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Impact of COVID 19 on Self-efficacy and Retention of Women Engineering Students

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Introduction

In today's society, companies continue to need college graduates with expertise in STEM fields. In fact, the number of bachelor's degrees in engineering has steadily increased since 2000 [1] due to a high need of skilled engineers in today's workforce. In the United States, women represent half of the population, nearly 47% of the workforce and approximately 57% of the bachelor's degrees awarded each year [2]. However, women comprise only 20% of bachelor's degrees in engineering fields [1] and represent less than 20% of the domestic engineering workforce [3]. This discrepancy can be attributed to several factors, making engineering professions seem less desirable to women [4].

As Higher Education Institutions continue to strive to support the demand for individuals to enter the intellectually rigorous STEM career paths, increased recruitment and retention of women engineering students is of critical importance. However, self-efficacy, or one's personal belief in ability, has been previously identified as a primary barrier when recruiting women in engineering and encouraging persistence through their degree and into an engineering field. Programs aimed at increasing retention of women in engineering programs mainly focus on interventions which have been shown in increase self- efficacy. Many of these programs involved interpersonal communication, through individual meetings and group activities. With the onset of the COVID-19 pandemic, such activities have changed.

As a result of the COVID-19 pandemic, most educational institutions have made changes to their extracurricular programs such as mentoring, student clubs and other support structures. While these programs are valued for their ability to increase retention of women in engineering programs, many of these activities have been either temporarily canceled, permanently removed or migrated to a virtual platform at institutions across the nation [5] – [7].

Numerous institutions have used platforms such as Zoom or Microsoft Teams to create virtual environments to replace face-to-face structures, but are these measures as impactful in retaining women engineering students? Do the virtual measures foster the same levels of self-efficacy in women engineering students as the previously offered face-to-face interactions? Do women engineering students feel additional isolation from their peer group and perhaps question their career path when faced with an increased amount of online presence and the removal of critical programs aimed at increasing retention?

While it is impossible to know the long-term impact on women engineering students due to the pandemic, it is possible to measure the immediate change in self-efficacy, sense of belonging and confidence in program of study. This study measured changes in self-efficacy, belonging and confidence of undergraduate women engineering students at a midwestern university to better understand the immediate impact of the pandemic on retention of women in engineering.

Review of Literature

Self-efficacy can be defined as "an individual's perceived level of competence or the degree to which she or he feels capable of completing a task" [8]. In an academic program, self-efficacy impacts choosing a plan of study that aligns with a desired profession that you anticipate joining

after obtaining your degree. In this way, self-efficacy has direct impact on the recruitment of women into engineering programs of study, as women must first see themselves as a successful engineer before committing to an engineering major. Additionally, self-efficacy is demonstrated in individual courses, as students choose classes and approach their coursework with varying degrees of confidence or anxiety. The attitudes demonstrate how self-efficacy impacts student retention, as students must persist in their studies, despite potential challenges or setbacks.

The role of self-efficacy impacts the attitudes and perceptions about career paths and academic plans of study for all students. However, self-efficacy does not impact women and men in the same way; in engineering programs, this difference can account for the gender gap both in recruitment and retention of engineering students. Numerous studies have shown lower self-efficacy in women in engineering than their male peers [8] – [13]; with great consistency, the research in this area demonstrates that women in engineering are capable of success, but often suffer higher levels of doubt, anxiety and stress regarding their engineering coursework. There are multiple factors influencing this gender difference, including but not limited to: lack of women faculty for mentoring and acting as role models [14], [15]; ongoing gender-based stereotypes and bias in STEM fields by both men and women [8], [9], [10], [16]; workplace habits that reinforce gendered work assignments [10], [13] and lack of community to provide encouragement and support throughout the program [2], [4], [10], [14], [15].

The focus on self-efficacy is based on studies that have shown a direct relationship between retention of women in engineering programs and self-efficacy. The more women believe in their abilities and can visualize themselves as successful engineering students and professionals, the higher the persistence and retention rates [2], [4], [8], [11], [15], [17]. In fact, one study showed that 90% of students who graduated from an engineering program had declared engineering as their major prior to attending the institution, regardless of gender [12]. In other words, students rarely transfer into an engineering program from another major. If a student does not come to the institution in mind, they will rarely change to an engineering program, often due to perceptions of engineering being too hard for most students [12]. This highlights the need for creating a sense of self-efficacy in young women to pursue engineering. If they have not made that choice during their time in elementary and secondary education, it is doubtful they will decide to join engineering programs later. This also emphasizes the need of supporting a vision as a professional engineer in each student, to retain them within the engineering program. Students come to the program wanting to be engineers, but the rigorous coursework and other challenges can cause them to leave the program for other studies, often transferring to other STEM programs [12]. Unfortunately, women in engineering programs often face gender isolation, bias from professors and lack of role models within the engineering profession which add to the challenges every engineering student faces in their academic studies [2], [6], [15], [17].

Based on these concerns, numerous studies across varying institutions have listed best practices for retention of female engineering students including faculty mentoring programs, assistance in academic coursework, extra-curricular activities, female industry mentors and other interventions [4], [15], [16], [17], [18]. Each of these interventions has the intention of increasing self-efficacy by increase a sense of community, providing a vision for a career after completing their education and encouragement through the barriers encountered during their engineering studies. As women comprise a small percentage of the engineering student body, these close relationships can be the largest factor in completion of their engineering degree [4].

Women engineering students with mentors reported higher levels in a sense of belonging in their program of study, lower levels of anxiety in their coursework and had higher levels of motivation for both their academic studies and future career plans. This is partly due to mentors supporting engineering students in developing their own professional identity which directly impacts long term persistence both in their studies and in their careers [2],[15],[17]. Other studies have shown great effectiveness of mentoring students early in their academic career, to better establish self-efficacy and establish personal practices necessary to be successful in rigorous engineering coursework later in their academic programs [2], [17], [18]. Mentoring can include formal programs established with assigned peer, faculty, alumni or industry mentors, but can also include informal programs like student organizations, living learning communities, shared workspaces and woman-focused events. While formal mentoring can ensure a given frequency of meeting or set of activities, much of the community experience is drawn from informal mentoring relationships [9].

Studies evaluating interventions for women in engineering programs have shown great increases in retention, attributing much of the success to an increase in self-efficacy [2], [15], [17]. However, the onset of the COVID-19 pandemic caused a significant shift in extracurricular activities of all kinds. Typical closures included the elimination of face-to-face social activities, migration of coursework to online platforms, reduction of student services and elimination or alteration of student organizations [5] – [7]. These changes to programming or elimination of services alters the very support structures shown to be effective in retaining women in engineering programs. While the health and safety of the student body is critical, mental and emotional health have suffered due to changes in academic structures brought on by campus responses to the pandemic [5].

The long-term impact of the pandemic on students is not yet known, however, studies surveying college students enrolled during the pandemic have all documented increases in stress and anxiety. One worldwide studied stated that the loss of routine and social connections caused an increase in pre-existing mental health issues in 83% of respondents [5]. Another study reported high levels of anxiety and specific fears of inadequate progress in their academic studies [6]. Additional concerns over health, finances, future employment and family members contribute to symptoms of anxiety and depression in students [6], [7] leading to lower mental wellbeing and higher rates of abuse of alcohol [7].

These issues may not have immediate resolution, as campus continue the COVID-19 protocols established during the spring of 2020. At one midwestern campus, courses being planned for the fall remain hybrid with socially distant seating and many support systems remain virtual or synchronous using Zoom technologies. Understanding the immediate impact on women in engineering studies is crucial to strategic efforts in retention, despite the pandemic.

Methodology

The goal of this research was to investigate if the COVID-19 pandemic would potentially impact the retention of women in engineering programs. Rather than wait several years and evaluate retention and graduation rates pre and post COVID-19, the author sought to better understand the current psyche of women in engineering programs amid the pandemic. To accomplish this, the author chose attributes directly impacting the retention of women in engineering programs, as previously established by research. These attributes include the sense of belonging, self-efficacy and ability to maintain persistence in programs despite challenges or threats. In a study

conducted by Dennehy and Dasgupata, these attributes directly impact both retention and persistence into professional engineering fields [17].

Previous research in the area of retention of women in engineering had demonstrated the efficacy of a survey in determining a sense of belonging, self-efficacy, more motivation (challenge), and less anxiety (threat) through peer mentorship [17]. This study also demonstrated the reliability and validity of the survey tool to appropriately measure these attributes in undergraduate women in engineering programs. The study using this survey tool also demonstrated these attributes to appropriately measure areas impacting the retention of women in engineering programs and their intention to persist to the engineering career path [17]. This tool contained other questions directly applicable to peer mentoring relationships, which were not relevant to the work being done in this study, which were not included in this current work.

Therefore, the author used the survey questions focused on self-efficacy to better understand the change in attitudes or perceptions due to COVID-19, by asking students to rate their academic experience prior to the pandemic and currently, in the midst of the pandemic. The questions of the survey included topics of a feeling of belonging with their peers, the students' confidence in their ability to overcome challenges encountered in class, the students perceived levels of anxiety and stress caused by their engineering coursework and the students' confidence in becoming an engineer upon graduation.

This survey was administered during the 3rd consecutive semester of adjusted academic experiences due to the COVID-19 pandemic. Adjustments to instruction and campus life include but are not limited to: reduction in academic semester duration; required hybrid or online instruction; elimination of face-to-face students organization activities; elimination of face-to-face student mentoring programs; elimination of face-to-face tutoring and interventions; elimination of face-to-face office hours with professors; social distancing on all on-campus facilities (requiring 6-feet distances between all individuals); requirement of face masks at all times on campus. Wherever possible, face-to-face interactions were replaced by synchronous or asynchronous Zoom activities. While these interventions are consistent with other universities around the world [5] – [7], for this campus, it meant that nearly all efforts to support retention in women in engineering programs were either eliminated or adjusted to Zoom formats.

For this study, every woman enrolled in an engineering program at this small midwestern university was emailed with the request to participate in the study. Students were informed about the purposes of the research, the intent to publish results and the option of completing the survey anonymously. The survey was conducted using Google Forms and students were provided with the survey link embedded in the email invitation. Students were also informed that 1 in 10 students who completed the survey would be randomly selected to receive a $20 visa e-gift card. To participate in the drawing students had to include a valid email. However, all personal identifiers were removed prior to the review of data.

At this midwestern institution, there are currently 69 women enrolled in undergraduate engineering programs; this represents 14.8% of the enrollment total for the engineering department [19]. At the time of the study, the average retention rate of women in engineering programs into the third year of study is calculated to be 52.8% [19]. All 69 individuals were contacted with information about the research and the survey link. Of these 69 students, 47 completed the survey (n=47) providing a 68% response rate. While this study is from only one institution, the response rate provides a high reliability in the response to accurately portray the

impact of COVID-19 on women in engineering programs at this institution, across all other student demographics including class year and first-generation college attendance.

As previously stated, the survey questions used for this research were replicating the study of Dennehy and Dasgupta, both in content and in measurement scale [17]. For all questions in the survey, a 7-point Likert scale was used where respondents would rate whether they agreed or disagreed with the statement by indicating from 1(not at all true) to 7 (very true). While the questions each correspond to distinct attributes, the questions themselves were presented in a randomized order. The first portion of the survey instructed participants to answer from their academic experiences before the COVID-19 pandemic (pre-March 2020). The second portion of the study repeated the same questions (adjusted for present tense), in a randomized order, but instructed participants to rate their academic experience at this current time.

Results

Internal consistency for each grouping of questions was completed using Cronbach's alpha and compared to the work of the original study. The results were consistent with the study by Dennehy and Dasgupta, verifying the internal validity of the survey. Analysis of Likert-based data is typically considered to be categorical and not normally distributed [20]. Therefore, after descriptive statistics were computed for each group, the pre-post comparison was made using the Sign Test for Median of the difference of the pre-post response pairs, a methodology shown to be most effective when analyzing changes in responses using a pre-post methodology based on a Likert measurement scale [20].

Social Belonging. The first category of questions was to investigate social belonging. These questions were "I feel connected to my peers in engineering." and "I feel accepted by my peers in engineering." These two questions had the lowest internal consistency as measured by Cronbach's alpha ($\alpha = .69$ and .79, pre-COVID and post-COVID respectively). However, both questions showed a dramatic (statistically significant) fall in social connection due to COVID-19, with connection measuring at mean of 3.7 out of 7 and $p=0.034$ and 0.000, respectively. These results signify a decrease in social connection, due to changes in their academic experience brought about by the pandemic.

Challenge. The second category of questions investigate the challenge experienced by the participants. These questions are to measure one's confidence in themselves to rise to challenges and find success. This is one facet of self-efficacy, as it demonstrates the participants belief to overcome obstacles encountered while in pursuit of their goals. The questions included: "I feel I have what it takes to complete my engineering classes."; "I feel confident in my ability to perform well in my engineering classes."; "I feel confident in my basic skills and abilities to be successful in my engineering classes."; "I feel confident in my ability to overcome any difficulties experienced in my engineering classes." In this grouping, there was high internal consistency as measured by Cronbach's alpha ($\alpha = .88$ and .84, pre-COVID and post-COVID respectively). Additionally, other than the first question of this category, responses in this grouping remained consistent from before COVID to the present time (p-values ranging from 0.087 to 0.345). The question about completing their engineering coursework decreased in a statistically significant way (p-value of 0.015), showing potential concern in the students regarding their ability to complete their coursework. For the most part, participants remain confident in their abilities to rise to the challenge presented by their engineering coursework.

Threat. This third category of questions is the reverse of the challenge mentality. Rather than being confident in their abilities, these questions look to areas of uncertainty, anxiety and stress. These factors are threats to the student's persistence in the field and threaten their self-efficacy as engineering students. Questions include: "I feel unsure about my engineering classes."; "I expect my engineering classes to be difficult."; "I feel stressed about my engineering classes."; "I feel worried about my engineering classes."; I feel anxious about my engineering classes." Once again, in this group, there was high internal consistency (α = .89 and .89, pre-COVID and post-COVID respectively). However, there was a split in the responses as to the impact of COVID. For the questions stating that they expect the course to be difficult and that they feel stressed, there was no statistical change in the responses before or during COVID. In both cases, the mean response was high (6.0/7.0 and 5.4/7.0, respectively) demonstrating that engineering courses are expected to be difficult and bring about feelings of stress in students, even without a global pandemic. In the questions related to uncertainty, worry and anxiety, students showed a statistically significant increase for all three categories. The COVID-19 pandemic has made the students greatly more uncertain (from 3.6 to 4.7), more worried (from 4.8 to 5.4) and more anxious (from 5.0 to 5.4).

Self-efficacy. The final question is evaluating whether or not the students feel confident in becoming an engineer. In this case, there was a significant decrease in confidence (mean decreasing from 6.1 to 5.1, p-value = 0.001), demonstrating that COVID-19 has caused these students to doubt their abilities to work as engineers upon graduation.

The data is summarized in the table below.

Grouping	Question #	Mean (pre-COVID)	Mean (post-COVID)	p-value	Avg. Cronbach's Alpha
Social Connection	1	4.7	5.7	0.034	0.74
	4	5.6	4.8	0.000	
Challenge	5	5.8	5.4	0.015	0.86
	7	5.2	4.8	0.087	
	9	5.6	5.1	0.185	
	12	5.4	5.3	0.345	
Threat	2	3.6	4.7	0.000	0.88
	3	6.0	5.9	1.000	
	6	5.4	5.5	1.000	
	8	4.8	5.4	0.050	
	11	5.0	5.4	0.006	
Self-efficacy	10	6.1	5.1	0.001	

Discussion

Social connection and a sense of belonging has been demonstrated to be a key component of self-efficacy in women, and more specifically in women in engineering programs, as so few women enroll in these courses of study. While Zoom or online coursework may provide a mechanism for maintaining coursework during the pandemic, it does not offer the same community as face-to-face instruction. In my own experience teaching engineering students pre-COVID in a traditional environment and now in an online environment, the challenge to

maintain energy in the classroom and create an engaging environment is difficult. Additionally, students participating in online supports may be able to connect to a peer but do so from the isolation of their residence or a private location on campus. Even the platforms themselves can inadvertently create additional separation. When in a face-to-face class or event, students are interacting directly with the individual. Using Zoom or other technologies, students can select to turn off their cameras or use an avatar instead, removing opportunities for eye contact, changes in facial expression and other visual cues. Working through electronic devices, students can multitask and become distracted from the main speaker or activity. It is not surprising that students report a decrease in connection with these barriers in mind.

At stated by the originators of the survey tool, Dennehy and Dasgupata, "challenges" are opportunities for students to rise to an occasion and successfully overcome difficulties encountered in their studies, while "threats" are those difficulties that could potentially thwart their efforts towards completion [17]. Engineering coursework is challenging to most students and accepted as a rigorous educational pathway requiring skillsets in mathematics, physics, mechanics and other complex fields. The data is clear that students expect challenges in their coursework but are anxious in those circumstances which threaten their ability to complete their desired course of study. As such, it is also understandable to see that while students expect coursework to be challenging, the pandemic has led to an increase in uncertainty and anxiety. Changes in the classroom instruction have happened rapidly and with little warning. Instructors were required to quickly adopt software with little training and potentially no prior experience. Schedules for class times and modality changed mid-semester for most institutions, catching students and faculty by surprise. While this institution did offer the option for students to select a Pass/Fail option, rather than a letter grade, this option was not recommended for any students on scholarship or taking classes requiring a "C" or higher to continue to a subsequent course in certain course sequences (such as Engineering Statics requiring a "C" or higher before continuing to Engineering Dynamics). As such, few students in engineering programs chose the Pass/Fail option, even though it may have potentially reduced anxiety in some students.

Finally, for most students in engineering, a co-op or internship experience is a key component for understanding what it will be like to work as an engineer in the workforce. Many of the experiences were cancelled due to the pandemic and the transition of many white-collar jobs to hybrid or work from home environments [5]. For junior and seniors, this pandemic may have eliminated all opportunities for work experience prior to graduation. It is natural that self-efficacy would decrease in this area, given the circumstances.

Conclusion

Overall, for those teaching during the pandemic, it is not surprising to see an increase in stress and anxiety and the corresponding decrease in social connection. These results validate global studies on the college student experience due to COVID-19 [5] – [7]. Unfortunately, these increases in stress and threats to self-efficacy could prove to be the difference in whether or not a woman studying engineering completes her engineering degree or chooses to leave engineering for a field more diverse and gender balanced. This is especially demonstrated by the final question, where students greatly decreased their reported self-efficacy as an engineer and in the question about having confidence in completing their program. They may have confidence that they can overcome challenges in coursework, but they are losing confidence in pursuing a career in engineering or potentially remaining in this major. It is these exact problems which led to the

previously documented efforts to increase retention of women in engineering programs. However, the interventions employed at institutions to support women, proven to be successful, are mostly eliminated or migrated to online platforms due to the pandemic.

This study focused specifically on women and did not survey male students, as previous research has shown self-efficacy to be much lower in women in engineering compared to their male counterparts. However, the author acknowledges that it would be interesting to see differences in women and men and their self-efficacy in light of the pandemic. Future research will include all students, allowing for a comparison by gender, in addition to providing insight on the impact of COVID on engineering students in general.

For students suffering the loss of support programs within their institution, faculty are the most capable of extending support and encouragement during this season of limited access or elimination of programs. Faculty are in direct communication with their students, allowing for one-on-one mentorship both within the courses they teach and outside of class time. While no one faculty member can take the place of all support functions typically offered by the university, faculty can work to encourage student persistence and give hope for future experiences after the pandemic is over. Limited individual support of faculty is better than no support at all.

Faculty are in a key position to try to foster community, give students confidence in their courses and work to decrease anxiety in their coursework through their regular interactions with students throughout the semester. While Zoom may not be the optimal platform for such tasks, it is the faculty who can most quickly adjust to better connect with students and encourage persistence in the course, the major and the career as a whole. This pandemic may be impetus for new teaching methodologies and innovations not yet practiced widely in engineering classrooms. However, it is critical that all faculty make a diligent and intentional effort to retain the women in their engineering courses now. Otherwise, the meager gains from the last 5-10 years may be completely undone during this pandemic season.

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