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Longitudinal Examination of Gender Differences in Engineering Self-Efficacy and the Impact of COVID-19: A Six-Year Study

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Abstract

This paper presents a longitudinal analysis of gender differences in undergraduate engineering students' feeling of self-efficacy across a six-year period, including the impact of the COVID-19 pandemic. Engineering self-efficacy was measured by the Longitudinal Assessment of Engineering Self-Efficacy (LAESE) instrument, while pandemic-related stress was measured with a COVID screener comprised of twenty Likert-type questions. Surveys were administered to engineering students at a small, primarily undergraduate university every semester from Fall 2018 through Spring 2024 and also included one summer survey following a move to online teaching in 2020. Results of long-term data collected over six years (thirteen timepoints) indicated no significant differences in engineering self-efficacy between genders or over time. COVID screener responses from during the pandemic highlighted significantly more social/emotional and academic stress among women compared to men. Post-pandemic the average stress levels for both genders decreased. Social/emotional stressors were significantly higher for women than men, whereas academic stressors for both genders were similar. Despite the high stress levels during the pandemic years, measures of engineering self-efficacy for both genders in this engineering program remained relatively stable over time. This may indicate resiliency of the students and their engineering self-efficacy during this challenging time, and may also reflect the efforts of the faculty to remain in-person and as "normal" as possible during this period (e.g., teaching in physical classrooms as much as possible). The study provides information on the resiliency of the engineering students at this institution throughout the last six years, including both before and after the COVID pandemic as well as offers insight as to other factors that may increase self-efficacy and ultimately resiliency of the students in this program and beyond.

Introduction

During the COVID-19 pandemic, engineering students faced significant academic challenges as universities transitioned quickly to remote learning. The abrupt shift disrupted hands-on labs, group projects, and practical experiences important to an engineering education and many engineering courses [1, 2]. With the loss of access to physical lab spaces, equipment, and campus facilities, instructors sought creative solutions for achieving course goals and ABET learning outcomes remotely. Faculty and students had to learn to adapt to these new learning modes, tools, and technology quickly, which was challenging since few instructors or students in engineering had remote teaching and learning experience.

Documented effects on student learning during this time are mixed. Many students reported that their academic performance worsened during online learning [3]. While at other universities, student indirect assessments of ABET mandated student learning outcomes indicated no significant change from before and during the pandemic, with the exception of outcomes for laboratory courses [2]. Direct assessments of student work (e.g., homework, exams) were challenging, since concerns were raised about academic integrity as well as equitable access to resources. One solution for addressing academic integrity was having students turn their cameras on during exams, but many students indicated concerns with being watched and recorded while in their homes. In some student populations, over half the students did not have access to a private or quiet space to attend the online classes or to study [4]. Students from underprivileged backgrounds faced challenges with internet connectivity, access to devices, and conducive learning environments at home. In a study of 627 students from California State University (one of the largest and most diverse four-year universities in the U.S.), students indicated that the greatest logistical issues were related to having reliable internet, software access, and printer/scanner access [4].

The shift to remote learning during the COVID-19 pandemic also took a significant social and emotional toll on engineering students. Isolation from peers made collaboration difficult, reducing the sense of community and connection while students were receiving their engineering education. A study by Balta-Salvador, et al., (2021) highlighted declines in students' relationships with peers and instructors as well as increased boredom over a six-month period during the pandemic [3]. Many students experienced heightened anxiety, stress, and depression [5]. Research by Ely (2021) found that women students at a Midwestern university reported increased stress and reduced social connection between pre- and post-pandemic timepoints [6].

The pandemic also altered personal workloads, with some students, especially women, taking on additional caregiving responsibilities at home [7]. For many, focusing on coursework in a home environment proved challenging. A study by Asgari et al. (2021) revealed that 70% of students struggled with focus and Zoom fatigue from consecutive online sessions. In the same study, over half of students reported feeling socially disconnected from classmates, 64% felt disengaged during online classes, and 60% of students expressed frustration with unclear guidance or communication from instructors [4]. These factors underscore the broader emotional strain and the critical need for tailored support to help students navigate the unique challenges of the pandemic.

The COVID-19 pandemic had nuanced effects on engineering students' self-efficacy, which is the belief in one's ability to accomplish tasks and achieve goals [8]. Previous research indicates that engineering self-efficacy is a significant predictor of resilience in STEM programs [9, 10, 11]. Recent studies of pandemic effects on self-efficacy have revealed mixed effects. Milord et al. (2021) found that despite the abrupt shift to online learning, students' engineering self-efficacy statistically increased for both genders across three timepoints during the pandemic. Students maintained confidence in their ability to succeed in coursework and their intentions to persist in engineering. However, in this same study, 69% of students experienced decreased motivation, suggesting a divergence between self-efficacy and motivation. Similarly, Tsenn (2021) found no significant differences in engineering design self-efficacy between traditional and remote capstone projects, indicating that self-efficacy was not strongly tied to instructional format [12]. On the other hand, Khan et al. (2022) reported that students from underrepresented groups faced disproportionate challenges due to limited access to study spaces, reliable internet, and peer networks, although the loss of traditional labs did not significantly impact overall self-efficacy or motivation [13]. These findings suggest that while engineering self-efficacy was resilient during the pandemic, broader social and structural issues, such as family health concerns and reduced social support, influenced students' academic experiences and motivation.

Goals of the Study

This study aims to explore gender differences in self-efficacy and pandemic-related stressors among engineering students at a small, private university in the United States. The small engineering program offers Bachelor of Science degrees in Engineering and typically enrolls around 300 students total annually. This study assesses the engineering self-efficacy and pandemic-related stressors experienced by engineering students over a six-year period, including thirteen survey timepoints. The surveys were administered before the COVID-19 pandemic, during the pandemic, and post-pandemic. Insights gained from this unique study can help engineering educators understand how a major disruption in learning, such as that resulting from a pandemic, can affect students' academic, social, and emotional needs, recognizing that these needs may vary by institution type, gender, and stage of the academic journey. Furthermore, the findings can inform improvements to academic and social support systems, as well as curriculum and teaching practices, to enhance recruitment and retention efforts—not only for underrepresented groups but for all students.

The research questions guiding this study are:

1. Does engineering self-efficacy differ across genders between the timepoints before, during, and after the COVID-19 pandemic?

2. Do academic and social/emotional stress levels in engineering students differ across genders between the COVID-19 pandemic and post-pandemic timepoints?

Methods

This study explores a subset of six years of survey data collected at thirteen different timepoints which can be categorized into the following three time periods: pre-pandemic, pandemic, and post-pandemic. These time periods are defined based on how our university responded to the pandemic and how the students and faculty likely perceived the academic experience. The pre-pandemic period includes all time prior to the spring semester of 2020. During this time period, all engineering courses (lectures, laboratories, capstone projects, etc.) were conducted fully in-person.

For this study, the pandemic time period is considered to span four semesters, beginning in the spring of 2020 through the fall semester of 2021. The spring 2020 semester started in-person but after spring break in March of 2020 abruptly transitioned to online learning where all classes, labs, and design activities were conducted remotely. Faculty with little to no training on how to teach online had to adapt course materials and delivery with only a week's notice. Students had to adapt their learning styles to a new online environment when classes resumed after spring break. The remainder of the spring 2020 semester was completed fully online and summer 2020 courses continued remotely.

The 2020-21 academic year continued to be impacted by the pandemic. Starting in the fall semester of 2020, the engineering program adopted a hybrid model for courses that complied with the university's COVID guidelines; restricting the number of people that could be in a room at the same time, with additional specifications related to social distancing. The engineering program's hybrid model for each course included up to three different formats per course. Depending on the size of the class and the size of the room, the students in each class were split into sub-groups that rotated locations with each lesson. One group was in the same physical classroom as the instructor, another group was also in-person but in a room down the hall with a live video feed of the instructor, and a third group participated virtually on Zoom. For example, in a course with 30 students, on a given lesson day, 10 students would be in the classroom with the instructor, 10 would be in another room with the live video feed of the instructor projected, and the remaining students would be completely virtual, participating from their dorm rooms. COVID testing for all students and faculty was required on campus from the spring of 2020 until the spring of 2021. While the university returned to fully in-person classes, without overflow rooms, in the fall semester of 2021, the university still followed some of the COVID procedures including fully masking. Thus, the pandemic period defined in this work begins in the spring of 2020 and continues through the fall of 2021.

The post-pandemic time period for this study begins in the spring semester of 2022 and continues to the spring of 2024. In the spring 2022 semester the university resumed "normal" operations with all courses fully in-person, without a masking or COVID testing requirement, and no split classrooms.

Study Procedure

The measures for this study were reviewed and approved by the Human Subjects Review Board (HSRB). Surveys were distributed via email to all engineering students using the engineering student listserv. The email included a link to a Qualtrics survey, and engineering instructors encouraged students to participate, emphasizing that participation was voluntary and anonymous. Surveys were administered twice each academic year, in the fall and spring semesters, beginning in fall 2018 and continuing through spring 2024. An additional survey was conducted in the summer of 2020, totaling thirteen surveys overall. Each survey remained open for approximately two weeks, after which responses were de-identified for analysis. To incentivize participation, students received Amazon gift cards ranging from $20 to $30, with additional rewards for completing the survey across multiple timepoints. The survey measures were the same each time the survey was administered, with the exception of the addition of the COVID related stressor questions which were added in the summer of 2020 and remained in the survey through the spring 2024 timepoint.

Participant Demographics

All engineering students at our institution were eligible for participation in the study. The engineering program at this small private university typically enrolls around 300 total students. The program awards Bachelors of Science degrees in Engineering, where students can select from an array of specialization areas including civil, computer, electrical, environmental, mechanical, or a custom area. Within the program, approximately 25% of the students identify as women. The program majority also consists of traditional four-year college students and the student body is majority White.

Table 1 summarizes the demographics of all the survey participants from all of the thirteen surveys administered between the fall of 2018 and the spring of 2024. Survey demographics from each individual time point can be found in the Appendix. Survey demographics are similar to the program demographics, with slightly higher participation from the women-identified student population than the men-identified students. It should be noted that there were students who did not identify as women or men, but their population was too small to explore trends in their identity group. Therefore, this study focuses on only the responses from women and men identified students throughout the survey timepoints.

Table 1. Summary of survey participant demographics from thirteen surveys administered from Fall 2018 to Spring 2024.

Category	Survey Selection	Average	Min	Max
Total n	-	90.7	51	158
Gender	Woman	32%	25%	41%
	Man	66%	55%	73%
	Transwoman	0%	0%	1%
	Transman	0%	0%	2%
	Nonbinary	0%	0%	1%
Race/ethnicity	Caucasian/White	84%	74%	94%
	African American/Black	1%	0%	6%
	Asian/Pacific Islander	4%	1%	8%
	Hispanic/Latino/Chicano	4%	2%	8%
	Middle Eastern	0%	0%	1%
	Other	4%	0%	10%
Class standing	First-year	22%	4%	34%
	Sophomore	22%	13%	36%
	Junior	26%	19%	33%
	Senior	25%	16%	36%
	Other	3%	0%	22%
Specialization	Civil	22%	19%	24%
	Computer	4%	0%	9%
	Electrical	13%	6%	19%
	Environmental	4%	1%	9%
	Mechanical	46%	39%	51%
	Custom	6%	1%	15%

LAESE (Longitudinal Assessment of Engineering Self-Efficacy)

The Longitudinal Assessment of Engineering Self-Efficacy (LAESE) is a tool for measuring the engineering-specific self-efficacy of undergraduate and graduate students [14, 15, 16]. It has been normed and validated with engineering students and is employed by researchers examining self-efficacy in a variety of engineering programs from large public universities to small private colleges [10, 11, 14, 17, 18]. The thirty-one survey items encompass several dimensions of self-efficacy, including outcome expectations, workload management, major selection, coping strategies, career exploration, and the influence of role models. Additionally, the survey considers students' experiences both within and outside the classroom, such as extracurriculars and jobs.

The instrument consists of six subscales, calculated by averaging responses on a 7-point Likert scale (1 = strongly disagree, 7 = strongly agree) for various prompts:

1. Engineering Career Success Expectations

    This subscale includes 7 items measuring respondents' expectations of success in an engineering career. Examples include “A degree in engineering will allow me to get a job where I can use my talents and creativity,” and “someone like me can succeed in an engineering career.”

2. Engineering Self-Efficacy 1

    Prompts from this subscale assess students' perceptions of their future success in engineering, with 5 items such as “I can succeed in an engineering curriculum”, “I will succeed (earn an A or B) in my math courses” and “I will succeed (earn an A or B) in my engineering courses.”

3. Engineering Self-Efficacy 2

    This subscale evaluates students' confidence in completing required components of an engineering degree. It includes 6 items such as “I can complete any engineering degree at this institution” and “I can persist in an engineering major during the next year.”

4. Feelings of Inclusion

    Questions in this subscale explore students’ feelings of inclusion within the field of engineering, using 4 items. For example, “The other students in my classes share my personal interests” and “I can relate to the people around me in class.”

5. Coping Self-Efficacy

    Focusing on students’ coping strategies in challenging situations, this subscale consists of 6 items, including “I can cope with not doing well on a test” and “I can approach a faculty or staff member to get assistance.”

6. Math Outcome Expectations

    This subscale measures students' expectations regarding the outcomes of math-related efforts. It includes 3 items such as “Doing well at math will enhance my career/job opportunities” and “doing well at math will enhance my career/job opportunities.″

COVID Screener

The study of students’ risk and resiliency in our engineering program began pre-pandemic in the fall of 2018 and continued into the post-pandemic era with a final survey point in the spring of 2024. This timespan presents a unique opportunity to measure pandemic-related effects on students’ mental health. After pivoting to remote learning midway through the spring 2020 semester, a unique summer survey was administered in mid-June, including newly added screener questions to assess students’ stress levels as a result of the pandemic.

The COVID-19 Family Stress Screener [19] was adopted and expanded to measure students’ feelings of pandemic induced stress. The first ten prompts were drawn from the COVID-19

Family Stress Screener and an additional ten prompts were written by the authors of this study. Bock's original ten prompts are related to social/emotional factors, while the latter ten survey items address academics. All twenty of the COVID-19 screener questions remained in the larger survey for the remainder of the study's duration. The twenty survey prompts are listed in Table 2, categorized into two subscales; social/emotional and academics.

Each prompt started with the phrase: *"Because of COVID-19 related events and changes, I have felt increased stress about…"* Responses were collected using a Likert-type scale (1 = strongly disagree, 5 = strongly agree).

Table 2. Questions included in the COVID measure adapted for this study

Because of COVID-19 related events and changes, I have felt increased stress about:		
Social/ Emotional	1	Food running out or being unavailable:
	2	Losing a job or decrease in family income
	3	Housing or utilities
	4	Loss of or limited childcare
	5	Taking care of children, including those who are normally in school
	6	Tension or conflict between household members
	7	Physical health concerns for me or a family member
	8	Increased anxiety or depression
	9	Reminders of past stressful/traumatic events
	10	Loss of social connections, social isolation
Academics	11	Not being in my academic classes
	12	What my academic future will hold
	13	If I will be able to return to school in the fall because of financial reasons
	14	If I will be able to return to school in the fall because of public health reasons
	15	Connecting with my faculty for class related concerns
	16	Connecting with my faculty for mentorship related topics
	17	Not learning as well in an online classroom
	18	Falling behind in content material that we will build on in future semesters
	19	That my grades from on-line learning will be problematic
	20	Connecting with classmates to collaborate on assignments

Data Analysis

Survey data were collected in Qualtrics and exported to Excel spreadsheets. Data were deidentified to maintain student anonymity. The six LAESE subscale scores were calculated according to the instructions provided by [16], at each of the 13 survey timepoints, separately for women and men. Similarly, the quantitative Likert-type scale responses to the COVID-19 Screener were analyzed at each of the 9 survey timepoints comparing pandemic and post-pandemic periods. These data were also computed separately for women and men. Mean values for LAESE subscales, COVID social/emotional prompts, and COVID academic responses were calculated at each timepoint of data collection, separately for women and men. Figures were created to visualize trends in responses over time, by gender. To determine where differences between genders, and changes over time, were statistically significant, paired sample t-tests were conducted in Excel.

Results

Engineering Self-Efficacy

Students' responses to the LAESE survey items were collected using a 7-point Likert scale (1 = strongly disagree, 7 = strongly agree). The survey prompts were posed in a positive way, for example "I can succeed in an engineering curriculum," such that higher scores indicate stronger feelings of achieving career success, self-efficacy, feelings of inclusion, etc.

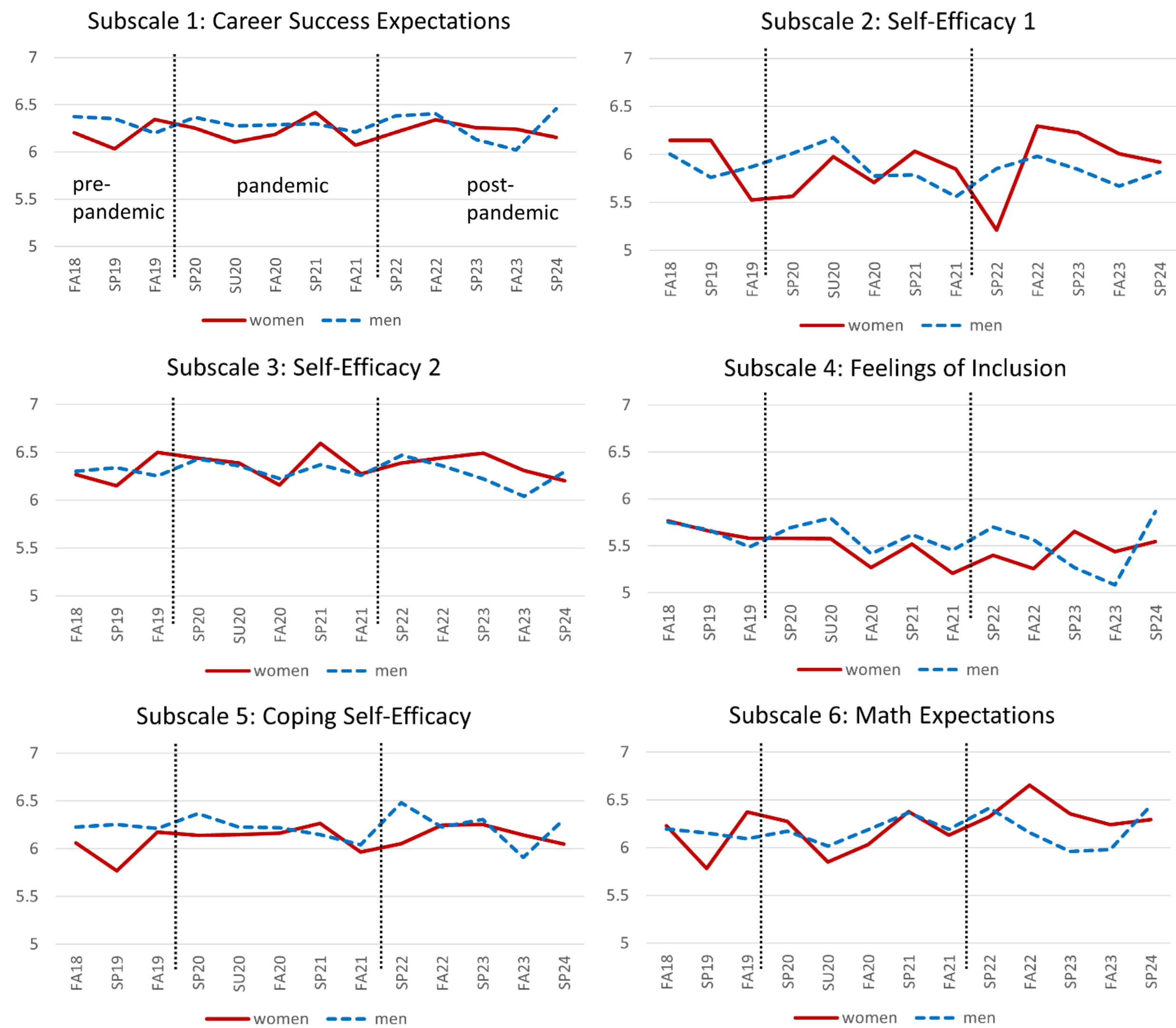

Figure 1. Mean values for LAESE subscale scores across time for women (solid red line) and men (dashed blue line). *Responses collected with a 7-point Likert-type scale (1 = strongly disagree, 7 = strongly agree).*

The mean value for each of the six LAESE subscales – career success expectations, self-efficacy 1, self-efficacy 2, feelings of inclusion, coping self-efficacy, and math expectations – are shown for men and women across all thirteen timepoints in Figure 1. Vertical lines mark the transition points between the three main time periods explored in this study, pre-, pandemic, and post-pandemic. These time periods are defined by the changing modality of teaching and learning at each of the 13 timepoints between the fall of 2018 and spring of 2024, the first and last surveys, respectively.

To further examine gender differences across the subscales, paired sample t-tests were conducted with the null hypotheses that population means are equal between men and women. Table 3 uses single and double asterisks to denote significant ($p < 0.05$) and highly significant differences ($p < 0.01$), respectively. The p-values in each comparison fell above 0.05, indicating no significant differences between the genders for any of the six LAESE subscales when the results from all timepoints were aggregated.

Table 3. Results of Paired Sample t-tests for LAESE subscale scores between women and men.

LAESE Subscale	Women: Average Score	Men: Average Score	p-value
1: Engineering Career Success Expectations	6.218	6.282	0.201
2: Engineering Self-Efficacy 1	5.871	5.841	0.771
3: Engineering Self-Efficacy 2	6.360	6.302	0.282
4: Feelings of Inclusion	5.473	5.551	0.334
5: Coping Self-Efficacy	6.113	6.224	0.072
6: Math Outcome Expectations	6.224	6.178	0.586

Note: * and ** would indicate significant ($p < 0.05$) and highly significant ($p < 0.01$) differences between mean scores. No significant differences were found here.

Next, paired t-tests were run to compare differences in each gender's LAESE subscale scores between the three major time periods of this study – pre-pandemic, pandemic, and post-pandemic. The results of three paired sample t-tests for each of the women's subscale scores are shown in Table 4. Paired t-tests compared pre- to pandemic, pre- to post-pandemic, and pandemic to post-pandemic periods. In each comparison, the p-values were above 0.05 indicating that no significant differences exist between LAESE subscale scores across any of the three timepoints for women.

Table 4. Results of Paired Sample t-tests for LAESE subscale scores among women.

	Pre- to pandemic			Pre- to post-pandemic			Pandemic to post-		
LAESE Subscale	Time point	Mean	p-value	Time point	Mean	p-value	Time point	Mean	p-value
1: Engineering Career Success Expectations	Pre	6.188	0.960	Pre	6.188	0.612	Mid	6.196	0.566
	Mid	6.196		Post	6.249		Post	6.249	
2: Engineering Self-Efficacy 1	Pre	5.835	0.811	Pre	5.835	0.300	Mid	5.891	0.103
	Mid	5.891		Post	6.111		Post	6.111	
3: Engineering Self-Efficacy 2	Pre	6.323	0.873	Pre	6.323	0.810	Mid	6.353	0.949
	Mid	6.353		Post	6.360		Post	6.360	
4: Feelings of Inclusion	Pre	5.618	0.179	Pre	5.618	0.321	Mid	5.392	0.542
	Mid	5.392		Post	5.472		Post	5.472	

5: Coping Self-Efficacy	Pre	5.971	0.351	Pre	5.971	0.236	Mid	6.135	0.655
	Mid	6.135		Post	6.172		Post	6.172	
6: Math Outcome Expectations	Pre	6.077	0.937	Pre	6.077	0.248	Mid	6.098	0.091
	Mid	6.0983		Post	6.386		Post	6.386	

Note: * and ** would indicate significant ($p < 0.05$) and highly significant ($p < 0.01$) differences between mean scores. No significant differences were found here.

Similarly, t-tests between the three major time periods were conducted for men's LAESE subscale scores, with results shown in Table 5. These results also revealed no significant differences across any time period for any of the LAESE subscales for men.

Table 5. Results of Paired Sample t-tests for LAESE subscale scores among men.

	Pre- to pandemic			**Pre- to post-pandemic**			**Pandemic to post-**		
	Time point	**Mean**	**p-value**	**Time point**	**Mean**	**p-value**	**Time point**	**Mean**	**p-value**
1: Engineering Career Success Expectations	Pre	6.276	0.891	Pre	6.276	0.899	Mid	6.268	0.898
	Mid	6.268		Post	6.254		Post	6.254	
2: Engineering Self-Efficacy 1	Pre	5.814	0.966	Pre	5.814	0.908	Mid	5.823	0.980
	Mid	5.823		Post	5.827		Post	5.827	
3: Engineering Self-Efficacy 2	Pre	6.297	0.917	Pre	6.297	0.563	Mid	6.304	0.379
	Mid	6.304		Post	6.230		Post	6.230	
4: Feelings of Inclusion	Pre	5.577	0.968	Pre	5.577	0.641	Mid	5.571	0.536
	Mid	5.571		Post	5.445		Post	5.445	
5: Coping Self-Efficacy	Pre	6.232	0.324	Pre	6.232	0.770	Mid	6.158	0.791
	Mid	6.158		Post	6.187		Post	6.187	
6: Math Outcome Expectations	Pre	6.124	0.574	Pre	6.124	0.952	Mid	6.190	0.690
	Mid	6.190		Post	6.135		Post	6.135	

Note: * and ** would indicate significant ($p < 0.05$) and highly significant ($p < 0.01$) differences between mean scores. No significant differences were found here.

Pandemic Stressors

Students responded to the twenty COVID Screener prompts using a 5-point Likert-type scale (1 = strongly disagree, 5 = strongly agree). In this tool, the prompts were posed in a more negative light, such as "*Because of COVID-19 related events and changes, I have felt increased stress about…* Not learning as well in an online classroom." Therefore, higher scores from the COVID Screener indicate heightened levels of stress.

The average responses to each of the twenty screener questions was computed across all time, separately for women and men. The results are shown in Figure 2, grouped thematically by social/emotional (left) and academic (right) prompts.

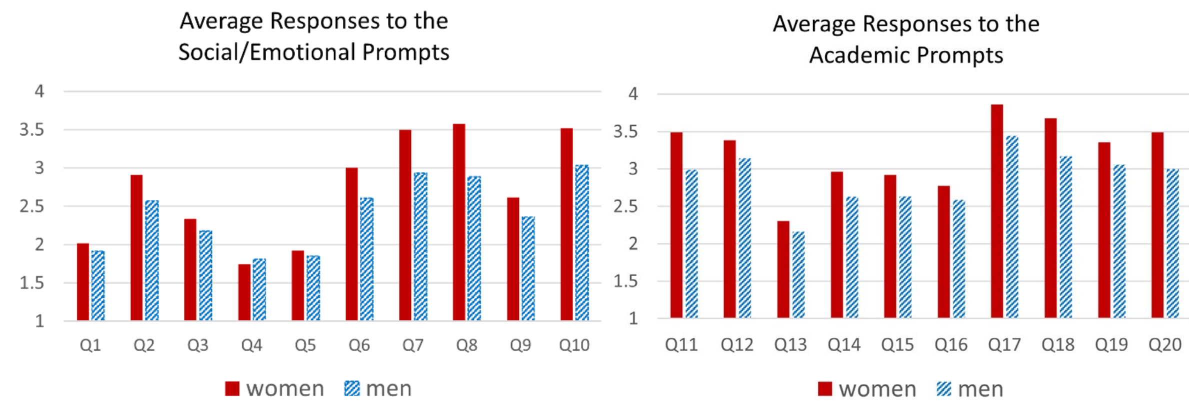

Figure 2. Average responses to each of the COVID Screener prompts by gender. The survey items are grouped into two categories; social/emotional (left) and academic (right). Responses collected with a 5-point Likert-type scale (1 = strongly disagree, 5 = strongly agree).

Average response values were calculated for survey prompts 1-10, related to social/emotional factors at each of the 9 survey timepoints that included the COVID Screener. Similarly, average responses were computed for prompts 11-20 that queried students' stress levels related to academics, at each survey timepoint. In both cases the averages were determined separately for women and men. These thematic averages are shown as a function of time in Figure 3, with the social/emotional and academic results on the left and right, respectively.

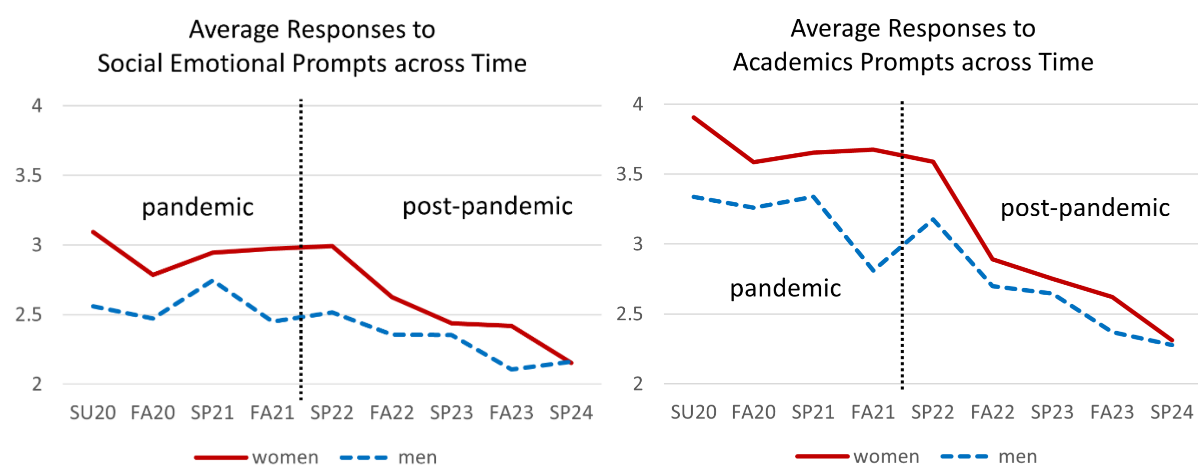

Figure 3. Average responses to social/emotional and academic prompts from the COVID Screener tool as a function of time, for women and men.

To test for significance in changing trends over time, as well as across differences, multiple sets of t-tests were run. In all cases, tests were performed with the null hypothesis that population means are equal – between timepoints or between genders, depending on the comparison.

First, the effects of time were examined by comparing differences in responses between pandemic survey timepoints and post-pandemic. These paired sample t-tests were run separately for responses in the social/emotional category and academic umbrella, as well as individually for women and men. Here, four t-tests were run to explore the significance of time on students' feelings of stress related to COVID-19. The results are presented in Table 6. indicate highly significant decreases were found in three tests; women's scores for social/emotional and academic, as well as men's academic scores. A significant decrease was found for men's social/emotional stress levels.

Table 6. Results of Paired Sample t-tests among women and among men, comparing mean scores with time: pandemic and post-pandemic.

	Women			**Men**		
Category	**Pandemic mean score**	**Post-pandemic mean score**	**p-value**	**Pandemic mean score**	**Post-pandemic mean score**	**p-value**
Social/emotional	2.967	2.529	0.007**	2.574	2.302	0.011*
Academic	3.692	2.813	1.05E-09**	3.183	2.620	3.5E-07**

Note: * and ** indicate significant ($p < 0.05$) and highly significant ($p < 0.01$) differences between mean scores from women and men, respectively.

Gender differences were tested for significance by performing further paired sample t-tests, examining how responses compared during and the pandemic and then in the post-pandemic period. Again, responses were explored along thematic lines, differentiating between social/emotional and academic prompts. Results for these four t-tests are shown in Table 7. The results showed that during the pandemic women experienced significantly higher levels of social/emotional stress, while their academic stress was greater than men's in a highly significant way. In the post-pandemic period, women's social emotional/stress remained significantly higher than men's, but no difference was found between genders for academic stress.

Table 7. Results of Paired Sample t-tests comparing mean scores between women and men during the pandemic and post-pandemic.

	Pandemic			**Post-Pandemic**		
Category	**Women**	**Men**	**p-value**	**Women**	**Men**	**p-value**
Social/emotional	2.967	2.574	0.016*	2.529	2.302	0.047*
Academic	3.692	3.183	5.27E-05**	2.813	2.620	0.087

Note: * and ** indicate significant ($p < 0.05$) and highly significant ($p < 0.01$) differences between mean scores from women and men, respectively.

Discussion

Survey results collected from undergraduate engineering students over a six-year time period (thirteen timepoints), showed no statistically significant gender differences in engineering self-efficacy as measured by LAESE. Gender differences were explored for each of the measurement's six subscales, and there was no significant difference when the survey time points were aggregated together over time. Over the six years, there were also no statistically significant changes in measures of women or men's engineering self-efficacy pre-pandemic to pandemic, pandemic to post-pandemic, or pre- to post-pandemic. For this study, pre-pandemic was defined as fall 2018 through fall 2019, pandemic was defined as spring 2020 through spring 2021, and post-pandemic was defined as fall 2021 through spring 2024. These results are consistent with other studies that measured self-efficacy of engineering students around the time of the pandemic [9, 12].

However, there were statistically significant gender differences during each time period of student COVID-19 related academic and social/emotional stressors, as measured by the COVID screener. On average, during the pandemic and post-pandemic time periods, women and men both reported higher academic stress than social/emotional stress. Women students typically reported higher social/emotional and academic stress levels then the men during the pandemic and into the post-pandemic period. During the pandemic, women's social and emotional stressors averaged 2.967 (on a scale of 1-5) which was statistically significantly higher than the average reported for men during the pandemic (2.574). During the pandemic, women also reported much greater academic stress (3.692 on average) than the men (3.183) and this difference was highly significant. Post-pandemic, women's social and emotional stressors were still significantly greater, averaging 2.529 while men's averaged 2.302. Women's post-pandemic academic stressors averaged 2.813, and were not any statistically different from men's average (2.620) during this time post-pandemic.

Both women and men's academic and social/emotional stress peaked during the pandemic and declined post-pandemic. The women's social/emotional and academic stressors both decreased (with high significance) from the pandemic to post-pandemic. The average social/emotional stressors for women decreased from 2.967 during the pandemic to 2.529 post-pandemic. The average academic stressors for women decreased from 3.692 during the pandemic to 2.813 post-pandemic. The men's social/emotional stressors significantly decreased from 2.574 to 2.302 during the pandemic to post-pandemic time periods, respectively. The men's academic stressors also decreased (with high significance) from 3.183 to 2.620 during the pandemic to post-pandemic time periods, respectively.

A key limitation of this study was the lack of racial and ethnic diversity within the engineering program, where on average the survey respondents were 84% White (range of 74% to 94% among all thirteen surveys). Additionally, the student population at this small private liberal arts university primarily consisted of traditional students aged 18-22 who entered college directly after high school. This homogeneity may limit the generalizability of the findings, as the results may not apply to groups with greater racial or ethnic diversity, greater socioeconomic differences, or to older more nontraditional student groups. Women students were also overrepresented in the survey, with 32% of respondents identifying as women (range was 25% to 41%) compared to the 20% representation within the overall engineering program. Although there may be relationships between the academic and social/emotional stressors during COVID-19 and engineering self-efficacy, this paper did not explore such relationships. Instead, the focus was on understanding how these measurements differed between genders during time points and how they changed for each gender changed pre-, during, and post-pandemic. Despite these limitations, the results highlight engineering self-efficacy for engineering students before, during, and after the COVID-19 pandemic and how academic and social/emotional stress related to college life changed during the pandemic and after.

Conclusions

Engineering students' survey responses from a six-year study, including thirteen timepoints, were analyzed here to address two research questions.

The first research question focused on measuring differences in engineering self-efficacy between women and men, as well as across the timepoints spanning from before, during, and after the COVID-19 pandemic using the LAESE instrument [15]. Equal population means were found for women and men's feelings of engineering self-efficacy across all six LAESE subscales. Engineering self-efficacy among the students in our program was not a gendered experience. Additionally, by chance, the survey captured the onset and multi-year duration of the COVID-19 pandemic, but investigations of longitudinal changes in self-efficacy showed no statistically significant findings. Neither men nor women's self-efficacy changed significantly as a result of the pandemic, compared to non-pandemic times.

The second research question addressed whether social/emotional and academic stressors beginning with the onset of the COVID-19 pandemic and continuing to the final, post-pandemic, timepoint differed between genders, or over time. Prior research of student emotional well-being during the pandemic has indicated higher levels of anxiety and stress among women students compared to men [19, 20]. Research has also suggested that baseline stress levels may also be greater in women than men [21]. In this study, both social/emotional and academic stressors for women and men were found to decrease significantly between pandemic and post-pandemic periods, in some cases with high significance. Further, women's stress levels were higher than their male counterparts during both pandemic and post-pandemic periods, with the exception of academic stressors in the post-pandemic period. Perhaps this shows that in non-pandemic times, men and women are equally stressed by academic factors, but the women carry a higher social/emotional stress load while maintaining the same level of engineering self-efficacy.

It is worth noting that our engineering program went to some extremes to maintain in-person classes while still complying with very restrictive university policies to maintain health and safety. For example, the three-way hybrid model, weekly to bi-weekly COVID testing, access to faculty office hours, etc., may be somewhat unique to our engineering program's handling of teaching and learning during the pandemic. Perhaps these factors buffered for longitudinal changes in self-efficacy. Another caveat of this study is relative lack of diversity in the survey participants (and student population in general), where most students identify as White and are predominantly traditional students who enter college directly from high school. Previous research has indicated that students of color report significantly higher levels of stress and anxiety than their peers compared to White students [20].

While the results presented in this paper focus on the unique period surrounding the COVID-19 pandemic, the findings can be extended to the future of engineering education, for example online learning. Examination of the average responses to the academic COVID screener questions shown in Figure 3 shows the highest averages (largest amount of stress) for questions 17-18; "Not learning as well in an online classroom," "Falling behind in content material that we will build on in future semesters," "That my grades from on-line learning will be problematic," and "Connecting with classmates to collaborate on assignments." Moreover, the averages were all higher for women than for men in these questions. It points to students' worry over many components of the online learning environment, while the last prompt speaks to the concern about an inability to connect with peers. While both women and men's scores demonstrated high levels of stress surrounding community-related prompts, the women's averages were consistently higher. Perhaps then, a sense of community is something educators can aim to foster, in particular for underrepresented students and in both online and in-person learning environments.

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Appendix: Survey Participant Demographics

			Gender					Race/ethnicity						Class standing				
		Total Participants	Woman	Man	Transman	Transwoman	Nonbinary	Caucasian/ White	African American/Blac	Asian/ Pacific Islander	Hispanic/ Latino/Chicano	Middle Eastern	Other	First-Year	Sophomore	Junior	Senior	other
Fall	n	158	39	116	1	0	2	147	3	4	3	1	1	54	27	44	25	
2018	%	100%	25%	73%	1%	0%	1%	93%	2%	3%	2%	1%	1%	34%	17%	28%	16%	
Spring	n	94	37	57	0	0	0	87	0	2	4	1	0	15	24	30	16	
2019	%	100%	39%	61%	0%	0%	0%	93%	0%	2%	4%	1%	0%	16%	26%	32%	17%	
Fall	n	113	36	76	0	1	0	106	0	2	4	0	0	29	15	29	36	
2019	%	100%	32%	67%	0%	1%	0%	94%	0%	2%	4%	0%	0%	26%	13%	26%	32%	
Spring	n	91	27	63	0	1	0	84	0	3	3	0	0	23	15	24	26	
2020	%	100%	30%	69%	0%	1%	0%	92%	0%	3%	3%	0%	0%	25%	16%	26%	29%	
Summe	n	95	31	61	0	1	0	84	0	1	3	1	1	4	16	18	34	21
r 2020	%	100%	33%	64%	0%	1%	0%	88%	0%	1%	3%	1%	1%	4%	17%	19%	36%	22%
Fall	n	124	37	80	2	1	0	100	2	1	8	0	7	24	35	28	32	2
2020	%	100%	30%	65%	2%	1%	0%	81%	2%	1%	6%	0%	6%	19%	28%	23%	26%	2%
Spring	n	57	15	40	0	0	0	49	0	2	1	0	3	14	11	14	16	0
2021	%	100%	26%	70%	0%	0%	0%	86%	0%	4%	2%	0%	5%	25%	19%	25%	28%	0%
Fall	n	99	26	67	1	1	0	82	1	3	2	1	6	29	26	22	19	0
2021	%	100%	26%	68%	1%	1%	0%	83%	1%	3%	2%	1%	6%	29%	26%	22%	19%	0%
Spring	n	72	19	52	0	0	0	59	0	1	6	0	5	7	26	23	15	0
2022	%	100%	26%	72%	0%	0%	0%	82%	0%	1%	8%	0%	7%	10%	36%	32%	21%	0%
Fall	n	51	16	35	0	0	0	38	2	3	3	0	5	10	11	17	12	1
2022	%	100%	31%	69%	0%	0%	0%	75%	4%	6%	6%	0%	10%	20%	22%	33%	24%	2%
Spring	n	72	28	43	0	0	0	55	2	6	3	0	5	18	14	22	16	1
2023	%	100%	39%	60%	0%	0%	0%	76%	3%	8%	4%	0%	7%	25%	19%	31%	22%	1%
Fall	n	85	35	47	0	0	0	64	1	6	3	0	5	21	18	19	24	0
2023	%	100%	41%	55%	0%	0%	0%	75%	1%	7%	4%	0%	6%	25%	21%	22%	28%	0%
Spring	n	68	26	41	0	0	0	50	4	4	4	0	5	18	14	14	19	2
2024	%	100%	38%	60%	0%	0%	0%	74%	6%	6%	6%	0%	7%	26%	21%	21%	28%	3%