.S. "The contribution of email volume, email management strategies and propensity to worry in predicting email stress among academics." *Computers in Human Behavior*, Vol. 29, No. 3, pp. 991–996, 2013.
33. Logel, C., Walton, G.M., Spencer, S.J., Iserman, E.C., von Hippel, W. and Bell, A.E. "Interacting with sexist men triggers social identity threat among female engineers." *Journal of Personality and Social Psychology*, Vol. 96, No. 6, pp. 1089–1103, 2009.
34. Jones, B.D., Ruff, C. and Paretti. "The impact of engineering identification and stereotypes on undergraduate women's achievement and persistence in engineering." *Social Psychology of Education: An International*

Journal, Vol. 16, No. 3, pp. 471–493, 2013.
35. Villa, C.G. and González, E.M. “Women students in engineering in Mexico: Exploring responses to gender differences.” *International Journal of Qualitative Studies in Education*, Vol. 27, No. 8, pp. 1044–1061, 2014.
36. Steele, C.M. and Aronson, J. “Stereotype threat and the intellectual test performance of African Americans.” *Journal of Personality and Social Psychology*, Vol. 69, No. 5, pp. 797–811, 1995.
37. De Pillis, E. and De Pillis, L. “Are engineering schools masculine and authoritarian? The mission statements say yes.” *Journal of Diversity in Higher Education*, Vol. 1, No. 1, pp. 33–44, 2008.
38. Woodcock, A., Hernandez, P.R., Estrada, M. and Schultz, P.W. “The consequences of chronic stereotype threat: Domain disidentification and abandonment.” *Journal of Personality and Social Psychology*, Vol. 103, No. 4, pp. 635–646, 2012.
39. Goodenow, C. and Grady, K.E. “The relationship of school belonging and friends’ values to academic motivation among urban adolescent students.” *The Journal of Experimental Education*, Vol. 62, No. 1, pp. 60–71, 1993.
40. Wilczynska, A., Januszek, M. and Bargiel-Matusiewicz, K. “The need of belonging and sense of belonging versus effectiveness of coping.” *Polish Psychological Bulletin*, Vol. 46, No. 1, pp. 72–81, 2015.
41. Gopalan, M. and Brady, S.T. “College students’ sense of belonging: A national perspective.” *Educational Researcher*, Vol. 49, No. 2, pp. 134–137, 2020.
42. McBeath, M., Drysdale, M.T.B. and Bohn, N. “Work-integrated learning and the importance of peer support and sense of belonging.” *Education and Training*, Vol. 60, No. 1, pp. 39–53, 2018.
43. Lewis, K.L., Stout, J.G., Finkelstein, N.D., Pollock, S.J., Miyake, A., Cohen, G.L. and Ito, T.A. “Fitting in to move forward: Belonging, gender, and persistence in the physical sciences, technology, engineering, and mathematics (pSTEM).” *Psychology of Women Quarterly*, Vol. 41, No. 4, pp. 420–436, 2017.
44. Good, C., Rattan, A. and Dweck, C.S. “Why do women opt out? Sense of belonging and women’s representation in mathematics.” *Journal of Personality and Social Psychology*, Vol. 102, No. 4, pp. 700–717, 2012.
45. Cheryan, S., Master, A. and Meltzoff, A.N. “Cultural stereotypes as gatekeepers: Increasing girls’ interest in computer science and engineering by diversifying stereotypes.” *Frontiers in Psychology*, Vol. 6, 2015.
46. Walton, G.M., Cohen, G.L., Cwir, D. and Spencer, S.J. “Mere belonging: The power of social connections.” *Journal of Personality and Social Psychology*, Vol. 102, No. 3, pp. 513–532, 2012.
47. Chiu, M.M., Chow, B.W., McBride, C. and Moi, S.T. “Students’ sense of belonging at school in 41 countries: Cross-cultural variability.” *Journal of Cross-Cultural Psychology*, Vol. 47, No. 2, pp. 175–196, 2016.
48. Perry, J.C., Liu, X. and Pabian, Y. “School engagement as a mediator of academic performance among urban youth: The role of career preparation, parental career support, and teacher support.” *The Counseling Psychologist*, Vol. 38, No. 2, pp. 269–295, 2010.
49. Pitzer, J. and Skinner, E. “Predictors of changes in students’ motivational resilience over the school year: The roles of teacher support, self-appraisals, and emotional reactivity.” *International Journal of Behavioral Development*, Vol. 41, No. 1, pp. 15–29, 2017.
50. Kashy-Rosenbaum, G., Kaplan, O. and Israel-Cohen, Y. “Predicting academic achievement by class-level emotions and perceived homeroom teachers’ emotional support.” *Psychology in the Schools*, Vol. 55, No. 7, pp. 770–782, year = 2018.
51. Košir, K. and Tement, S. “Teacher–student relationship and academic achievement: A cross-lagged longitudinal study on three different age groups.” *European Journal of Psychology of Education*, Vol. 29, No. 3, pp. 409–428, 2014.
52. Hussein, E., Daoud, S., Alrabaiah, H. and Badawi, R. “Exploring undergraduate students’ attitudes towards emergency online learning during COVID-19: A case from the UAE.” *Children and Youth Services Review*, Vol. 119, No. 6, 2020.
53. Maelan, E.N., Gustavsen, A.M., Stranger-Johannessen, E. and Nordahl, T. “Norwegian students’ experiences of homeschooling during the COVID-19 pandemic.” *European Journal of Special Needs Education,* Online, 2021.
54. Rice, L., Barth, J.M., Guadagno, R.E., Smith, G.P. and Mccallum, D.M. “The role of social support in students’ perceived abilities and attitudes toward math and science.” *Journal of Youth and Adolescence*, Vol. 42, No. 7, pp. 1028–1040, 2013.
55. Szkody, E., Stearns, M., Stanhope, L. and McKinney, C. “Stress-buffering role of social support during COVID-19.” *Family Process*, pp. 1–14, 2020.
56. Luan, L., Hong, J., Cao, M., Dong, Y. and Hou, X. “Exploring the role of online EFL learners’ perceived social support in their learning engagement: A structural equation model.” *Interactive Learning Environments,* Online,

2020.
57. London, B., Rosenthal, L., Levy, S. and Lobel, M. “The influences of perceived identity compatibility and social support on women in nontraditional fields during the college transition.” *Basic and Applied Social Psychology*, Vol. 33, No. 4, pp. 304–321, 2011.
58. Cadaret, M.C., Hartung, P.J., Subich, L.M. and Weigold, I.K. “Stereotype threat as a barrier to women entering engineering careers.” *Journal of Vocational Behavior*, Vol. 99, pp. 40–51, 2017.
59. Smeding, A. “Women in science, technology, engineering, and mathematics (STEM).” *Sex Roles*, Vol. 67, No. 11-12, pp. 617–629, 2012.
60. Ertl, B. “The impact of gender stereotypes on the self-concept of female students in STEM subjects with an under-representation of females.” *Frontiers in Psychology,* Online, Vol. 8, 2017.
61. Paulhus, D.L. “Two-component models of socially desirable responding.” *Journal of Personality and Social Psychology*, Vol. 46, No. 3, pp. 598–609, 1984.
62. Ro, H. and Loya, K. “The effect of gender and race intersectionality on student learning outcomes in engineering.” *Review of Higher Education: Journal of the Association for the Study of Higher Education*, Vol. 38, No. 3, pp. 359–396, 2015.

APPENDIX A

	Baseline measures		Current sample	
	Frequency	Percentage	Frequency	Percentage
Male	4541	75.22%	292	59.10%
Female	1496	24.78%	202	40.90%

Table 1. Biological sex.

Note: the frequency distribution for the participants' biological sex. This table includes baseline measures from a publicly available database (REFERENCE), which represents the number of undergraduate students enrolled in Carleton's Faculty of Engineering and Design (FED).

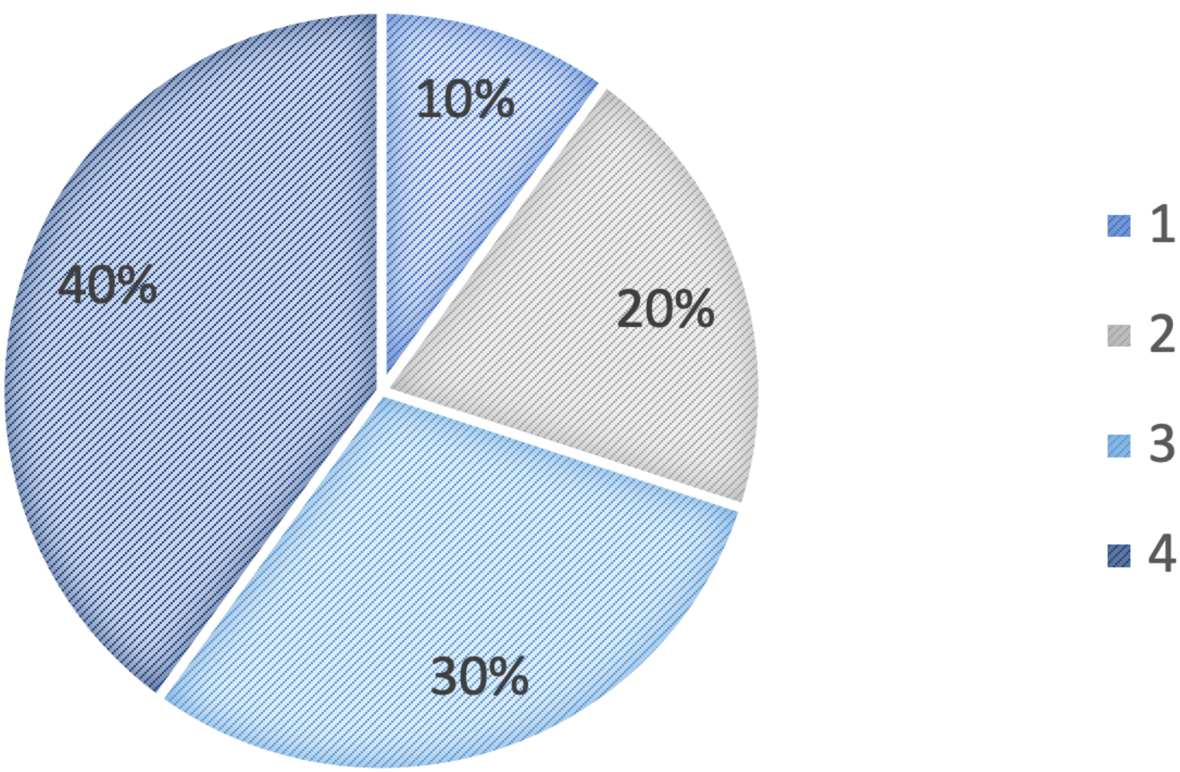

Fig. 1. Pie chart depicting breakdown of the sample by year of study, whereby 10% of the sample was in their first.

Program	Frequency	Percentage
Aerospace Engineering	109	22%
Interactive Multimedia and Design	47	9%
Architectural Studies	39	8%
Computer Systems Engineering	37	7%
Network Technology	36	7%
Biomedical and Mechanical Engineering	35	7%
Engineering Physics	30	6%
Biomedical and Electrical Engineering	28	6%
Communications Engineering	25	5%
Architectural and Stainability Engineering	22	4%
Optical Systems and Sensors	22	4%
Environmental Engineering	17	3%
Information Resource Management	14	3%
Sustainable and Renewable Energy Engineering	9	2%
Industrial Design	6	1%
Electrical Engineering	5	1%
My program is not listed	5	1%
Civil Engineering	4	1%
Media Production and Design	3	1%
Software Engineering	3	1%
Mechanical Engineering	0	0%

Table 2. FED enrolment breakdown of survey participants.

Ethnicity	Frequency	Percentage
Caucasian	312	63.16%
African American	26	5.26%
Asian Decent	73	14.78%
Middle Eastern Decent	60	12.15%
Hispanic	10	2.02%
First Nations	2	0.40%
Other	4	0.81%
No Response	7	1.42%

Table 3. Self-reported ethnicity of participants.

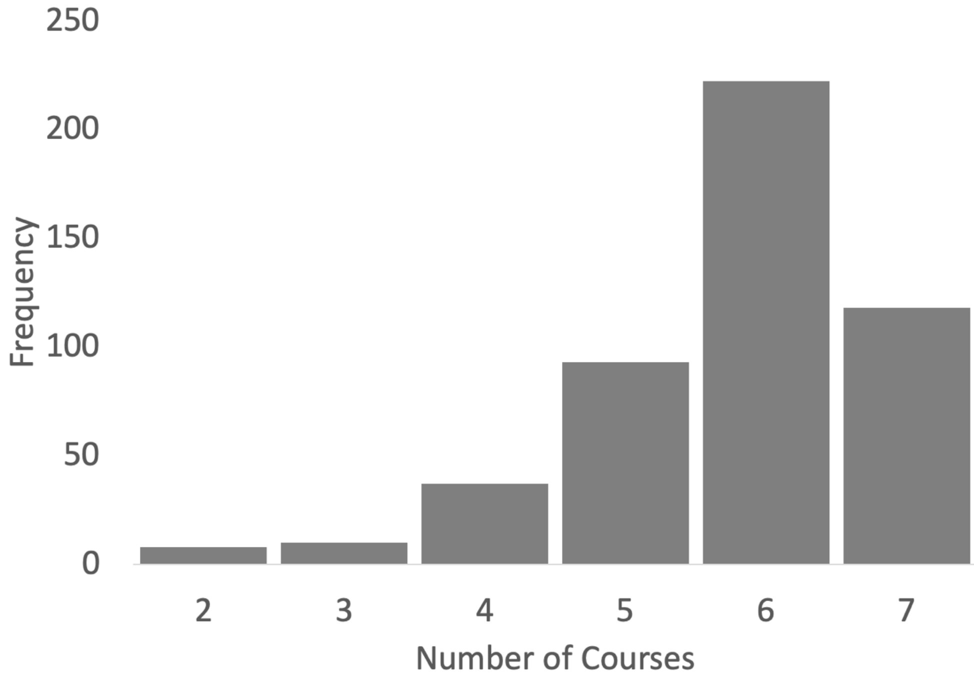

Fig. 2. Number of courses that participants were enrolled in at the time of the study.

APPENDIX B: INVITATION FORMS

Email Invitation: Undergraduate Students in The Faculty of Engineering and Design Programs
Subject: Invitation to participate in a research project on exploring psychological and social barriers to success of undergraduate students in faculty of engineering and design (FED) programs during online learning

November 25, 2020

Hello,

My name is Senah Qwai and I am an undergraduate student in the department of Psychology at Carleton University. I am working on a research project under the supervision of Prof. John Hayes.

I am writing to you today to invite you to participate in a study entitled "Exploring Psychological and Social Barriers to Success of Undergraduate Students in Faculty of Engineering and Design (FED) Programs During Online Learning". This study aims to examine the experiences of undergraduate students in engineering and design programs during online learning.

This study involves completing approximately an 18-minute survey on your personal computer or phone at your chosen location and timing. With your consent, we ask you to complete a survey that questions various topics such as social support, stress, and experiences relating to online learning.

This project does not involve any risks. The survey does not collect any personal identifiers and the data would be completely anonymous. The data will be retained for research use but will not link responses to any specific individuals. You will not be able to discard your response after submitting them because the study is anonymous, and we cannot link the responses to participants.

You will have the right to end your participation in the study at any time, for any reason, any time before submitting your responses. If you choose to withdraw, all the information you have provided will be destroyed.

There are no compensations of any type for participating in this study.

All research data, including your responses will be stored on encrypted/password-protected computers of the researchers involved. Any hard copies of data will be kept in a locked cabinet at Carleton University. Research data will only be accessible by the researchers and the research supervisor.

This research has been cleared by the Carleton University Research Ethics Board-B

Clearance #: 114953 Clearance Date: December 09, 2020

To be eligible to participate in this study, participants must be: 1) An undergraduate student, 2) enrolled in any of the Faculty of Engineering and Design (FED) programs, and 3) be taking at least 1 online course. Should you have any ethical concerns with the study, please contact the REB Chair, Carleton University Research Ethics Board-B by email at Ethics@carleton.ca. For all other questions about the study, please contact the researcher. If you would like to participate in this research project, or have any questions about the research, please contact me at (ph. 613-501-0209) or (Senahqwai@cmail.carleton.ca)

Sincerely,

Senah Qwai

Online Invitation: Undergraduate Students in the Faculty of Engineering and Design Programs. *Posted on (Instagram, Facebook, Twitter, and other social media platforms)*:

Volunteers needed for exploring psychological and social barriers to success of undergraduate students in faculty of engineering and design (FED) programs during online learning.

We are looking for volunteers for a study on the experiences of undergraduate students in the Faculty of Engineering and Design (FED) programs during online learning. This project aims to explore the presence and extent of various factors (e.g., social support, coping, etc.) among male and female students in FED programs.

You will be asked to rate various statements on a scale to indicate whether you agree or disagree with them.

To be eligible, you must be: 1) An undergraduate student, 2) Be enrolled in a program in the Faculty of Engineering and Design, and 3) Be taking at least 1 online course.

The study will take place online, anywhere and anytime as it can be completed on your personal computer or phone. It should take approximately 18 minutes to complete. No compensation will be provided for participation.

If you have any questions or concerns, please email Senah Qwai at (Senahqwai@cmail.carleton.ca) for more details on participating.

If you are interested in participating, please click the link below to be directed to the survey: **Link**

This research has been cleared by the Carleton University Research Ethics Board-B

Clearance #: 114953 Clearance Date: December 09, 2020

This project is being conducted under the supervision of Dr. John Hayes at Carleton University.

Should you have any ethical concerns with the study, please contact the REB Chair, Carleton University Research Ethics Board-B by email at Ethics@carleton.ca. For all other questions about the study, please contact the researcher.

Thank you!

APPENDIX C: SURVEY AND EXPLORATORY FACTOR ANALYSIS (EFA)

Factor		Item	Loading
1 Perceived faculty support Cronbach's $\alpha = 0.926$ $(n = 8)$	FS1	My professors have adapted their courses to make it manageable for students	0.771
	FS2	I feel supported by my faculty members	0.843
	FS3	My professors have been helping me through email and/or other online platforms	0.807
	FS4	My questions are adequately answered by my professors	0.808
	FS5r	Faculty members do not care about my success	0.734
	FS6	I feel confident in approaching my professors for help on course material	0.612
	FS7	My program faculty members are doing their best to support students	0.818
	FS8*	My professors are doing their best to help students during online learning	0.863
2 Interest in program Cronbach's $\alpha = 0.878$ $(n = 6)$	Int1*	I want to be in my program	0.812
	Int2	I am interested in my field 0.785	
	Int3r	My program is boring	0.756
	Int4	I enjoy what my program offers me	0.686
	Int5	The knowledge I learn in my program in interesting	0.738
	SB1	I belong to my program	0.627
3 Connectedness among colleagues Cronbach's $\alpha = 0.849$ $(n = 8)$	SB2	I feel welcomed in my program	0.571
	SB3	I fit in with other students in my program 0.714	
	SB4*	I have developed personal connections with other people in my program	0.799
	SB5	I get involved with activities or programs related to my field of study	0.587
	SB6	I share similar values with other students in my program	0.678
	SB7	I can express my authentic self among peers in my program	0.768
	SB8	If I miss a lecture, I can rely on another student to help me catch up	0.674

Table 1. Factors retained.

Note: the factors and the items included within each factor (along with their loadings on each factor). An "r" refers to a reverse coded item and an asterisk "*" denoted which variable was considered the marker variable for each loading.

Factor		Item	Loading
4 Self-eccicacy Cronbach's $\alpha = 0.863$ $(n = 7)$	SelfEff1	I am confident that I will succeed in my program during online learning	0.486
	SelfEff2	If I put in the time and effort, I will do well in my program	0.513
	SelfEff3	I can fulfill my academic requirements	0.739
	SelfEff4	I can master the concepts that I study	0.678
	SelfEff5	I consider myself competent in my program	0.594
	SelfEff7*	I can reach my academic goals	0.778
	SelfEff8	I believe that I can overcome my academic challenges	0.703
5 Coping efficacy Cronbach's $\alpha = 0.820$ $(n = 6)$	CE1*	I can cope with academic stressors	0.706
	CE2r	It feels that things are out of control in my academic life	0.447
	CE3	I can efficiently deal with day-to-day life hassles	0.699
	CE4	I am on top of things	0.652
	CE5	I have the resources to get through academic challenges	0.375
	CE6	I can manage my emotions in the face of academic stressors	0.710
6 Preference Toward Online Learning Cronbach's $\alpha = 0.848$	OL1	Overall, online learning has been a positive experience for me	0.669
	OL2*	I prefer online courses compared to in-class ones	0.872
	OL3r	It is easier to be in class than engage in online lectures and assignments	0.352
	OL4	Online education has been rewarding for me	0.698
	OL5	If I could choose, I would complete my degree online rather than on campus	0.807
	OL6	My transition from in-class learning to online learning went smoothly	0.579
7 Perceived Social Support Cronbach's $\alpha = 0.775$ $(n = 6)$	SS1*	I feel supported by my family in my decision to pursue the program I am in	0.851
	SS2	My family encourages me to continue in my studies	0.755
	SS3	My friends think that I am a good fit for my program	0.428
	SS4	I can discuss challenges that I experience in my program with my family	0.682
	SS5r	My friends criticize my choice of pursuing my program	0.385
	SS7	I feel that I can talk about my program without being negatively judged by my family	0.746

Table 1. Factors retained, continued.

Note: the factors and the items included within each factor (along with their loadings on each factor). An "r" refers to a reverse coded item and an asterisk "*" denoted which variable was considered the marker variable for each loading.

Factor		Item	Loading
8 Positive attitude toward female engineers	PGS1	Females can do just as well as males in engineering and design programs	0.796
	PGS2r	Females should not be in engineering and design programs	0.558
	PGS3	Both males and females can excel in engineering and design programs	0.785
	PGS4	Engineering is not only a “man’s field”	0.483
Cronbach’s $\alpha = 0.644$	PGS5*	Female students can make valuable contributions in my program	0.821
$(n = 6)$	PGS6	Engineering and design programs are well suited for women	0.474
9 Stress toward online learning	Stress1*	Online learning has been overwhelming	0.600
	Stress2	My academic obligations stress me out	0.512
	Stress3	It has been hard to keep up with course work	0.598
Cronbach’s $\alpha = 0.786$ $(n = 4)$	Stress5	My professors expect too much from me	0.491

Table 1. Factors retained, continued.

Note: the factors and the items included within each factor (along with their loadings on each factor). An “r” refers to a reverse coded item and an asterisk “*” denoted which variable was considered the marker variable for each loading.

DEMOGRAPHICS

- Are you enrolled in any of the Faculty of Engineering Design programs?
  - Yes ⇒ *Dropdown menu: Aerospace Engineering, Architectural Conservation and Sustainability Engineering, Architectural Studies, Biomedical and Mechanical Engineering, Civil Engineering, Communications Engineering, Computer Systems Engineering, Electrical Engineering, Engineering Physics, Environmental Engineering, Industrial Design, Information Resources Management, Interactive Multimedia and Design, Mechanical Engineering, Media Production and Design, Network Technology, Optical Systems and Sensors, Software Engineering, Sustainable and Renewable Energy Engineering*
  - No ⇒ Ends the survey
- How many online courses are you taking right now? *Dropdown menu: None (Redirects to: You have indicated that you are not taking any online courses, is this correct? Yes ⇒ Ends the survey; No ⇒ Please indicate how many online courses you are taking, 2, 3, 4, 5, more than 5
- What is your academic year standing? *Dropdown menu: first year, second year, third year, fourth year*
- What is your age? *input*

- What is your biological sex?
  - Male
  - Female
  - Other (please specify) *input*
  - Prefer not to disclose
    + We are analyzing participants' responses to examine any differences between biological sexes. This information is paramount to this study. Would you reconsider disclosing this information?
      · No, I do not want to disclose
      · Yes, I want to disclose (please specify) *input*
- What is your gender?
  - Male
  - Female
  - Other ⇒ (please specify) *input*
  - Prefer not to disclose
    + Information about participants' genders would be helpful for research purposes. Would you reconsider disclosing this information?
      · No, I do not want to disclose
      · Yes, I want to disclose ⇒ (please specify) *input*
- What is your ethnicity?
  - White (e.g., German, English, French, etc.)
  - Black or African (e.g., Jamaican, Haitian, Ethiopian, etc.)
  - Asian (e.g., Filipino, Japanese, Chinese, etc.)
  - Middle Eastern (e.g., Lebanese, Algerian, Jordanian, etc.)
  - Hispanic, Spanish, Latino (e.g., Mexican, Colombian, Dominican, etc.)
  - Other (please specify) *input*

APPENDIX D. CONSENT FORM

Name and Contact Information of Researchers:
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Carleton University
Department of Psychology
Tel.: 613-520-2644
Email: Psychology@carleton.ca

Supervisor and Contact Information: John Hayes, Ph.D, P.Eng Tel.: 613-520-2600 ext. 5661
Email: Johnhayes@cunet.carleton.ca

Project Title
Exploring Psychological and Social Barriers to Success of Undergraduate Students in Faculty of Engineering and Design (FED) Programs During Online Learning
Project Sponsor and Funder (if any)
N/A
Carleton University Project Clearance
This research has been cleared by the Carleton University Research Ethics Board-B. Clearance #: 114953
Date of Clearance: December 09, 2020
Invitation
We are asking you to complete this survey because you are an undergraduate student enrolled in any of the Faculty of Engineering and Design (FED) programs at Carleton University. This survey is being conducted by Senah Qwai of Carleton University in the Department of Psychology (Senahqwai@cmail.carleton.ca; ph. 613-501-0209) and Lindsay Richardson (Lindsayrichardson@cunet.carleton.ca; ph. 613-520-2600 ext. 2537) working under the supervision of Prof. John Hayes (Johnhayes@cunet.carleton.ca; ph. 613-520-2600 ext. 5661).
Objectives and Summary:
The aim of this study is to better understand *the psychological and social barriers to success experienced by undergraduate students in the Faculty of Engineering and Design (FED) during online learning. We aim to measure and compare the presence and extent of various variables across male and female students.*
Eligibility:
To be eligible to participate in this study, participants must be: 1) An undergraduate student, 2) enrolled in any of the Faculty of Engineering and Design (FED) programs, and 3) be taking at least 1 online course. We estimate that the survey will take about 18 minutes to complete. Your participation in this survey is voluntary, and you may choose not to take part, or not to answer any of the questions. You will be able to end the survey at any point; in which case all your responses and participation will be discarded. You will not be able to withdraw your data from the study after submitting your responses because no personal identifies are linked to any of the responses. We expect to survey a total of 800 people.
Risks and Benefits:
We do not anticipate any risks from taking the survey, nor do we anticipate that you will derive any benefit. There is no compensation for taking part in this research.
Confidentiality and Data Storage:
We will treat your personal information as confidential, although absolute privacy cannot be guaranteed. No information that discloses your identity will be released or published without your specific consent. The survey does not require you to provide any identifiers that can be linked to you in any way. We will assign a code to each participant so that no responses can be linked to any identity. Research records may be accessed by the Carleton University Research Ethics Board in order to ensure continuing ethics compliance. The results of this study may be published or presented at a conference or meeting, but the data will be presented so that it will not be possible to identify you. All research data will be stored on password-protected computers of the researchers involved. Any hard copies of data will be kept in a locked cabinet at Carleton University. We will password-protect any research data that we transfer. After the study is completed, we will retain your anonymous data indefinitely for future research use. Your data will be stored and protected by Qualtrics Control 1 Type II audited data centers in SSAE-16 Service Organization
REB Review and Contact Information:
This project was reviewed and cleared by the Carleton University Research Ethics Board. If you have any ethical concerns with the study, please contact the Carleton University Research Ethics by email at Ethics@carleton.ca.

Implied consent:

By completing the online survey, you are agreeing to participate in the study.

Direct Consent:

I voluntarily agree to participate in this study.

Yes No

APPENDIX E: OTHER GRAPHS DEPICTING RESULTS

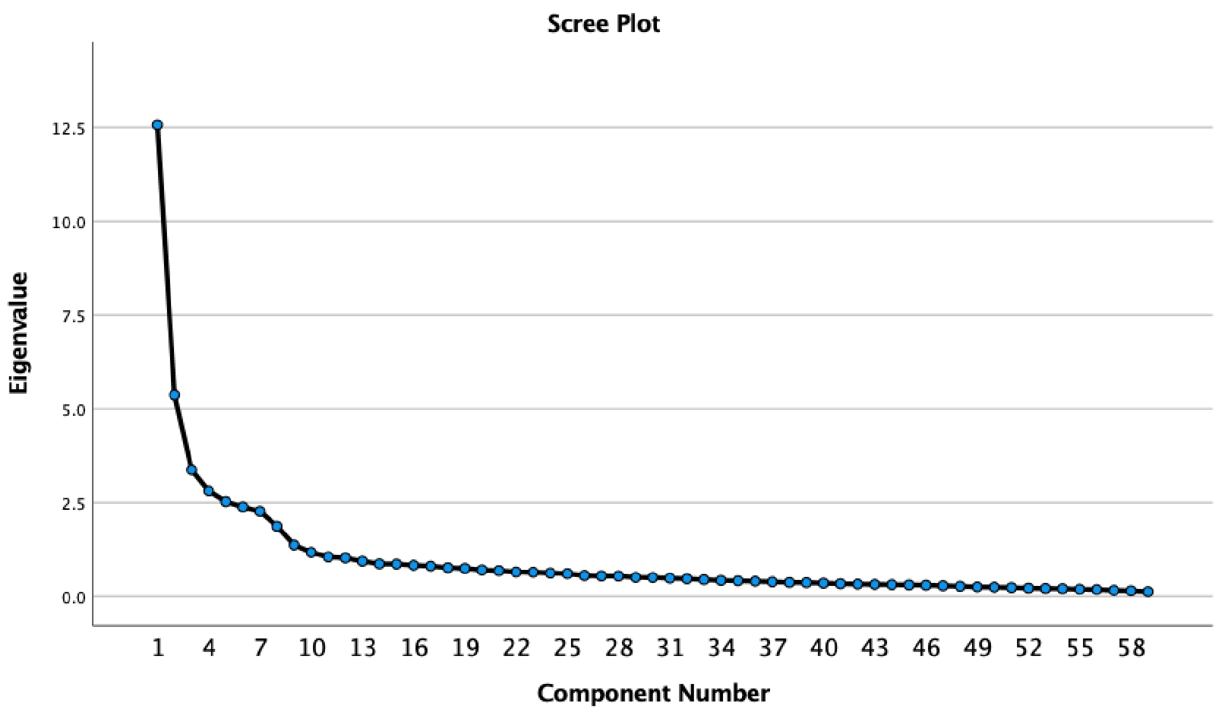

Fig. 1. A Scree Plot demonstrating that the number of factors to be retained is between 4 and 12, as the “bend” in the plot appears to be within that range.

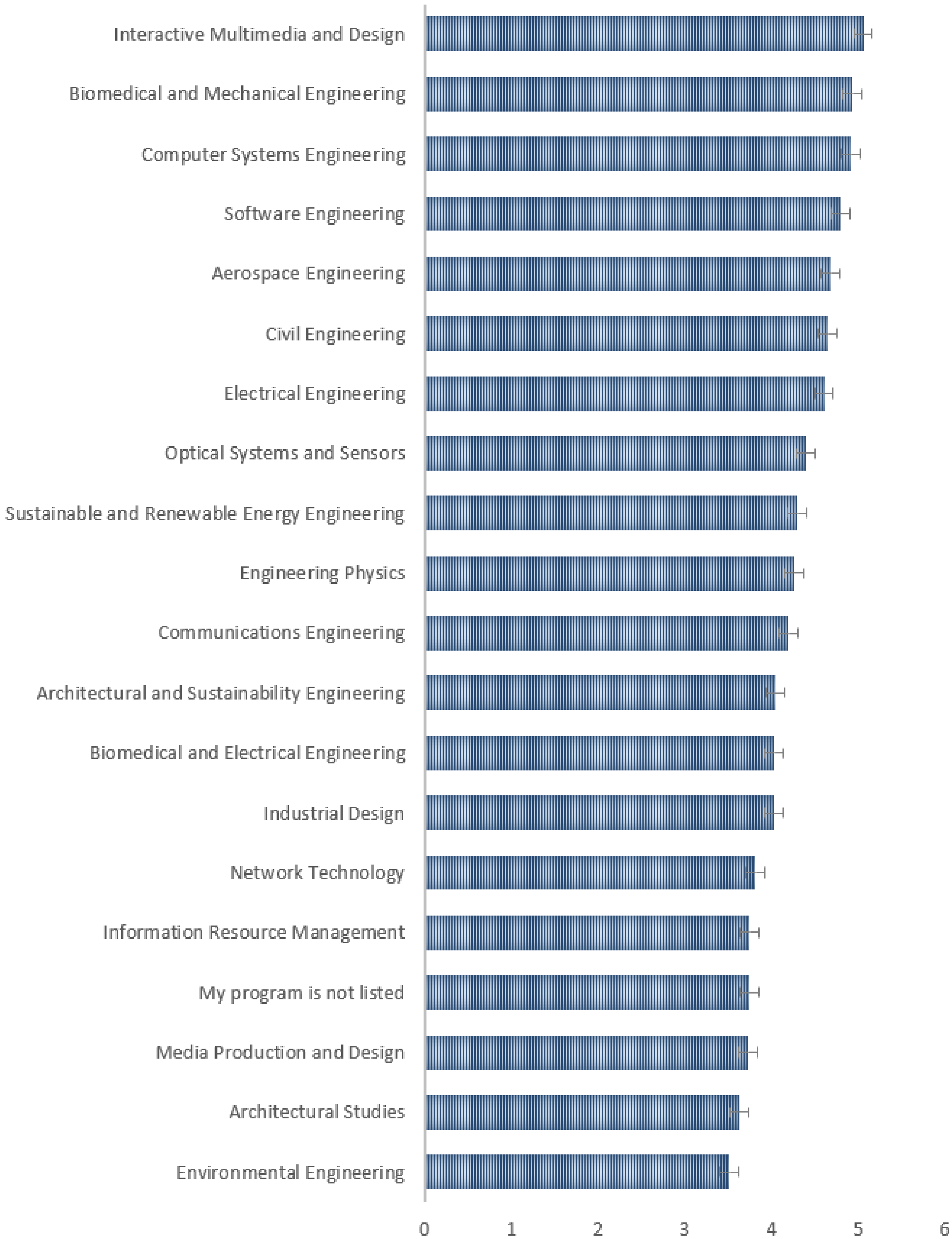

Fig. 2. A bar chart depicting the perceived level of faculty support for students from different FED programs.

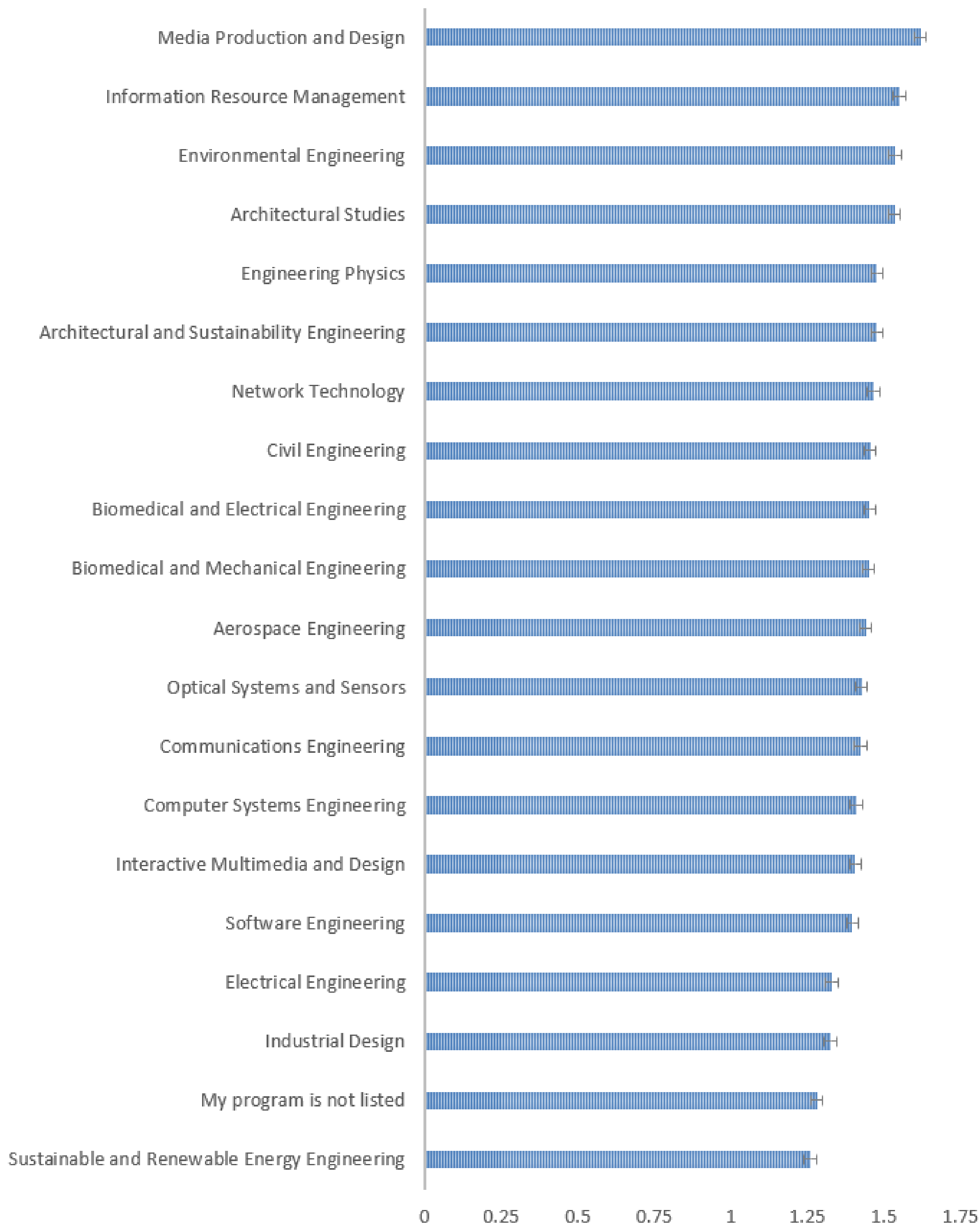

Fig. 3. A bar chart depicting the level of interest in a program for students from different FED programs.

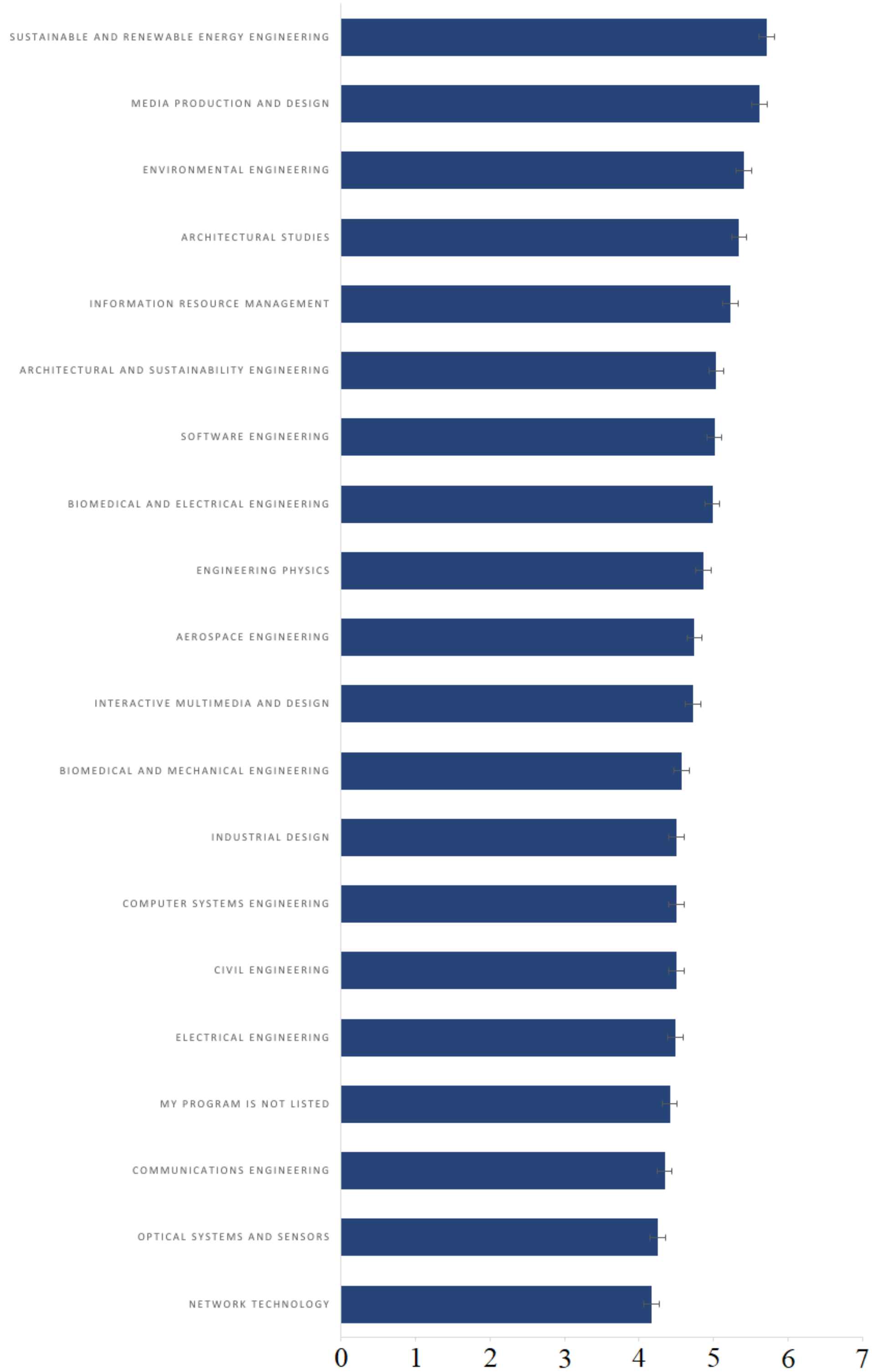

Fig. 4. A bar chart depicting the level of connectedness among colleagues for students from different FED programs.

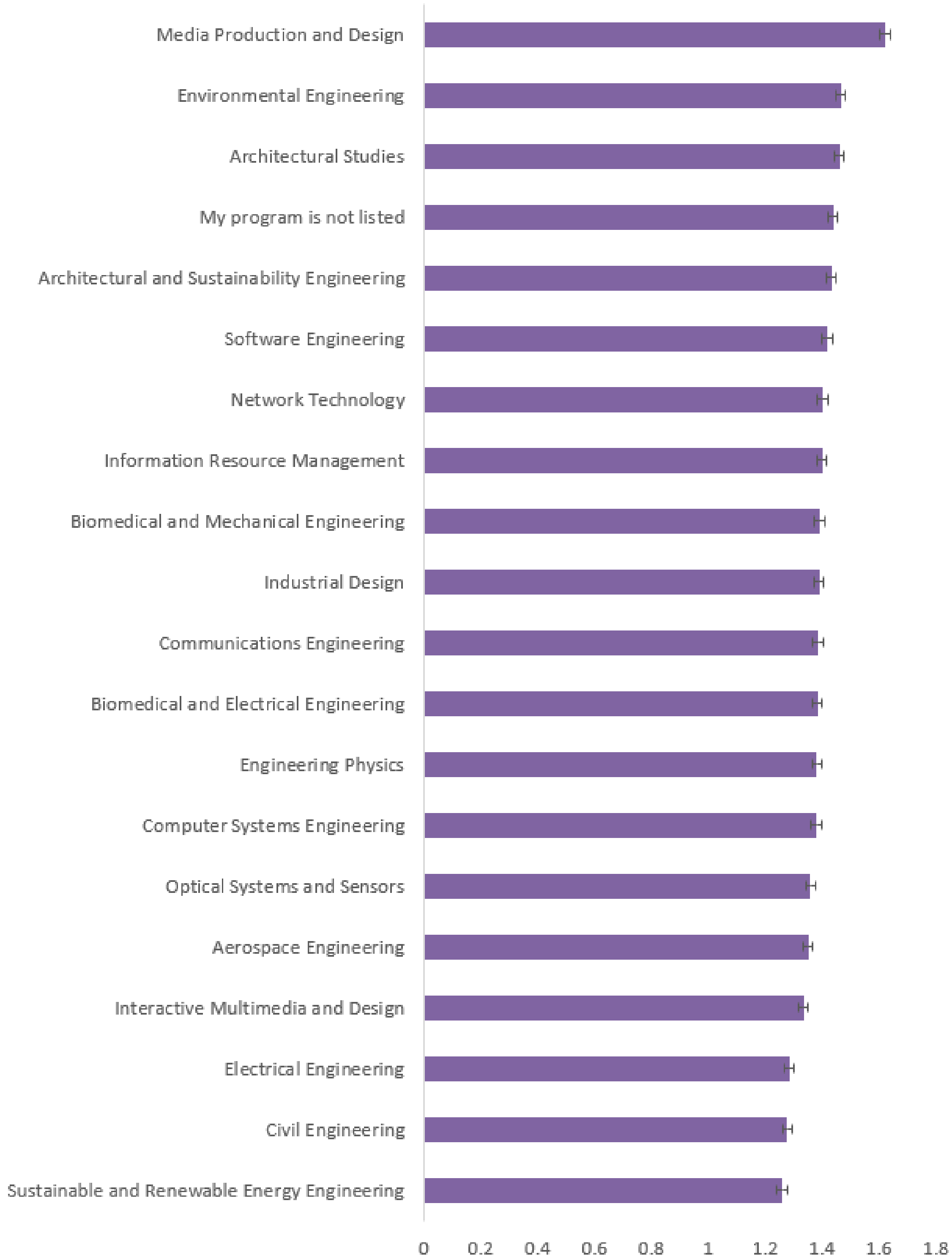

Fig. 5. A bar chart depicting level of self-efficacy for students from different FED programs.

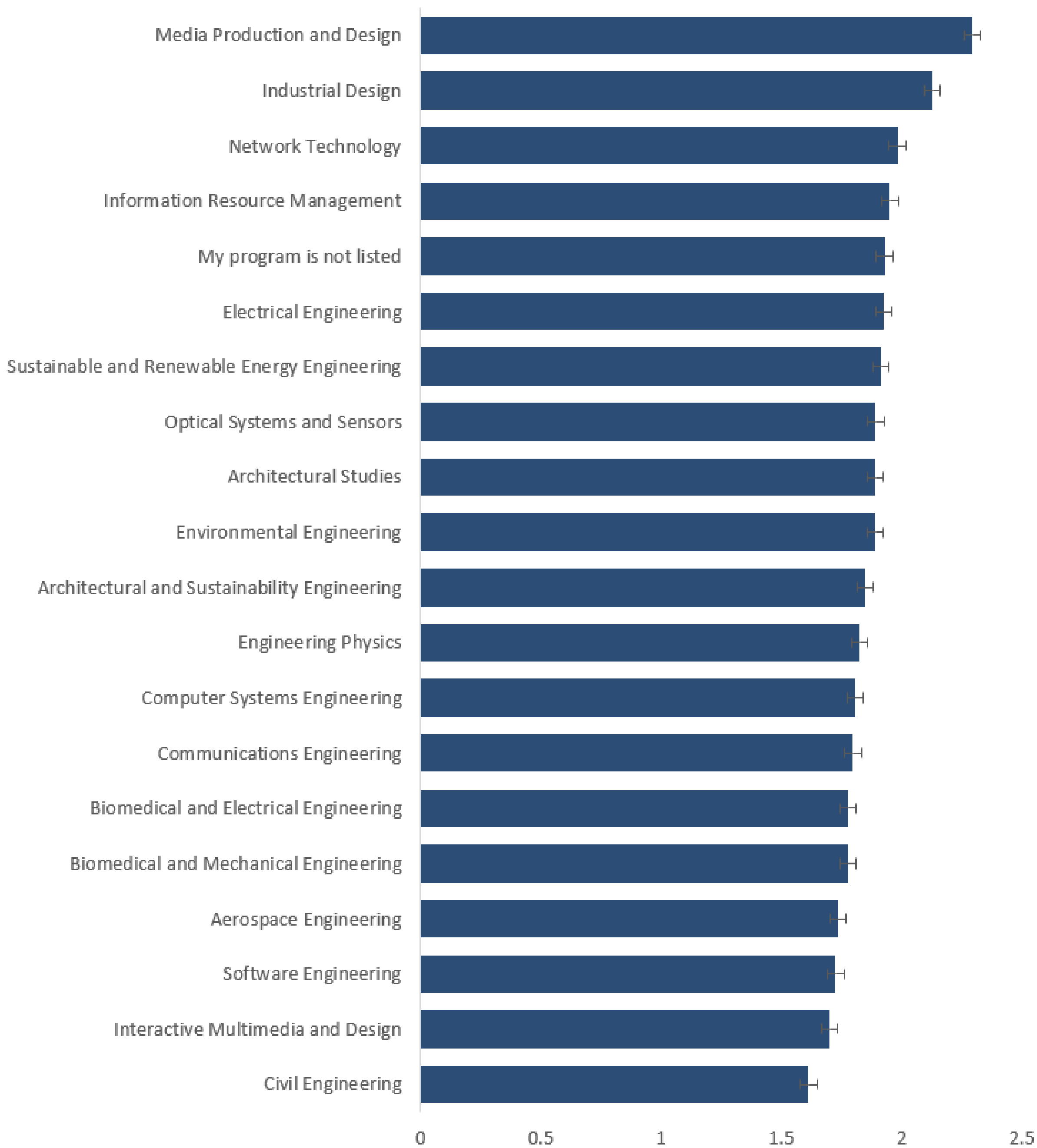

Fig. 6. A bar chart depicting level of preference for online learning for students from different FED programs.

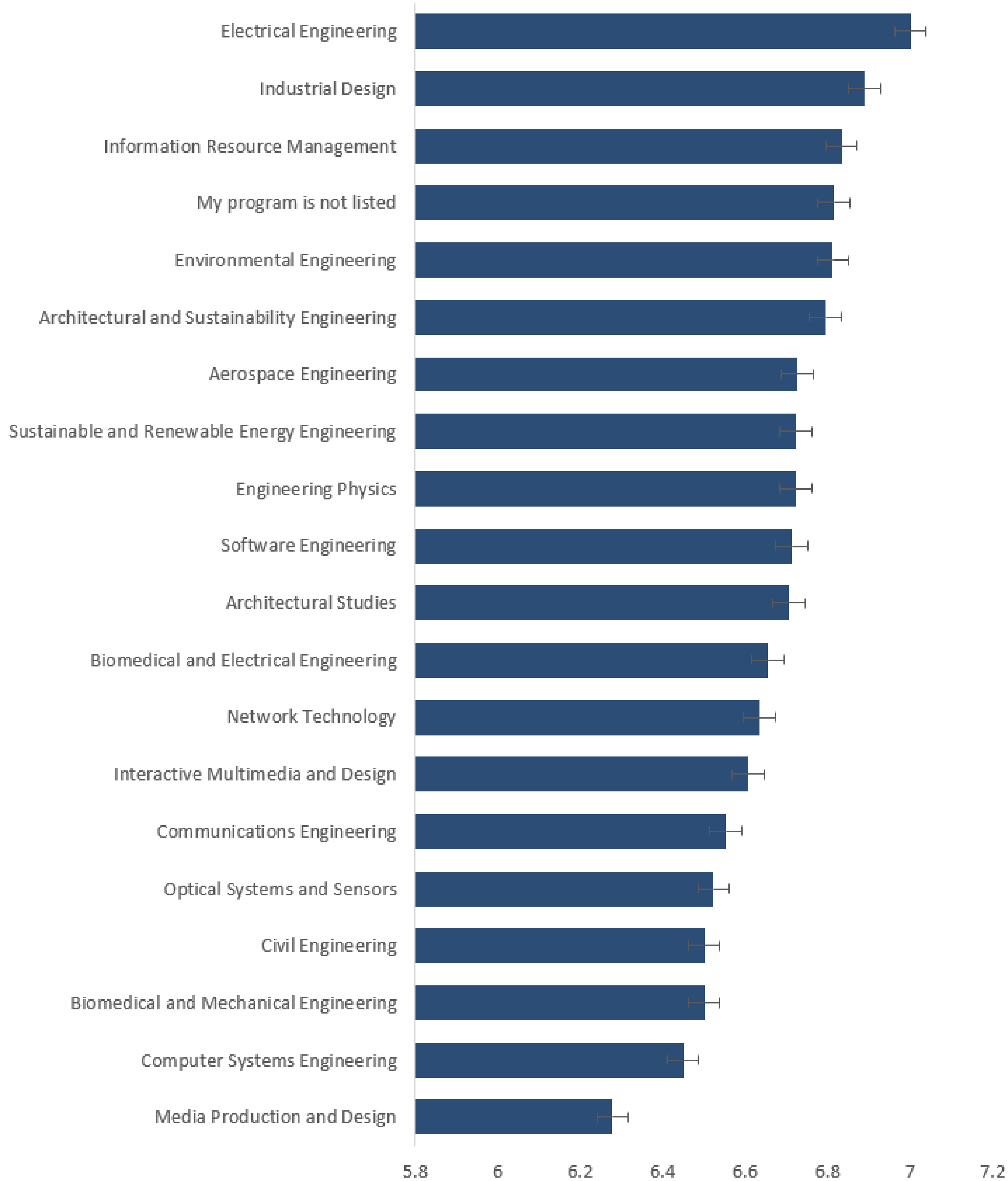

Fig. 7. A bar chart depicting positive attitudes towards female engineering for students from different FEB programs.

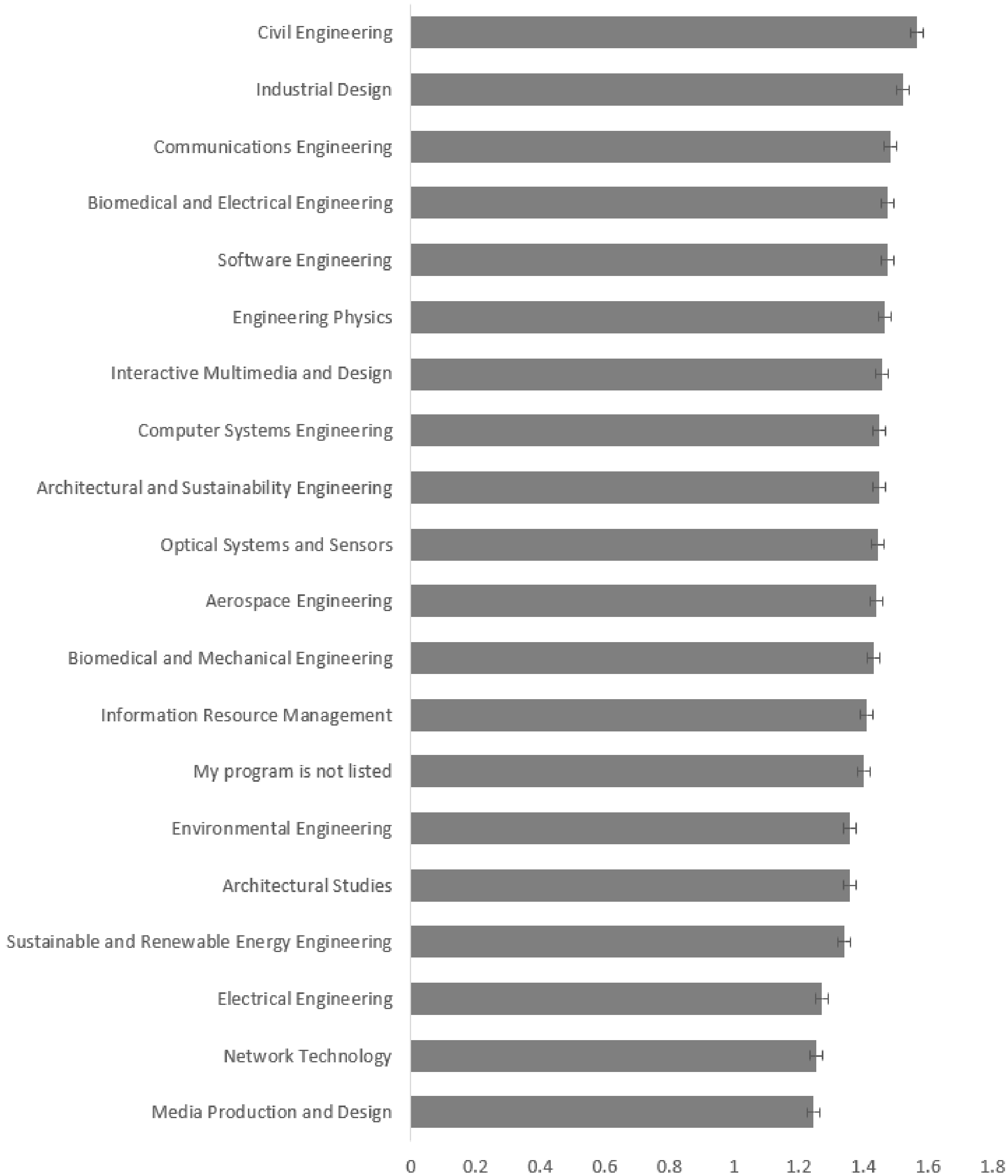

Fig. 8. A bar chart depicting students' stress toward online learning for students from different FED programs.

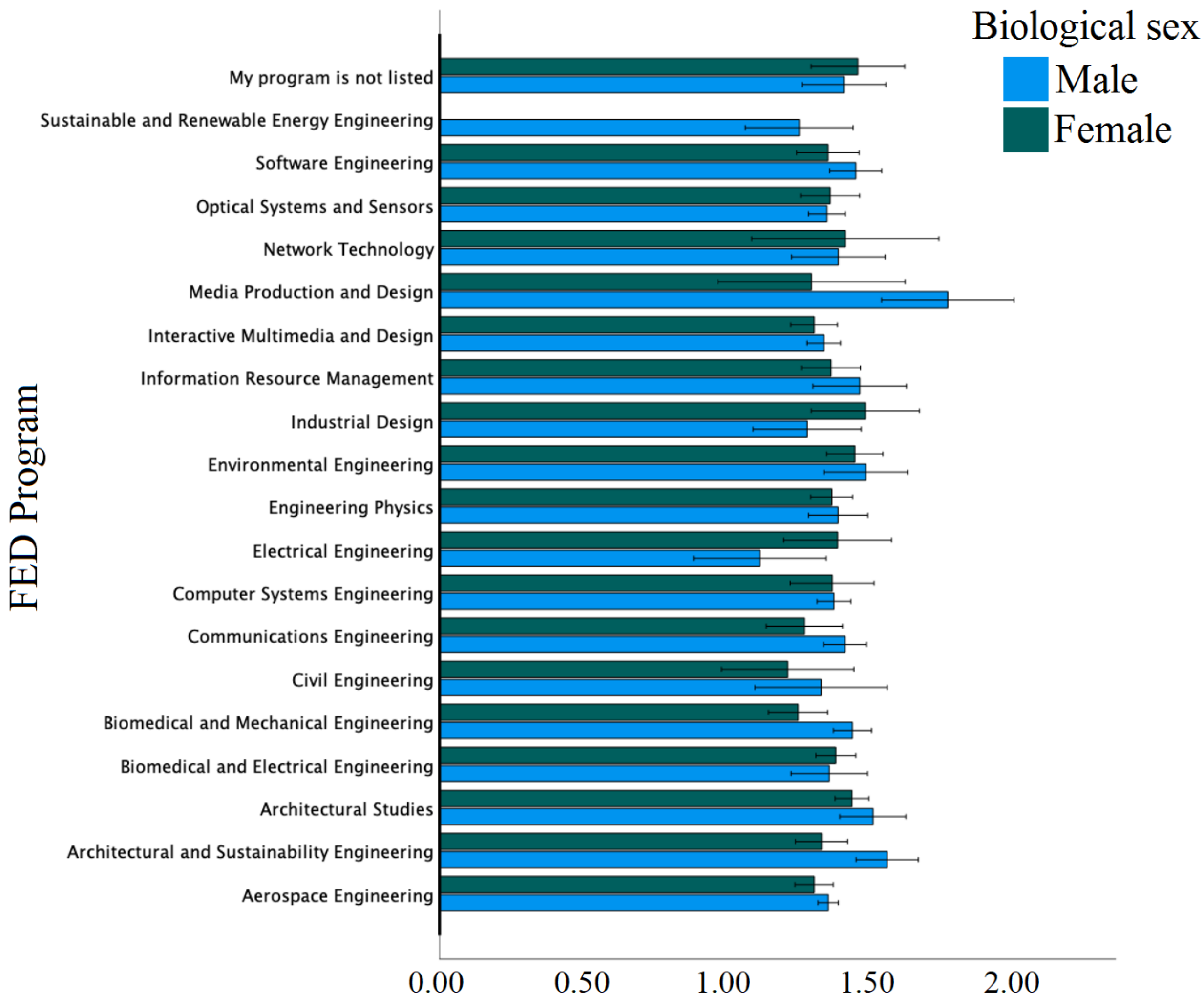

Fig. 9. A bar chart depicting males' and females' self-efficacy for students from different FED programs. Errors bars represent 2 standard errors from the mean.

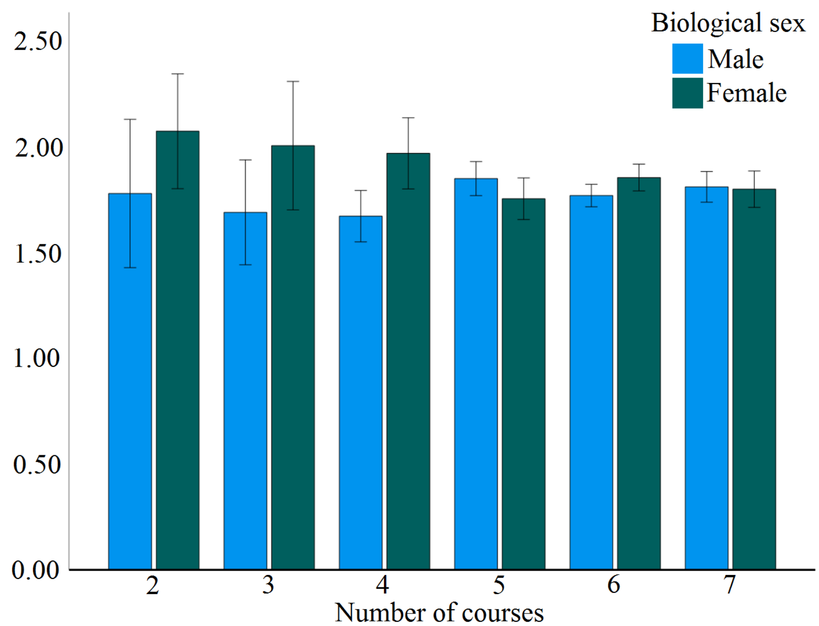

Fig. 10. A bar chart depicting males' and females' preference for online learning while taking between 2 and 7 courses in fall 2020. Error bards represent 2 standard errors from the mean.

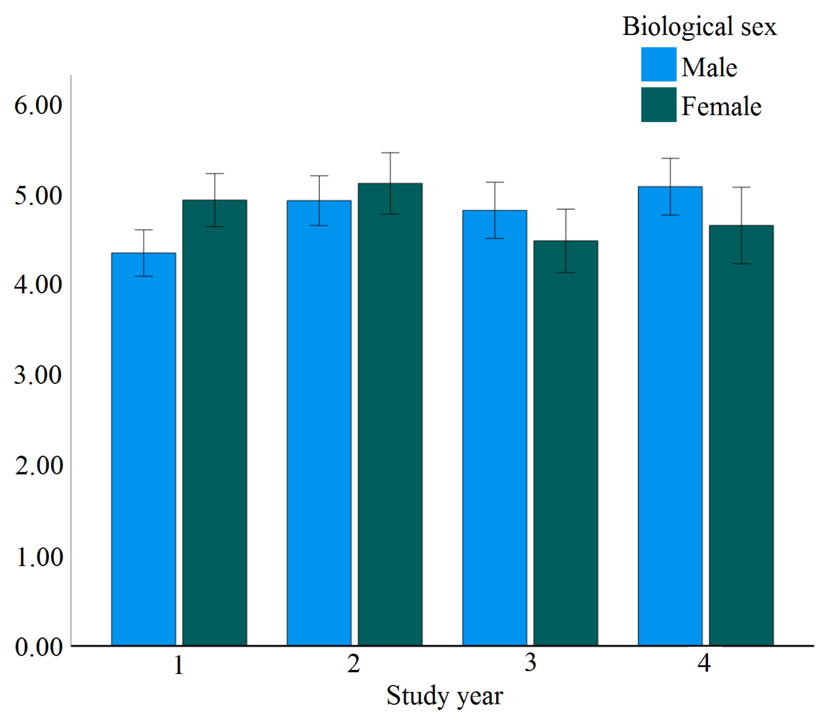

Fig. 11. A bar chart depicting males' and females' connectedness among colleagues for first-, second-, third-, and fourth-year students. Errors bards represent 2 standard errors from the mean.

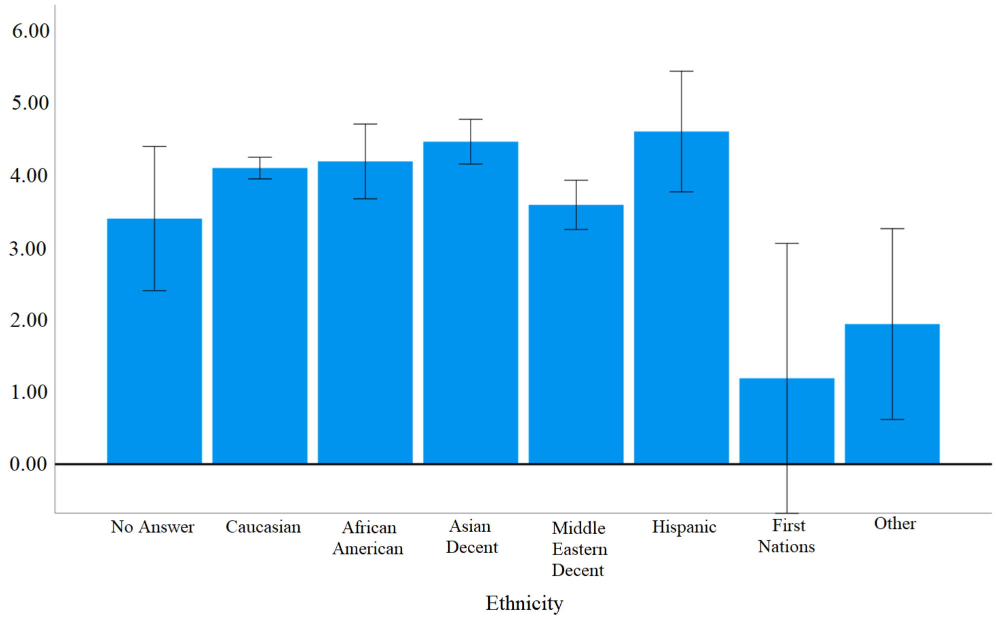

Fig. 12. A bar chart depicting perceived faculty support for students with different ethnic origins. Errors bards represent 2 standard errors from the mean.

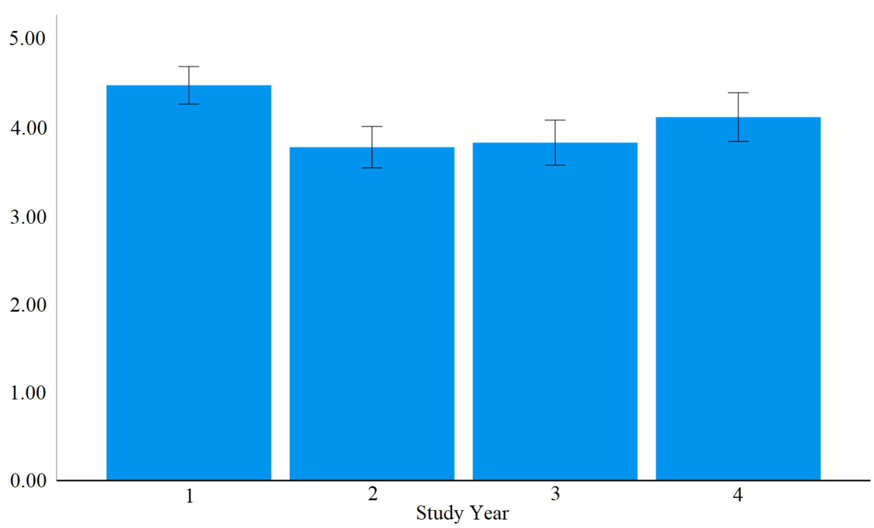

Fig. 13. A bar chart depicting perceived faculty support for first-, second-, third-, and fourth-year students. Errors bars represent 2 standard errors from the mean.