Breaking Barriers and Building Confidence: Unleashing the Power of Digital Tools and Gender-Balanced Teams in Engineering Education

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***Abstract*—This research-based full paper focuses on building confidence and inclusion for women engineering students by implementing various modes of learning (e.g., an interactive online textbook, Pre-recorded Lecture Videos (PLVs), and equally gendered-ratio teams for in-class team worksheets and course project) into a sophomore-level engineering course. It has been recognized that lack of inclusion has been linked to negative outcomes in student performance, specifically for women. As men dominate most engineering majors, it has been seen that women students find it hard to participate in group work settings. When working in groups, women students have experienced gender biases that were demeaning and often have their ideas or designs second-guessed. These feelings of self-doubt and lack of involvement, repeated over time, led many women students to leave engineering. It is hypothesized that by providing many learning opportunities outside the classroom that positively reinforce their knowledge and understanding and by balancing the gender ratio of teams, women will be more confident in their abilities and feel more included, respectively. Confidence plays a deciding factor in the retention rates of women within science, technology, engineering, and mathematics (STEM) fields of study.**

Anecdotally, it was discovered that during the development and implementation of an interactive online textbook and using PLVs, many women within the introductory Statics and Mechanics of Materials 1 course felt something unfamiliar compared to other STEM courses: confidence. Confidence is a prime indicator of successful completion of a program. To further explore this finding, a study involving focus groups was conducted with three assemblages of women within the course. Two focus groups discussed using the interactive online textbook (n = 8 and n = 9), while one discussed using PLVs (n = 8). These focus groups were moderated by two women, a Ph.D. student in Physics and a current Mechanical Engineering undergraduate student. The focus groups were recorded using the University's approved video recording platform (Panopto) and transcribed using NVivo, being corrected and verified by researchers.

Various themes were found, with one indicating that women felt more confident about their abilities and knowledge when engaging with the interactive online textbook than when using traditional educational methods. Interestingly, using the textbook and PLVs also helped women feel more confident going into and asking questions in the classroom. Another finding was that the women viewed the equally gendered structuring of groups for in-class team worksheets and projects as a very positive action. The findings of this study set up future work scrutinizing which mechanisms not only promote confidence but a sense of belonging for women within engineering and, hopefully, other fields within STEM.

***Index Terms*—Flipped class format, online lecture videos, engagement with digital media, women, gender, engineering**

I. Literature Review

As of 2018, women earned only 13.3% of Bachelor of Science degrees in Computer Engineering, compared to 50.6% in Environmental Engineering, with varying percentages across other engineering disciplines [1]. Research into the low representation of women in engineering suggests that factors such as confidence and stereotype threat contribute to this disparity. These factors can either discourage women from pursuing engineering or lead them to leave programs before completion [2].

Marsh et al. found that women often leave STEM fields due to negative perceptions [3]. Ertl and Hartmann suggested that one reason for these negative views might be the mismatch between women's altruistic tendencies and the traditionally problem-solving focus of engineering courses [4], i.e., these courses focus on tangible creations to solve a problem, whereas women tend toward "people-oriented" solutions. Oddly, the purpose of engineering is to advance humanity. However, the notion by Ertl and Hartmann is challenged by Lakin et al. [5], suggesting that belonging uncertainty might be a more significant factor than negative views.

A sense of belonging, especially social belonging, is crucial for student success and retention. Seeing other students similar to yourself contributes substantially to a sense of belonging.

Women in historically men-dominated engineering fields often experience a diminished sense of belonging [6]. A diminished sense of belonging can also be attributed to stereotype threat [7], which can also impair academic performance [8, 9], and can promote scientific disidentification [10].

Belonging uncertainty and reduced confidence can also come from actions like being excluded from group work, being picked last, and microaggressions [11]. Often, there were escalations of microaggressions into discriminatory actions, which led to women, Latinx, and Black students leaving STEM more often than their Asian and White male counterparts; approximately one-half of women who experienced discrimination decided to leave the STEM field [12]. Discrimination in STEM is not limited to academia; Nguyen et al. found that negative behavior from men can lead pre-engineering women to feel excluded and discouraged [13].

The research shares a commonality: various mechanisms undermine women's confidence and sense of belonging, either discouraging them from pursuing STEM careers or causing them to leave STEM fields. Interventions have been implemented to address some identified issues, such as stereotype threat and imposter syndrome. Good et al. found that mentoring programs, where college students support seventh graders, helped mitigate stereotype threat and improved standardized math test performance [14]. Robinson et al. developed an online video mentoring program to combat imposter syndrome [11]. Ortiz-Martínez et al. suggested that remote mentoring, digital networking, and faculty training on systemic issues are key to increasing retention among women in STEM [15]. Additionally, ecological interventions aimed at improving the retention of Black, Latinx, and Indigenous students have targeted issues of belonging and confidence [16].

Recent studies on virtual learning, prompted by the COVID-19 pandemic, indicated that online environments, due to their anonymous nature, may make women feel more comfortable participating for their anonymity removed preconceptions and judgments from their peers [17]. It can be seen that mentorship and virtual platforms can address systemic issues of stereotype threat, imposter syndrome, and retention.

II. Introduction

This research addresses the following questions:

1) When mentorship cannot be given, such as in large-format collegiate engineering courses, are there other methods to support and encourage women to help increase their confidence and sense of belonging?
2) How can collegiate course structures be reformed to minimize stereotype threat, imposter syndrome, and discrimination while fostering social belonging?
3) What aspects of digital learning can benefit women in engineering?

It is hypothesized that an interactive and engaging online learning environment, as opposed to a digital yet static learning environment, will enhance women's confidence and participation. Specifically, digital materials like PLVS and interactive online textbooks can provide a safe and supportive learning environment and the means to restructure a course to minimize microaggressions and discrimination. It is also hypothesized that having the most significant interaction-based component of the course (i.e., class time activities and learning) be done in a microcosm of the classroom where women were not the minority (i.e., part of a gender-balanced team), that the women within teams would provide support to one another and therefore foster an increased a sense of social belonging.

To this end, a restructured introductory engineering course at the researchers' university was implemented to provide various learning modalities that may promote women's confidence and sense of belonging. This study focused on how women perceive this learning environment. A Flipped Class Format (FCF) was implemented, which used interactive and online learning modalities outside the classroom. This was paired with team-building exercises inside the classroom. An interactive online textbook authored by a woman, known as the Top Hat textbook (THT) [18], was used for learning outside of the classroom. The THT contained embedded questions used to test students' understanding of concepts. These questions were graded for participation only and provided hints if answered incorrectly and positive affirmations and explanations when answered correctly. Previous research has detailed the development of the textbook [19], documented the positive impacts of engagement with the textbook on course performance [20, 21], as well as students perceptions of engagement with the textbook [21, 22].

PLVs paired with online conceptual checkpoint questions were also used outside the classroom. The PLV questions were similar to the THT questions in that they provided hints and feedback but were more conceptual. PLVs, when used in an FCF, create time in the classroom for additional student-instructor and student-student interaction [23]. Chiquito et al. demonstrated that an FCF directly impacted women students, specifically grades, compared to those taught using a traditional lecture format [24]. Additionally, prior research showed that engagement with PLVs through interactive means led to increased student performance [25].

Class time was spent on in-class team worksheets instead of an instructor-centric lecture. The teams for these worksheets were created using CATME [26], and teams with women were gender balanced (i.e., an equal number of men and women comprised the team). The students in the course would work with their teams during every course meeting to complete additional problems and could seek assistance from their instructor and teaching assistants if needed. The students would also work in the same teams for their term project. Thus, by transforming the course structure and the modes of dissemination of information, various opportunities were created where the women could learn the material independently of their peers, minimizing external and internal threats. When they worked with their peers, they did so in a non-men-dominated manner.

Focus group interviews were conducted to determine the effects of course restructuring, the use of digital learning tools, and gender balancing of teams. Women in the course

were asked questions about their identity as engineers, their experiences with self-doubt when using these learning tools compared to learning within a conventional course structure, and whether or not they felt more included and comfortable with participating. This paper presents their views.

This study's research team comprises faculty, graduate, and undergraduate student researchers from education, social psychology, engineering, engineering education, physics, and astronomy. The majority of the research team has been extensively involved with the design and administration of the course and course materials; the course and course materials serve as the basis for the research context. The research team comprises both men and women, and the women's experiences within STEM fields have influenced the direction of this research, particularly the questions asked in the focus groups and the interpretation and presentations of the results, specifically regarding feelings of confidence and belonging. The research team has taken great care in analyzing and interpreting the results of this study, understanding that only qualitative data is being presented in terms of viewpoints and experiences. The research team recognizes the need for further study, using both qualitative and quantitative methods, before being able to draw any formal conclusions.

III. Methodology

Three focus groups of women enrolled in a sophomore-level Statics and Mechanics of Materials 1 course were created. Two focus groups discussed using the interactive online textbook ($n = 8$ and $n = 9$), while the other discussed using PLVs ($n = 8$). The course used in this study was taught in four sections: author 1 taught a section at noon and another at 2:00 PM. Two other instructors taught sections, one offered at noon and the other at 5:00 PM. The course was split into four sections for multiple reasons: there were a total of 268 students enrolled in the course during the semester in which the study took place; this course is offered to all majors within the engineering program at the researcher's university, and thus there needed to be multiple offerings to fit the schedules of all students. The course content and material were the same in each section—one instructor coordinated the administration of all content and assessments within all four sections. Focus group participants were from all four sections of the same course; in ascending order, the percentage of women per class in each section was 23%, 28%, 44%, and 53%. Considering all four sections, the approximate ratio of women to men for the course is 35%.

The focus groups were moderated by two women: a senior Mechanical Engineering student and a Physics Ph.D. student. The students were allotted 50 minutes to discuss the given prompts. The interviews were semi-structured, allowing the students to answer the provided questions and discuss topics they found relatable. The focus group discussions were recorded using Panopto via a laptop and were transcribed using NVivo (and manually corrected and verified by the researchers). No visual data was recorded during the interviews or used for this study.

The research team then reviewed the transcripts to understand the students' thoughts and feelings about the learning modalities and their impact on their confidence and sense of belonging. Two researchers independently applied codes and categories to recurring themes. Upon completing the transcript analysis, they met and decided on a final set of codes and categories before reanalyzing the data. The final analysis involved interpreting the underlying meanings of statements made. These responses were analyzed following the procedure outlined by Creswell et al. [27]. The questions asked to the two focus groups are as follows:

1) *Do you identify with the term "engineer?" Did your perspective on whether you would label yourself as an engineer change while using this textbook/PLVs compared to a standard classroom experience?*
2) *Did you experience self-doubt more or less often while working with this textbook/PLVs compared to a standard classroom experience? Is this change related to working/learning alongside men in a standard classroom experience?*
3) *Does the course set-up (flipped lecture format, interactive textbook, team worksheets) make you feel more included? Do you feel more or less comfortable participating in online discussions?*

IV. Results and Discussion

Data from the focus groups is presented below in categories that relate to common themes but also lead to a concluding sentiment; all of these tools are helping treat a symptom of a systemic issue that begins early in these women's careers, a problem that is exacerbated when these women interact not only with their peers but instructors and men outside their field of study. The four main areas that emerged from the analysis, each of which is a subsection of this section, are as follows:

1) PLVs and the THT increased the confidence of women and prepared them to feel more comfortable with participating in the classroom (IV-A);
2) Microaggressions were most often experienced outside of the classroom and from persons not related to their academics or in their field of study (IV-B);
3) Corrective actions need to happen sooner—the interventions used within this study, although beneficial, should be occurring much earlier in the women's academic careers (IV-C);
4) Interventions should not be targeted just toward women. To address systemic issues, men must be a part of the solution (IV-D).

The data presented is an exploratory investigation into the women's perception of the learning modalities (an interactive online textbook, FCF, and gender-balanced team) and how and why these methods may or may not have impacted their feelings of confidence and inclusion.

We start by probing the effect of learning modalities on confidence (e.g., PLVs, the THT, and gender-balanced teams). We then progress into the timing aspect of these teaching methods,

followed by scrutinizing mechanisms that undermine(d) their confidence and sense of belonging. We then reflect on how we, as educators and mentors, are implementing these pedagogies and who we are directing them toward.

A. Do Learning Materials and Modalities Help?

The research team wanted to know if PLVs and the THT changed women's perspectives on whether or not they identified as engineers, whether these modalities reduced self-doubt (or conversely increased confidence), and/or increased their feelings of inclusion and comfort with participating within the classroom environment (physically or virtually). Below are numerous quotes from respondents within the focus groups. It was found that by providing PLVs to students, the participants' understanding of the material improved due to their ability to watch and re-watch the content. Not only did the PLVS complete their intended function (i.e., provide an understanding of the material), but having a learning mechanism to prepare for class led to women reporting increased confidence within the classroom. This increased confidence helped the women overcome the adverse effects of stereotype threat. One student noted:

> *I agree that watching the videos and... being able to rewind is really helpful... I feel like that helps me feel more confident when I go to class because I feel like I understand the material better than some of my classes where I just sit there and listen and don't always absorb what they're talking about... I don't really feel like it would make a difference whether or not I was sitting next to a male classmate or something like that. But I do feel like there are implicit biases we have within ourselves as women... I feel like growing up, it was like "Boys are good at math, and boys are good at physics," that I naturally feel stronger in the sciences. So then I feel like if I can go to class more confident by rewinding videos, then it helps me...*

Another woman noted the pre-class preparation helped them feel more confident in class and that this mechanism can counteract some negative effects of the behavior of men in class (e.g., monopolizing discussions/class time with questions), which was also seen previously [17]:

> *...any... chance to... know the content before class... helps with... self-confidence during class, like [being] able to answer questions sometimes... I think... learning against male peers... they usurp so much of the class time, [they] just ask questions... that aren't relevant whatsoever.*

It is seen that having an engaging and interactive method of learning before class (with an emphasis on a teaching mechanism where the students are active learners, not passive learners) helps the women feel more confident going into class and, thus, will more likely participate. The combination of online materials and how they were paired did have a positive impact on the confidence of women, as noted by one participant:

> *...I definitely like this way of teaching is being done for making me personally feel more confident in my abilities... and then... this way of teaching is making me feel more confident... However, the people, I'm going to use "men-gineer," the men-gineers around me like to dwindle that.*

These men engineers, or "men-gineeers," were noted to have large amounts of unfounded confidence, and the women within the study group did not have these artificially high levels of confidence. A student noted:

> *Confidence also plays a big role. I feel like... even though we're learning the same things, as a guy and as a girl. I feel like they approach it a lot more confidently... than a girl... So it's like stressing me out.*

The women interviewed mentioned that they were able to build up their confidence before class. Still, this confidence could be eroded through interactions with men, both students and instructors (as will later be discussed). However, the set-up of the class provided resources for women to learn on their own, and the gender-balanced teams helped reduce implicit biases, as one student noted:

> *I feel like at first I was really overwhelmed by the fact that it was flipped again because of how awful Physics 1 and 2 were for me and the entire time I was in Physics 1 and 2 I was like, "Should I be an engineer? [I]f I can't figure out Physics 1 and 2, should I be an engineer?" So that was definitely a huge self-doubt thing for me, and then going into Statics, "Oh, it's flipped again. And here's a textbook." And I was like, "Oh, God, here we go! Round two! Like, I'm just gonna cry myself to sleep every night because this is going to suck." And it literally has not been that bad. So I definitely think it helps with the self-doubt a little bit because I'm kind of proving to myself that I can figure it out on my own. I don't need to be... walked through everything and I can use resources to get somewhere. So I think it's really help[ed] me and I also like how it's a flipped class. We have group time. [B]ecause my group is two guys and two girls, I feel like it's been pretty even, we all know kind of what we're doing. We ask each other questions and there's not any bias that I've found from either side. So I think that's been good as well.*

Regarding the groups, one respondent noted, "I feel like my group is very good, an example of... us collaborating together and believing in each other in a way." Two students who were in the same group commented, in comparison to other courses they have taken, "[T]his has definitely been my best group out of all the ones I've had where it's just been all male[s] or all female[s]."

Another woman commented that this was the first time since they've been in college that someone has talked to them about how men may perceive them. Yet another student made the

same comment, stating, "I hadn't really thought about the male aspect in a while... now I feel like in class I don't think about it because I see just as many girls as I see as guys... since there's such an equal ratio now it just hasn't crossed my mind." This comment provides an insightful perspective on the matter that when women are not the overwhelming minority in a classroom, they don't think about the men within the classroom, which may, in turn, reduce stereotype threat and increase their sense of belonging. Many times in the interviews, students would note in previous classes how their teams were unbalanced and that once they were gender-balanced, they no longer noticed the lack of homogeneity. A student remarked, "I probably would feel weird if I was the only girl in the group. But... since I'm not, I don't think I've thought about it." Removing the cognitive load of noticing you are a minority does appear to have improved their experiences within the class. Along the lines of not thinking about being a woman in STEM until prompted, one respondent noted:

> *I think it's just the fact that the ratio of girls and guys [is] so much better now. But I guess it's good that I haven't thought about that in a while. And I do have a lot of male professors, but I also have way more female professors now, that I think... we see them a lot more commonly than we did before. It makes me feel more accept[ed] I guess.*

The major takeaway from these responses is that gender-balanced teams positively create a sense of social belonging and that seeing someone like yourself in a position above you, whether a more senior student or someone on the instructional team, creates another sense of belonging. The latter issue can't necessarily be controlled within a classroom. Still, efforts can be made to ensure that the teams are gendered-balanced and that the instructional team is diverse and representative.

The last remaining teaching modality was the THT. One participant said the textbook was shown to "...boost [my] confidence in a sense of my understanding and my learning." Another student noted that this boost in confidence comes from being able to do many practice problems and getting feedback on those problems. Along the same line, another student said "Yeah, the textbook makes me feel good about this." One woman noted:

> *I think it [has] really helped bring up our confidence as well... I was able to put two and two together from the lecture and past readings and videos and figure out the problem... I usually ask one of the men-gineers for help because they seem to always know what they're doing, but this time like I kind of stopped that.*

This is an exciting sentiment; if a resource creates a situation where a student does not have to pursue a path for help that may negatively impact their confidence and sense of belonging, then an improved educational and inclusive experience has been provided. An aspect of the interactive online textbook that was inadvertently implemented by the instructional team was the chat (or forum) feature, which can provide a very similar experience to the interactive nature of the THT. Some women in the focus group mentioned their peers used it and wished they had because "I don't ask questions in class and because I just don't feel confident enough." The chat features allow the student to ask questions, and their peers, TAs, or instructors can answer, and they can answer other's questions. Once this item was brought up, another woman noted:

> *Yeah, I wish I knew about that [be]cause I don't like asking questions in class... so then I just feel stupid in person, and I'd rather feel stupid over the internet.*

An interesting feature of the THT, in addition to the chat feature, is ACE. ACE is a version of ChatGPT that only pulls content and information from the textbook and no other online resources while forming responses to students' inquiries. ACE can answer questions, generate example problems, and even answer embedded questions in the text. One respondent commented on the use of generative artificial intelligence:

> *Yeah, I feel like now that we have ACE, though I still wouldn't really use the online forum because then you could just ask ACE any question and it would answer it for you.*

This indicates a preference for interacting with a non-judgemental resource over interacting with a peer or instructor in person or online, even if anonymously. An interesting and contrasting viewpoint was that without seeing how others were doing, there was no way to gauge your performance relative to others:

> *...I think with learning on your computer, you can't really see how other students are doing. [T]hey're like, "Oh, I'm struggling on this. But is anyone else confused or is it just me being stupid or something?" I think that's the only, or one of, the cons... yeah, so maybe a little more self-doubt.*

Immediately after, another student responded, saying "I never really understand things the first time I learned something... then I feel like I'm already getting behind, and that's intimidating." Her peer agreed and said that the class format "equalize[s] the access that we all have to... learning the material... everyone has the same chance to... put as much work into as they need to."

The interactive online textbook can only do so much. Yes, it can help the women feel confident in their abilities by providing an unbiased (hopefully) learning experience. But it is just a book and does not address systemic issues. One respondent noted: "I'm not really sure how the textbook relates to... gender roles or expectations in the classroom because the textbook... it's just sitting there. [T]he textbook can't really do anything." Another student shared a similar sentiment about how the instructional materials, although helpful to education and confidence, aren't addressing the real issue:

> *If the textbook is seen as a resource that would help even the playing field, I guess in that kind of sense. We're all like, what, twenty? Nineteen? I feel like this is a Band-Aid for anything that happened*

beforehand that would make the playing field uneven in the first place... So small, subliminal things from early childhood.... those small things, this textbook doesn't, isn't going to come in and save the day and start from scratch... but I feel like even though the textbook can help even out resources and those kind of things, I do think that the damage has already been done earlier.

These last two comments set the stage for a sobering realization: is what we are doing occurring too late in their educational career, and should these interventions and tools be implemented sooner? This will be discussed in Sec. IV-C, but we will first discuss whether it is the "men-gineers," or external actors that are sowing the seeds of self-doubt.

B. Where Do Microaggressions Live?

Many women identified where they experienced microaggressions and discrimination. Most negative experiences came from outside the classroom. Within the classroom, respondents noted that neither men nor women were the source of stereotype threat, discouragement, microaggressions, or discrimination. Instead, since both men and women engineering students were in the same program, the men did not look down on them but saw them as equals. Going through the program together created a sense of camaraderie. Outside the classroom, women experienced discouragement through interactions with instructors and external actors (i.e., men outside their educational experience). One student noted:

...I feel like this is a big conversation about men in our classes, but I feel like I've had more negative interactions with... my roommate's boyfriend [who] doesn't go to Pitt... was like, "You're building a bridge?" And I was like, "Yeah, for my statics class." And he was like, "Your bridge isn't going to hold a feather." And I think he was trying to be funny. But I was just like, "Baby I'm not another pretty face... I'm a little bit smart. You don't really know me that well." I feel like that was way more discouraging than any conversation.

Her peer immediately jumped into the conversation and commented:

[S]omeone who is completely different from what you're doing, who doesn't have any background in engineering telling you that your bridge isn't gonna hold a feather: "Wow. Great. Thanks" (in a very sarcastic tone)

The student who was discouraged by an external actor then continued:

...maybe that's just a note for whoever is conducting the survey, that it's not just men in the classroom... I feel like... the people in engineering... you all relatively know that all of you are smart... where that guy doesn't really know me... but that's one thing I would say like having read these questions... I have more negative experiences with men outside.

Regarding instructors being a source of microaggressions and discrimination, there were two note-worthy comments. One student commented on a time she went to office hours to get clarification on questions she missed on an exam. The instructor's first comment to the student was he thought she didn't come to class. The student noted how incredibly unfounded and mean this comment was, for she attended every class and was there to get help. This interaction left her feeling not only invisible but discouraged from getting help. A singular interaction had a lasting effect on this student's educational experience. A few women commented on one instructor who has demeaning and derogatory content about women posted on his website and how his views and behavior towards women directly resulted in them not learning from him. One student refused to go to this instructor's office hours after she witnessed said instructor arguing with a woman over her not understanding a concept he thought was simple.

Many students commented that they had/have supportive and encouraging men within their program, whether they were their peers, TAs, or instructors, who show patience and compassion. They did mention that some instructors were a source of self-doubt and belonging uncertainty. In particular, some respondents were discouraged from seeking help because their instructors would demean them for not knowing something the instructor assumed was common knowledge, which in most situations was gender-specific (e.g., related to machinery or cars, etc.). Interestingly, though, even if the woman had a STEM-based role model in their life, they vicariously experienced microaggressions and discrimination:

My mom is an engineer. She works with computers. She's a STEM major. And having said that, she's the only STEM major that I know of [who] is a female. But then, seeing the way that she gets disrespected by other male counterparts... her coworkers or just other male friends. It showed that no matter what you kind of did as a female, you're going to get disrespected. Either way, someone else will just be stupid and dumb and just do it, because either way, they're going to see it the way they are.

It appears that internal and external actors could undermine any positive work towards increasing the confidence and sense of belonging of women in this engineering course. Overcoming deeply rooted feelings of self-doubt and lack of inclusion requires more than topical and late-stage treatments.

C. Is It Too Late?

The findings of this work are that these teaching methods helped women feel more confident in their abilities and that many of these women agreed these interventions were happening too late. Without being prompted, the participants in one focus group noted that they did not, or do not, have many women role models within the STEM field in their formative years. Although this contrasts with what a respondent said in a prior focus group, it is well-founded. She said:

...it's not about being in the room with them [men] or learning next to them, it's about the root cause...

I feel like the root of self-doubt comes more from [that] I didn't have very many women in STEM in my childhood. Pretty much none at all. I don't know a single female engineering professional. I'm not related to any, no one in my family is an engineer, and so I feel like it's not about the stupid boys in the class... It's... deeper. Go talk to four-year old me and come back. It's like the self doubt is very deep rooted... it's not about the guys in the class.

It appears that online learning tools and gender-balanced teams treat an immediate symptom of stereotype threat and belonging uncertainty. Still, there is an inherent sense of self-doubt when there is no representation at all levels of a career ladder (e.g., a senior-level student, TA, instructor, etc.) during their formative years. Coupled with the continual erosion of their confidence, a dire picture is painted.

D. Are We Going About This Wrong?

This work, and many others, have been focused on pedagogy and interventions that encourage and support women in STEM and help them overcome barriers. But are we not trying to treat a symptom instead of the cause? One respondent described this perfectly:

I guess... there's [one] observation about... these questions, the theme. I feel like it seems the questions about the flipped class is "Do you feel more confident when you're not surrounded by your male peers?" But, "Why?" The fact that that's the question in the first place, why should it have to be like, "Let's separate you guys so that they don't bother you." Why don't we talk to the guys and work at the root of the problem and not make them obnoxious in the first place?

Another student shared the same sentiment, saying "OK. So we feel this way as a result. What is the problem, you know?" Although many of the respondents noted the 'damage has already been done' and that some focus should be on addressing the preconceived notions, implicit biases, and associated negative behavior of men (both students, faculty, and external actors), that does not mean we should stop trying to provide an educational experience that increases the sense of belonging and confidence of women.

V. Conclusion

The research team was interested in whether different learning modalities (PLVs, a THT, gender-balanced teams) would increase women's confidence and sense of belonging within an introductory engineering course. PLVs prepared women for class (i.e., they could watch and re-watch the content until they understood the material), which made them feel more confident going into the classroom. The THT increased confidence by providing them with the opportunity to not only complete numerous practice problems but also receive feedback on their understanding. Within the THT, women enjoyed the chat feature, which allowed them to ask and answer questions anonymously. Furthermore, respondents preferred ACE, a version of ChatGPT embedded within the textbook, because they could obtain assistance with the material judgment-free. Gender-balanced teams made the women feel more at ease; they did not notice the unequal gender ratios in the class (only two of the four-course sections were approximately equal in terms of gender (44% and 53%)). When the women were in gender-balanced teams, there was reduced stereotype threat and an increased sense of belonging.

Although these learning modalities had many perceived positive benefits towards building confidence, reducing stereotype threat, and increasing a sense of social belonging, many respondents noted that these initiatives are being done too late in their academic careers. Furthermore, these changes to their education don't address the root cause of self-doubt and a feeling of uncertainty about belonging. Internal (instructors, as opposed to peers) and external (men not within their field) actors were the most identified causes of self-doubt through either microaggressions or discriminatory actions. Most of the participants agreed that the focus should not be placed on trying to diminish the symptoms they feel by creating new educational experiences for them; instead, the focus should placed on eliminating the biases, preconceived notions, and inappropriate behavior of men. There also needs to be recourse for unacceptable behavior by men within their academic setting. If women felt more confident and included, it is hypothesized more women would be in role-model positions, filling in the existing vacancies that these students noted; there are few women instructors and practicing engineers, which leads to a diminished sense of belonging. We begin to see the circular nature of these issues.

VI. Future Work

With the existing data set, the research team plans to code the data further for patterns that emerge within the responses to gain a richer sense of the data. This may give further insight into common themes represented within focus groups. In future work, the researchers would also like to improve upon their original focus group questions and begin to explore what other teaching modalities may not only improve the experiences of women within engineering but also begin to address some of the main causes of self-doubt, imposter syndrome, and a lack of a sense of belonging.

To better understand the impacts of these teaching tools, the authors would like to re-run this study with a control group. One cohort would have online educational materials, whereas the other would learn via a traditional didactic lecture. Although this would provide a basis for comparison, it does create situations where women could become discouraged from learning and participating, and the authors believe this may not be the best method to scrutinize the impacts of the proposed teaching modalities. Instead, the authors would like two groups to use the same online instructional methods (i.e., THT and PLVs). One group would view PLVs narrated by the instructor, and another would view PLVs narrated by women in STEM (e.g., recent graduates who are now established

in technical fields or engineering). This would allow the researchers to understand the impacts on women and men within the program without diminishing the educational experience for any student. The authors could also conduct longitudinal studies to see if these interventions affected confidence and retention.

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