International Journal of Doctoral Studies

An Official Publication of the Informing Science Institute
InformingScience.org

IJDS.org

Volume 16, 2021

IMPOSTOR PHENOMENON AMONG ENGINEERING EDUCATION RESEARCHERS: AN EXPLORATORY STUDY

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ABSTRACT

Aim/Purpose	The purpose of this study was to explore reasons that engineering education researchers experience impostor phenomenon.
Background	Experiencing impostor phenomenon includes a psychological discomfort experienced by some high-achieving individuals who, by the very virtue of being successful, mistakenly believe that they are fraudulent and faking their success. Impostor phenomenon has been studied more broadly in science, technology, engineering, and mathematics (STEM), with little research specifically in engineering and computer science and none, to the author's knowledge, in engineering education research. As an emerging discipline, some of the challenges in engineering education research include its poor connection with engineering teaching and learning, establishing multidisciplinary collaborations, and advancing global capacity. As a result of its poor connection with engineering fields, and being a new discipline, it is possible that engineering education researchers hold an identity that is different from engineering researchers. Some of them could be experiencing their training differently, struggling to find mentors from a similar background, and possibly feeling like impostors.
Methodology	Using purposive sampling and snowball sampling, US-based engineering education researchers participated in a short survey and a semi-structured interview. The survey consisted of demographic questions, items of the Clance Impostor Phenomenon Scale, and an open-ended question about an instance when participants experienced impostor phenomenon. Interviews examined, in detail, reasons for experiencing impostor phenomenon as engineering education researchers. The scale provided a measure of the intensity of impostor phenomenon. Interviews were analyzed inductively through constant comparison using a constructivist approach.
Contribution	Findings indicated various axes of othering (separating those who are perceived as different, non-dominant, or outsiders from the majority or popularly accepted norm) that made it difficult to develop a sense of be-

Accepting Editor Mohammed Abdel-Magid | Received: August 27, 2021 | Revised: October 24, November 11, November 25, 2021 | Accepted: November 29, 2021.
Cite as: Chakraverty, D. (2021). Impostor phenomenon among engineering education researchers: An exploratory study. *International Journal of Doctoral Studies, 16,* 757-776. https://doi.org/10.28945/4883

	longing, especially for women, and contributed to impostor phenomenon. Othering occurred through identity-based experiences (gender-identity, engineer-identity), different methodologies used to conduct research, and different vocabulary used for academic communication.
Findings	The sample comprised of eleven participants (PhD students, postdoctoral scholars, and faculty), all of whom experienced high to intense impostor phenomenon (range: 61-91/100; mean 75.18). Participants were predominantly white women from twenties to forties. Interviews indicated two reasons for experiencing impostor phenomenon: (1) existing in a separate world from engineering (referring to cultural differences between engineering and engineering education including differences in communication styles, methodologies, and identities); and, (2) facing gendered experiences (for women).
Recommendations for Practitioners	It is recommended that practitioners are mindful of the tensions between worldviews, commonly used methodologies, and demographic differences between engineering research and engineering education research that could shape one's experience in the field and contribute to "othering" during doctoral training and thereafter.
Recommendation for Researchers	Doctoral and post-doctoral training in engineering education research could be more inclusive and open to different research methodologies. Future studies deeply exploring various training challenges experienced by engineering education researchers could illuminate how the field could become more inclusive.
Impact on Society	The current study provides a nuanced understanding of the dichotomy between engineering and engineering education research, including the different styles in academic communication, research methodologies used, and identities. It also provides an understanding of the gendered experiences women have in the field, pointing to an overt or covert lack of recognition. Both these factors could make some feel like outsiders or impostors who question themselves and doubt their competencies and belonging in the field. Attrition from the field could be costly, even to the society, at large, given that the field is relatively new, evolving, and not (yet) as diverse in its worldviews, methodologies, and the demography of those it attracts for doctoral training and beyond. The study provides evidence-based understanding of how training in engineering education researchers could be re-imagined.
Future Research	Future research could examine, in detail, aspects of engineering education research training that may contribute to impostor phenomenon, poor belonging, poor identity, and othering experiences.
Keywords	engineering education, engineering education research, STEM education, higher education, impostor phenomenon, impostor syndrome

INTRODUCTION

Impostor phenomenon encompasses a perpetual, cyclic process of psychological discomfort experienced by some successful and high-achieving individuals who, by the very virtue of being successful, misguidedly believe that they are fraudulent, faking their success, and it is a matter of time before they are "found out" (Clance & Imes, 1978). What makes it interesting is the paradoxical nature of this phenomenon, which usually arises post success or after achieving a milestone, where the success itself creates self-doubt, second guessing, and other psychological impairments (Leary et al., 2000). Over the last four decades, impostor phenomenon has been studied in a variety of social settings and among varied populations, including students and professionals in science, technology, engineering, and mathematics (STEM). Engineering students are usually a sub-sample among many of these studies focused on STEM (e.g., Chakraverty, 2019; Chakraverty & Rishi, 2021; Lee et al., 2020; Lige et al., 2017; September et al., 2001; Simon, 2020; Simon & Choi, 2018), with findings that are more generic and less related to the environment in which engineering students or post-doctorates are trained. Only four studies so far have focused on impostor phenomenon among PhD students and post-doctorates in engineering and computer science (Burt et al., 2017; McGee et al., 2019, 2021; Rosenstein et al., 2020).

Engineering education research is the study of how people train in the technical and professional aspects of engineering. It includes the scholarship of teaching and learning of engineering in classrooms, curriculum development and assessment, nature of knowledge, as well as societal and organizational scaffolding of knowledge development in engineering (Borrego & Bernhard, 2011). While literature about impostor phenomenon and identity development among engineering education researchers is lacking, research from allied fields points to ample evidence for how experiencing impostor phenomenon could affect multiple axes of identity development including cultural identity (Burt et al., 2017), gender identity (Chakraverty, 2019; Chakraverty & Rishi, 2021), racial identity (Bernard et al., 2018; Lige et al., 2017), STEM identity (Collins et al., 2020), engineering identity (McGee et al., 2019), and, in general, academic identity (Chakraverty, 2020a; Ramsey & Brown, 2018).

Challenges in engineering education research include its poor connection with engineering teaching and learning, establishing multidisciplinary collaborations, and advancing global capacity, in addition to being a new, emerging discipline (Jesiek et al., 2010). It is possible that engineering education researchers hold an identity that is different from engineering researchers, experiencing their training differently, struggling to find mentors from a similar background, and possibly feeling like impostors. To the author's knowledge, no study has examined impostor phenomenon among students and faculty in engineering education research. However, impostor experiences could color the way doctoral education and training is perceived and also make one doubt their competency, feeling insecure in their personal and professional identity development (Bernard et al., 2018; Clance & Imes, 1978; Hutchins & Rainbolt, 2017; Knights & Clarke, 2014). The current study aimed to examine what are the reasons engineering education researchers experience impostor phenomenon.

LITERATURE REVIEW

Impostor phenomenon was first discovered and described in the 1970s following interviews with several successful women in the US (Clance & Imes, 1978) who were unable to attribute their success to competence or hard work. They believed that their successes were due to luck, other's generosity, and their ability to trick their assessors, living in a constant fear of being "found out" as guilty of fraudulence. It could be linked to insecurity, negatively impacting academic identity development, research productivity, teaching efficacy, and the ability to perform the tasks expected of an academic (Hutchins & Rainbolt, 2017; Knights & Clarke, 2014). PhD students in STEM experiencing impostor phenomenon compare themselves unfavorably with their peers, struggle to develop skills for academic communication, and face challenges in applying newly learnt skills, fearing judgment when they ask for help (Chakraverty, 2020a). Postdoctoral trainees in STEM experience similar challenges

in addition to not making academic connections, not applying for opportunities, procrastination, and experiencing mental health issues (Chakraverty, 2020b). Academic impostor phenomenon could be challenging in developing an identity and sense of belonging in the department, university, or discipline (Chakraverty, 2020c).

As indicated, only four studies so far focused on impostor phenomenon among students and professionals in engineering and computer science. In the first (interview) study, nine PhD students (all Black and male) indicated racialized experiences of impostor phenomenon during classroom and outside interactions (Burt et al., 2017). In the second (interview) study, 48 early career researchers (PhD students and post-doctorates) in engineering and computing who identified as Black revealed similar findings; race-based impostor experiences were due to the dismal number of Blacks in their field (McGee et al., 2019). Another study showed similar findings about the racialized experiences of Black early career researchers, with participants struggling to fit into STEM programs culturally, although only a sub-sample of them were from engineering and technology backgrounds (Chakraverty, 2020c). In the third study, more than 200 undergraduate and graduate students in computer science were surveyed using the Clance Impostor Phenomenon Scale (CIPS) (Clance, 1985) at one large, research university in the US (Rosenstein et al., 2020), revealing that a majority of students (especially women) in computer science experienced impostor phenomenon frequently. In the fourth and more recent (interview) study, 54 doctoral students in engineering and computing who identify as Black revealed that they experienced systemic racism that was positioned as impostor phenomenon (an irrational individual behavior) by campus administrators (McGee et al., 2021).

The CIPS (Clance, 1985) was developed to measure impostor phenomenon through self-reported assessments of the belief that external markers of success may not always represent true ability, masking incompetence and making those dealing with this incongruence feel like impostors. In addition to the four studies described above, the CIPS has been validated with surveys from 1,271 undergraduate engineering students at one US-university, showing satisfactory internal consistency reliability (French et al., 2008).

Engineering education research has been conceptualized as a discipline, a community of practice, and a field (Jesiek et al., 2009). It examines issues like the lack of demographic diversity where, historically, women have struggled to attain gender parity in engineering (Bix, 2014). In 2016, women in the US received only about 25% of master's degrees and 24% of the doctoral degrees in engineering, and about 31% of master's degrees and 20% of doctoral degrees in computer science (Hamrick, 2019). Women have historically struggled to develop and nurture their professional identity as engineers, experiencing many workplace issues due to a male-dominant culture including struggling to be taken seriously, trying to be "one of the guys" in order to integrate, and experiencing unwarranted sexual advances (Bix, 2014). A recent interview study has documented several instances of violence female PhD students in engineering and computer science experienced that made them feel like impostors (Chakraverty & Rishi, 2021). Other than often being the only woman in an academic setting, they tolerated flirtatious behavior from colleagues, heard gendered, sexist comments, experienced sexual harassment, and saw problematic depiction of female engineers in popular culture as eccentric, hyper-masculine, and sexually driven (Chakraverty & Rishi, 2021).

"Othering" (also defined as "that process which serves to mark and name those thought to be different from oneself") (Weis, 1995, p. 17) across multiple axes and power relationships could make certain groups vulnerable to impostor phenomenon due to looks, racial/ethnic identity (Peteet et al., 2015), and linguistic ability (including non-standard accents) (Harrison, 2014). Divergence from the socially-constructed hierarchies assuming normal STEM identity as predominantly White/male could contribute to marginalizing experiences for "others" who do not hold the dominant identity, perpetuated by both, oneself and others (Chakraverty, 2020c; Peteet et al., 2015). This is aggravated when those perceived as "others" lack critical mass in that discipline.

Othering could also occur due to widely accepted myths about science (Conefrey, 2001), such as its association with meritocracy and an explicit acknowledgment that science is agnostic to the socio-cultural frameworks within which scientific knowledge is created (Foor et al., 2007). In identity-based othering, one must consider research versus teaching identity and the tensions perceived by faculty who are, implicitly or explicitly, signaled to give primacy to their research identity over teaching identity and may resist adopting new pedagogical approaches in the face of prioritizing research output (Brownell & Tanner, 2012). Rather than focus on doctoral students' experiences alone, the current research aimed to understand impostor experiences across the continuum (PhD students, post-doctorates, and faculty who teach and train PhD students and post-doctorates) in the field of engineering education research. The author believes that it could provide a holistic view of the experience itself from both, the perspective of the trainee and the trainer.

METHODS

DATA COLLECTION

In 2017-2018, the author conducted a large-scale, US-based study to examine both field-specific and more generic experiences of impostor phenomenon in STEM. IRB approval was obtained from Washington State University – a large, research-focused public university. Data collection occurred through online surveys (~6-7 minutes) and telephone interviews (~45 minutes) with the same participants.

A study webpage hosted by Washington State University had information about impostor phenomenon, the author's contact information, and a link to the survey. The survey consisted of demographic questions, 20 items of the CIPS (Clance, 1985; shared with permission from Dr. Pauline R. Clance), and an optional, open-ended textual question (without word limit) asking for an instance when participants experienced impostor phenomenon. At the end of the survey, participants were asked if they would be willing to participate in a one-time interview (optional). Those interested shared their email address and were contacted within a week by the author. There was no compensation to participate in the study. Data were collected sequentially using a survey and an interview from the same participants (Chakraverty, 2020a; Creswell & Clark, 2017; Marshall & Rossman, 2014).

For the current study (which is a part of the larger study in STEM) that focused only on engineering education research, advertising the study and recruiting participant occurred in three ways. One, using purposive sampling (Etikan et al., 2016), the author leveraged her professional connections, requesting colleagues in engineering schools at her university to share the study webpage among their networks as well as in the American Society for Engineering Education conference. Two, the author shared information about the study on social media (including Facebook, LinkedIn, and Twitter). Three, after the conclusion of each interview, participants were requested to share the survey link in their professional network and encourage their colleagues to participate (snowball sampling) (Sadler et al., 2010). This sampling method ensured a wider reach all across the US and that only those who felt like impostors self-selected to participate in the survey/interview rather than the author contact individuals. Eligibility to interview included currently pursuing engineering education research in the US and experience of impostor phenomenon.

Interview questions were developed based on the literature gaps the author identified, and were semi-structured so that participants could articulate their own experiences. All participants were asked why they decided to participate in the study, what does it mean to experience impostor phenomenon, and what are their field-specific impostor experiences. Follow-up questions were asked based on responses to these questions. Interviews lasted 35-40 minutes, were recorded with consent and transcribed within a week through a transcription company. Participants were told that they could temporarily pause or stop the interview altogether at any time if they felt distress while sharing personal experiences or sensitive information. Additionally, if they wanted to withdraw from the study after the conclusion of the interview, they could do so by emailing the author. The author also contacted each

participant 6-24 hours after the interview by e-mail to ensure that they did not experience distress. None of the participants reported distress following the interview or wished to withdraw from the study at any point.

Member checking was conducted to improve trustworthiness (Birt et al., 2016); transcripts were de-identified and immediately shared with respective participants (so that they remember the interview), requesting them to read and edit for accuracy, adding anything they might have not shared or deleting anything that made them uncomfortable. Participants had agency in what was shared about them. All the participants read and emailed their revised transcripts. All of them either chose a pseudonym or approved one chosen by the author. The author conducted all the interviews. A similar study design was chosen for prior research published from the larger study (Chakraverty, 2020a, 2020b, 2020c).

Data Analysis and Positionality

The CIPS consisted of 20 Likert-scale items (1 = not at all, 2 = rarely, 3 = sometimes, 4 = often, and 5 = very true) that were added for a maximum possible total score of 100 to group participants as experiencing low (20-40), medium (41-60), high (61-80), or intense (81-100) impostor phenomenon. A higher score indicated more severe impostor phenomenon.

After member checking, each interview was individually read and open coded by the author and two PhD students (coders 2 and 3), looking for reasons one experienced impostor phenomenon. The three coders together came up with a list of initial codes that were used to analyze each interview once again. The codes used were: advisor, behavior, belonging, comparison, environment, evaluation, gender, health, identity, interactions, inter-disciplinary, judgment, leadership, micro-aggression, presenting, professional preparation, research methodology, stereotyping, support, teaching, and transition.

The coders met regularly to resolve coding disagreements through discussion until all three coders agreed with a final list of themes (and sub-themes) developed inductively through a constant comparison (Glaser, 1965; Glaser & Strauss, 2017; Patton, 2014; Pope et al., 2000; Thomas, 2006). Each theme reflected aspects of training in engineering education research that made participants experience impostor phenomenon (Connelly, 2010; Giorgi & Giorgi, 2003; Marshall & Rossman, 2014). All the coders addressed biases through reflexive journaling, mindful of their identity as women in STEM and STEM education (Antin et al., 2015), a demography popularly known to experience impostor phenomenon (Clance & Imes, 1978; Vaughn et al., 2019). Additionally, the author noted holding certain beliefs/assumptions at the beginning of the study, for example, women experiencing impostor phenomenon more frequently than men and thus participating in the study at a greater rate. While this was true, men also felt like impostors and participated in the study. The author wrote memos of such personal biases. The author was especially cognizant of her background, identifying as a woman of color in STEM/STEM education and an immigrant, non-native English speaking faculty in the US at the time of the study, that could have determined the kind of educational spaces she had access to, and the way the study was designed, data were collected/analyzed, and who participated in the study. For example, the low participation of men in the study could be attributed to a female interviewer in the study. The author journalled and noted all these assumptions and maintained an audit trail of data collection, analysis, and presentation to improve the trustworthiness of the study. Due to the limited understanding of impostor phenomenon among engineering education researchers, a dual mode of data collection helped in understanding the intensity of impostor phenomenon through CIPS as well as analyze narratives using a constructivist approach (Creswell & Clark, 2017). Interview findings are presented thematically with participant quotes (Castleberry & Nolen, 2018; Creswell, 2012).

RESULTS

Eleven participants (6 PhD students, 2 post-doctorates, and 3 faculty) from six research-focused universities across the US pursuing engineering education research completed a survey followed by an interview. Participant characteristics are presented in Table 1. The pseudonyms used are: Amanda, Beth, Catherine, Diane, Ethan, Florence, George, Heather, Isabel, Jessica, and Kimberly. Survey scores (range: 61-91 out of 100) indicated high to intense impostor phenomenon with a mean of 75.18 (high) at the time of data collection. Participants were predominantly white women aged in their twenties to forties. Their engineering discipline and geographical location are not disclosed (unless a part of a participant quote) as they could be identifiable. Participants experienced impostor phenomenon and felt inferior compared to how they thought others perceived them. Two themes emerged as reasons for experiencing impostor phenomenon: (1) existing in a separate world from engineering; and, (2) facing gendered experiences. Each theme is described with participant quotes.

Table 1. Participant characteristics

Characteristics	N=11
Current position	PhD student: 6 Post-doctorates: 2 Faculty: 3
Sex	Male: 2 Female: 9
Race/ethnicity	Asian: 1 White: 10
Age range (years)	20-29: 4 30-39: 5 40-49: 2
Clance Impostor Phenomenon Scale scores (0-100)	High (61-80): 8 Intense (81-100): 3 Range: 61-91 Mean: 75.18; Std. dev.: 10.8

THEME ONE: EXISTING IN A SEPARATE WORLD FROM ENGINEERING

Engineering education research and engineering were perceived as two different worlds by participants and their colleagues. Those who were the only one or among few conducting engineering education research in their department felt like outsiders. While Kimberly considered engineering as "rigorous and technical," her peers and faculty in engineering considered engineering education research as "soft and fluffy, not as technically rigorous." She felt like an "impostor engineer just doing educational research instead of technical research."

Amanda stood out in her engineering department as the only one doing engineering education research. She considered herself "the only engineering professor with an education background who has learned about assessment, active learning techniques, and fairness in the classroom." She heard comments from her engineering colleagues that indicated that her work was "lesser than the hard science research." She also experienced "some pushback" for pursuing education research.

Jessica viewed engineering education research with a "special lens" that her engineering colleagues did not have. She felt she was not a "real engineer, doing real engineering work." She stood out like an impostor, believing that her thesis was inferior compared to those in engineering. "They're doing an experiment, and I'm just doing modelling."

Isabel felt she neither belonged in engineering, nor would she succeed in engineering education research. "It brings a general sense of doubt. Like, you shouldn't exist here." George also felt like an impostor because of "being in a different pathway," feeling like he would always be behind. Beth added her reasons of experiencing impostor phenomenon: "Some days, I wonder why am I only one that speaks education systems language in this whole building. No one seems to understand me." Overall, three sub-themes emerged as differences between engineering and engineering education research: academic communication, pursuing qualitative research, and identity.

Sub-theme one: Academic communication

Communication style was different in engineering and engineering education research. In engineering, technical reports used mathematical equations and graphs. However, engineering education research used a different "vernacular" (term used by Ethan) that felt unfamiliar at first.

> It's about what students think and feel, how they learn. It's completely different from how I was taught in engineering. It felt like a new, different language. I'm trying to think and communicate in a different way. In the beginning, it was just awful. (Jessica)

Despite having the understanding, many struggled to develop the language, vocabulary, and the writing skills to clearly articulate their research. Ethan struggled with developing a "vocabulary" to communicate his research, adding, "That made me feel like, oh, did I make the right choice? Am I really supposed to be here?" This also made it difficult to develop a sense of belonging at first. He struggled to write papers using research-specific terms. George also struggled with academic writing. He felt like he had the knowledge, but did not have the words to articulate his message while writing a paper on social justice for the American Society for Engineering Education. This slowed him down and he felt stressed about his speed. "I could only write three paragraphs in six hours after procrastinating and sitting for two days trying to figure out what to write. I'd write a couple sentences and I'd delete them." This made him feel like an impostor.

Heather found herself "completely drowning in the jargon and the literature. Epistemology, ontology, axiology, etcetera ologies. I don't feel like I'm smart enough to write papers. In academia, I don't feel like I belong because of that." Without structured writing programs, academic writing felt complex and difficult to understand. Those who could not sound wordy or complex believed that they were not good academics, experiencing impostor phenomenon. Heather believed that papers written in a complex language were deemed to be more academic, although the ideas were not always as clearly explained. She could better address her impostor phenomenon if her peers more openly shared how they mastered academic communication.

> People should be open about the practices that went into improving their academic vocabulary by doing X, Y, and Z rather than just being, 'I'm the smartest person.' Revealing how we learn and supporting each other could address the feeling of inadequacy.

Jessica also commented on an academic culture where "if you can read and understand everything in one go, then probably it's not good enough. People have to be scratching their heads, not understanding." This made engineering education research inaccessible to engineering educators. While grounding research in theories and using methodological rigor is important, she explained,

> we sometimes lose sight of the practical application and how individuals might use this. The work we do in engineering education doesn't always translate to the daily practice of engineering educators. If that's the case, who's going to use it? Who will access it? I don't always see a lot of value in these papers that make everyone sound smarter, even after I've read them three times.

One must understand research to be able to implement it. George read a good paper recently that talked about "six pedagogical practices that make you a better teacher as an engineer, in bullet points.

This is the way we used to do it; this is the way we would do it now." It made him reflect on his ability to write effectively.

> The practical element of it is often so clouded. I feel like an impostor because I'm more focused on the practical. I value the practicality of application and problem-solving. I want the bullet points. I struggle to see the value in the often cryptic academic language and theoretical framework.

Others were also unable to relate to jargon used in academic writing, meetings, and oral presentations (conferences). Diane shared:

> My impostor syndrome peaks in meetings when I don't know what people are talking about. Often, I'm writing down things, acronyms, phrases I don't know, trying to listen and be present, but also wondering if I should be here if I don't know all these terms. Are other people faking it too?

Teaching an introductory-level engineering course but not being good at MATLAB (a programming language) made Beth feel like an impostor. People assumed that an engineer like her was good at MATLAB. As an instructor, she hung on to the belief that she should know everything without taking help. "Whenever we had these MATLAB-based class periods, I was just nervous and antsy all day. At the end of the year, one of my student evaluations said, 'Oh, she doesn't know very much about MATLAB.'" This made her fear that students knew she did not know her subject matter. Eventually, she accepted her limitations. "In doing engineering education research, I had to be okay with not knowing everything as an instructor. I can be open to some of my students helping me teach these topics I'm not as good at."

Sub-theme two: Pursuing qualitative research

Many expressed concern that qualitative methodologies were viewed as less by their engineering colleagues and high-impact engineering education journals. As a qualitative researcher, Florence (located in the college of engineering) worried about getting tenure. "They [her colleagues in engineering] at least had an appreciation for quantitative research, even though it was educational research. I was very concerned about how people not in my field but evaluating my case would view my research." Florence felt that qualitative research was valued less and not usually published in top journals, adding that it was a common narrative in the engineering education research community "that qualitative is less than quantitative, especially by those who don't understand it. I tell people that the words are the data. I feel like there's a tension, even within engineering education community about qualitative work." Ethan shared similar concerns when presenting a case-study with a sample size of one participant at a conference. The reviewers gave him feedback that his qualitative findings were not useful and he should present his proposal as a poster instead. "As somebody pursuing qualitative research for their dissertation, that's disheartening to hear." He felt like he was in an environment that did not appreciate qualitative research, making him nervous before his conference presentations and feeling like an impostor. He feared that the audience would question his findings because it was based on qualitative data from one participant.

Isabel felt like an impostor too, trying to legitimize the value of qualitative engineering education research to engineers. She had to argue with the "true" and "real engineers" that "there's value in understanding it [research] from the soft side, the feeling side," feeling like there is a line drawn between engineering research and engineering education research. She constantly rationalized her knowledge and expertise to justify her research to her engineering colleagues. "It's hard, especially when you can already tell that they're very doubtful of the work that you do." Heather also struggled to share her research with the practitioners and felt like an impostor. While the aim of engineering education research is to improve teaching and learning in engineering and her qualitative research was grounded in a theoretical framework, she feared that a practicing teacher/engineering educator would not know how to interpret her research. "As a teacher, do I know what critical race theory means? Why do I

care? Maybe I'm very aware of what that theory is constructed out of, but my teachers are most likely not going to know."

Sub-theme three: Identity

Participants described how a conflict within their professional identities made them experience impostor phenomenon. Ethan was trained as a scientist, an education researcher, and a teacher (not currently teaching), but felt like none. Although he studied about epistemology in education research, he did not know enough to call himself an epistemologist. "My current identity feels really weird to me." He compared himself to someone he met at a conference who was an expert in epistemology research in physics. "He had such a deep understanding of how different epistemology theories fit together and how they fit into education. I didn't have that kind of knowledge." Diane also shared, "I don't have a really clear identity." Her PhD dissertation focused on an education-based topic in civil engineering. She neither identified with the "true civil engineers," nor with engineering educators who pursued discipline-based education research. "It's not like a perfect fit. I feel like I fit between the two, but not really well in one or the other." She questioned her contribution to the field because of this. "My professional identity doesn't feel super defined. That probably contributes to my impostor syndrome." Heather added that she struggled to develop a clear identity, transitioning from a professional, male-dominated engineering job to engineering education research with mostly women. "Those are very different worlds. It made me wonder, 'Should I actually be here?' Making drastic shifts made me feel like an impostor." Kimberly shared that experiencing impostor phenomenon threatened her identity as an engineer, educator, and graduate student. She thought she is not good in either role. Especially, "I feel like my identity as a grad student is at risk if my performance is not sufficient to merit that."

One of the reasons participants failed to develop a strong identity is the inter-disciplinary nature of their work. Pursuing inter-disciplinary research made Ethan feel like an impostor. "You're stuck in between two worlds, so you can't call yourself one thing or the other. You're a mixture between the two of them." He felt like an impostor as a scientist and a science teacher. "When I was teaching science, I wasn't being a scientist. The impostor syndrome was like whoa, am I really a teacher? Am I really qualified to do this? Was I tricking them into hiring me?"

Diane added, "the education piece in engineering education isn't understood by a lot of the other engineering participants." Although she identified as an engineer and an engineering educator, she did not have a strong identity in either of them. She presented herself differently in front of civil engineers and engineering education researchers, adding,

> I don't feel like I fit either place very well. I'm somewhere in the middle, and I don't think others understand what it's like to be in the middle. I don't know that there's a good way to communicate that identity in the middle to others.

Beth, like Diane, felt like an impostor while communicating with her engineering colleagues. "It takes a lot of work to really get them to buy into what you're doing as valuable, and that's where I feel very impostor-y." Hers was the only thesis in her program that year that focused on an engineering education research topic. "Many of my cohort-peers told me that my work was easy. It wasn't real engineering. How can you do a thesis in engineering without doing a real engineering project?" Her advisor had to meet with other faculty of engineering to decide "whether or not they should let me graduate because I was doing an engineering education thesis. My advisor really had to stick up for me." She added,

> I felt the most impostor-y about the inter-disciplinary nature of my work. I'm publishing and have conference papers, and my peers were busting concrete cylinders all day, not publishing anything. Civil engineering deals with people, and I was working with people.

Due to identity conflict and impostor feelings, Diane struggled to develop a sense of belonging in engineering education research, afraid to be called an engineering education expert by her collaborators from engineering and engineering education.

> The lack of belonging happens most when I'm present with other people when I'm feeling impostor syndrome. There's a sense of fear or not being good enough or not being legitimate. I'm like, oh, maybe I'm not good enough to participate in this proposal, or maybe I don't have the background. I've to convince them that I can't be an expert.

Theme Two: Facing Gendered Experiences

Gendered experiences in engineering education research occurred at workplaces with mostly White men who did not support women. Women felt dismissed when their expertise or life experiences were, intentionally or unintentionally, ignored during workplace meetings and discussions. Women worked in environments surrounded by male engineering faculty, peers, and students who "sometimes have a higher opinion about themselves" (Florence) and "do not realize how they're treating others. My impostor syndrome comes out when they make comments" (Diane). Amanda felt "inadequate, being surrounded by men." While people in engineering were called doctors, Diane was called by her first name.

> One of my male colleagues addressed all the other PhDs in the room except for me. In the moment, you're shocked, wondering what do I say or do? I'm calling somebody out that needs to be called out, but then the attention is on me in a negative way, so my impostor grows in that situation. There's a lack of recognition.

Diane described civil engineering as a male-dominated field. Her campus was 85% White and her department was predominantly male. This was alienating as a woman in engineering education research.

> I feel like I have a handicap. I don't look like them. When I feel like an outsider, I over-justify my presence. I try to convince people. The men give very explicit messages about who is visible and who is not, whose voice is important or not.

Women in engineering education research experienced lack of recognition, their voices stifled when men's ideas were praised repeatedly to validate them while their ideas were not acknowledged. Florence internalized these experiences, thinking that she did not contribute as much as the other male engineers she worked with did. "My male leadership doesn't seem to listen. They will constantly talk about how the one thing that this other gentleman said, but they will not remember the PowerPoint or the other ways that I have shared the same information." She added:

> I feel like an impostor on a daily basis. I constantly have to remind my male colleagues of my qualifications, I never get addressed as doctor, and I'm constantly in a state of telling myself I'm just as qualified to be in the room and to have a voice as my colleagues.

Kimberly explained that even when she wanted to add something valuable to a conversation, she would keep quiet, not knowing if she can say things intelligently. "That impostor is like, they may not believe me. I may not have authority to be saying whatever I'm trying to share." She was "in a place where the white majority is the accepted norm and they're not working to change that. I feel a lot of micro-aggressions within my program where I don't feel like I belong." She questioned her fit knowing that she was pushing against the norm. She thought feeling like a minority was normal until she took the impostor phenomenon survey. "I was, wow, I didn't realize this was so much aligned with what I was feeling in my experiences." She did not see resources on campus to promote diversity and support minority students, especially provided by the College of Engineering to support diversity within engineering. "That, to me, shows that the school isn't committed to changing their homogeneous culture. For me, that impacts my sense of belonging within that culture."

Heather's department was traditional and predominantly White and male. She felt like "a minority in a male-dominated field as a woman engineer and then also as a graduate student in engineering education." She described it as "a different kind of impostor than feeling not technically savvy [as an engineering education researcher]." She feels her impostor phenomenon can be managed if male-dominated engineering departments continue efforts to improve diversity, including:

> diversity of thoughts, ideas, and experiences in the engineering field. Being willing to change a system that has been stagnant for 80 years, making changes in how we educate engineers, in how we view the field of engineering. We shouldn't have to continually state that diversity in engineering is important. That should be assumed at this point to change that feeling of impostor syndrome from the gender perspective.

Diane remembered getting her annual reviews that said that she was too outspoken and opinionated at meetings and needed to watch what she said. "He [her male mentor] told me that I shouldn't share my opinion in meetings. He said that's not something that we should do here. I'm constantly getting those types of messages at work, that I shouldn't be speaking up." Every time women in their research group took the lead on a project (including her), male faculty mentors added other men to the project without consulting them.

> We are never included in the conversation. My inner impostor is growing. It is a beast now. I constantly am doubting accomplishments. Part of me is like, I don't want to share my ideas because I am terrified that they will never give me credit for anything that I put effort into.

Other male team members had previously taken her ideas and presented them without giving her credit.

> They just stole what I said earlier in another meeting and brought it to this meeting to show off. It's so hard to deal with. There's not a great diversity, and there's not a lot of females in leadership roles. The environment makes you more prone to impostor syndrome.

She felt having to wear a "fake battle armor" in "an old white guys' club" as she interacted with colleagues in the building. "I feel like I am going into battle. From my last six months working here, nothing is collaborative." She felt anxious while interacting with her boss and other men. "I'm like, I've gotta put on my shield, be quick to say something for things that they do that are super offensive."

Gendered experiences came from things said and done by male faculty, peers, and students. In classrooms and during general interaction, Jessica shared that the examples male faculty posed involved male engineers, "making generalizations based on just the assumption that it's mostly guys, so they don't have to incorporate anything that would appeal to women, or women would be better at." This made her feel a lack of belonging. Catherine, on the other hand, was questioned in many ways by her department peers. Her suggestions about doing group homework a particular way was ignored, yet her male-peers' ideas would be considered. "I'm not heard in that space." Seeing more women (including women of color) in engineering would make Catherine feel less of an impostor. "We need a more collaborative and less authoritative atmosphere that would help with impostor syndrome."

Some of Amanda's graduate students were aggressive, "who believe in the male-majority model and don't understand why diversity is important in engineering." She shared, "on a daily basis, because of impostor syndrome, I'm more careful about my interactions with students who questioned the value of diversity in engineering. I have to prove that I deserve to be in engineering education." She taught an introductory engineering course and every semester, some male students asked her questions and would not believe her answers although they were in the textbook. She particularly talked about a student who asked her difficult questions and only accepted those answers when a male faculty confirmed them too. "He [the male faculty] had a very similar answer for him, but not quite as thorough as mine, but he took [name of male faculty's] answer as the word of God. He didn't challenge [the

male faculty]." This happened three or four times. "I didn't feel as an equal. My credibility was being questioned by the student."

DISCUSSION

Engineering education research is a new and growing discipline that aims to improve the retention and professional skill/competency development of engineering students worldwide. Several US universities have engineering education centers, departments, and doctoral programs to train students and support engineering faculty in their research and pedagogy (Murzi et al., 2015). This is one of the first studies to examine why engineering education researchers may experience impostor phenomenon. Two themes emerged based on eleven interviews: (1) existing in a separate world from engineering; and (2) gendered experiences.

THEME ONE: EXISTING IN A SEPARATE WORLD FROM ENGINEERING

The first theme described a dichotomy between engineering and engineering education research, including the different styles in academic communication, research methodologies used, and identities. All participants, while currently conducting engineering education research, had a background in engineering. Some of them still worked closely with their engineering colleagues. In the current study, qualitative research was perceived, by others or by oneself, to be less sound methodologically compared to quantitative research. Prior research confirms that the domain of engineering education research continues to show a strong preference for quantitative (experimental) studies. Many engineering education faculty, having trained in engineering, are more inclined towards quantitative, experimental studies and using post-positivist approaches (Borrego et al., 2009). Conference papers in engineering education research also tend to prefer quantitative studies compared to qualitative or mixed-methods studies (Borrego et al., 2009). However, research problems in engineering education are best addressed using additional methodologies such as "case study, grounded theory, ethnography, action research, phenomenography, discourse analysis, and narrative analysis" (Case & Light, 2011). The adoption of qualitative or mixed-methods approaches in engineering education research has been slow while the use of quantitative methodologies remain dominant (Leydens et al., 2004). This could make those who pursue alternate research methodologies feel like outsiders.

Qualitative studies with smaller sample sizes have furthered our understanding of identity development and belonging among minorities in engineering. For example, ethnographic research with one individual has provided "a microphone for the voices of the marginalized to be heard" and the ability to "hear each and every voice that would otherwise be lost in aggregate ethnography or statistical analyses" (Foor et al., 2007). Another case study with one student has found that individuals feel like an outsider in engineering despite their achievements because of their marginalized identities, with implications on retention (Danielak et al., 2014). The National Science Foundation's engineering grants call for evaluators to have expertise in both, qualitative and quantitative research to determine the effectiveness of a project (Daza, 2012). It is essential that those pursuing engineering education research are trained to use diverse methodologies guided by the research questions they are exploring.

There is some research showing a gendered preference for qualitative and quantitative research methodologies, with quantitative methods signifying objectivity and masculinity, and quantitative methods signifying subjectivity and femininity (Westmarland, 2001). Although this dichotomy was not explicit in the current study, it would be important to consider that a predominantly female sample in the study could have possibly biased the way participants viewed the merits of qualitative, quantitative, and mixed-methods research. Some of the methodological or disciplinary difficulties that engineering faculty pursuing engineering education research face include grounding research in theory, fully utilizing the scope of qualitative or mixed-methods designs, and collaborating across other disciplines (Borrego, 2007). Solving novel research questions in engineering education requires methodological innovation, exploration, and diversity using a variety of approaches instead of the fixation on quanti-

tative/qualitative paradigms. Transition experiences, during or after doctoral training, are seen as vulnerable junctions when students are typically more dissatisfied and at a greater risk of quitting (Chakraverty et al., 2018, 2020; Dabney et al., 2016). The transition from technical engineering research to engineering education research could be difficult if people are not trained adequately to understand these nuances that precludes applying methodologies used in engineering research to engineering education research. Concurring with Borrego and colleagues (2009), engineering education research should expand its scope to collaborate with other disciplines such as education and encourage transdisciplinary ideas, which could also popularize the practice of using qualitative and mixed methodologies in research.

In addition to academic communication and research methodologies used as frames for determining the state of belonging or feeling like an outsider (and an impostor) in engineering, the development of one's engineering identity was also discussed in ways that made participants experience impostor phenomenon. The development of engineering identity is determined through a variety of factors such as one's institutional affiliation, gender identity, academic identity, and occupational identity (Morelock, 2017). Faulker (2007) described engineering identity as a technicist (technical) and a heterogeneous (social) identity, focusing on the hard and the soft (e.g., communication) skills respectively. In all the instances in the current study, impostor phenomenon was described to show boundaries between what is considered mainstream in engineering and what is not using a framework of one's "outsider" status.

In the current study, othering happened with participants describing what was considered as the accepted norm and what was considered peripheral. For example, accepted norms included using quantitative (versus qualitative) methodologies, pursuing engineering (versus engineering education) research, developing an engineering identity (versus engineering education identity), using numeric data (versus narratives), and developing hard skills (versus soft skills). Gendered perceptions of this othering (being female in a male-dominant field) is described next. Multiple instances of othering occurred and were related to impostor phenomenon.

Theme Two: Gendered Experiences

The second theme found that women faced unpleasant experiences in engineering education research based on gender. Historically, engineering has been a male-dominated field with men as the "central actors" who asserted their dominance through gendered stereotypes (Bix, 2014). In the US, the field has historically excluded certain groups based on their perceived competence or potential in engineering as a function of their ascribed (marginalized) identities (Slaton, 2015). Several studies have examined women's gendered identity in engineering (e.g., Alonso, 2012; Chachra et al., 2008; Dryburgh, 1999; Du, 2006; Faulkner, 2007). For example, Conefrey (2001) examined the culture of science to understand women's experiences in science and engineering and why, despite their higher average scores on standardized tests, women tend not to continue in these fields. She explained some of these gendered myths that culturally views science as gender-neutral, placing the onus of success on meritocracy alone, with challenges and competition considered as natural prerequisites for success and failures occurring due to individual fault (Conefrey, 2001). The burden of failure due to individual faults could make women even more vulnerable to impostor phenomenon. Engineering identity being viewed as a gendered identity could make women feel "othered" (Alonso, 2012). Gendered experiences contribute to engineering identity development and the different ways in which men and women make sense of engineering as they progress in their undergraduate and graduate training (Chachra et al., 2008). In order to fit and be accepted in a male-dominated discipline, female engineering students sometimes behave as allies of their male peers rather than antagonists, projecting themselves as competent, denying sexism and gender discrimination, if required, and spending additional effort and energy managing the impressions others build of them (Dryburgh, 1999).

Engineering identity is largely gendered, developing through everyday practices, symbolism, and signaling (Du, 2006). The cultural identity largely assumed in engineering is masculine; women often are

at a risk of feeling invisible in such environments due to subtle and overt practices. Professional identity development and gender identity are essentially linked closely in engineering and women spend more time managing these identities as well as behaving in ways to be better accepted in the field in addition to mastering content and building technological expertise (Chakraverty & Rishi, 2021; Du, 2006; Hatmaker, 2013). This might make some women vulnerable to feeling like impostors.

Othering and gender tensions across boundaries in engineering (Faulkner, 2007) describe the "technical/social dualism" in engineering identity, the technical aspect perceived as more masculine while the social aspect as more feminine, giving rise to what Faulkner (2007) coined as "gender in/authenticity." This is yet another axes of othering in engineering. Pawley (2007) used the word "boundary" as a metaphor (similar to "othering") in engineering in conjunction with other popularly used metaphors such as "pipeline" and "chilly climate" to show gendered boundaries in engineering. She highlighted the gendered ways in which engineering is unintentionally perceived, through the overlooked boundaries of exclusion where women's participation and contribution are largely rendered invisible (Pawley, 2007). Women experience challenges because their gendered identity is more visible than their occupational identity as engineers during workplace interactions and due to imposed gendered expectations based on gendered stereotypes (Hatmaker, 2013). In a male-dominant culture, women struggle to gain legitimacy, their visibility amplified as women and poorly visible as engineers (Hatmaker, 2013). Professional interactions marginalize women in gendered ways through the amplification of gender, gendered expectations, and gendered stereotypes such as questioning technical knowledge and abilities as well as ignoring ideas and contributions, rendering women invisible and voiceless (Hatmaker, 2013). Experiencing impostor phenomenon could affect identity development as an engineer, engineering educator, or engineering education researcher due to hostile academic cultures where certain groups (e.g., women) may be unable to see themselves succeed or be valued by the larger community, no matter how able or competent they are. This could, in turn, lower their belongingness in STEM fields and impact their STEM identity development, making them less likely to persist in these fields (Strange, 2020).

Limitations and Strengths

The study sample is limited in being predominantly white and female. With poor demographic diversity, the voices of racial/ethnic minorities could not be included. It is possible that men experience impostor phenomenon differently than women. However, only two men participated in the study and no gender-based comparisons were possible. The findings are not generalizable across the larger population of engineering education researchers in the US or outside. Yet, this study contributes to the literature in multiple ways. One of its contributions is methodological, where using a multi-mode approach of surveys and interviews from the same participants, focusing more on their narratives, brought out the stories and personal experiences of why those in engineering education research experience impostor phenomenon. Additionally, this study focused on three different populations of interest: PhD students, post-doctorates, and faculty to develop a more nuanced understanding of the experiences of the entire pipeline. Prior research on impostor phenomenon in STEM shows many similarities in experiences among PhD students and post-doctorates (Chakraverty, 2020a, 2020b). It is possible that all the three groups have similar experiences.

Conclusion

The four prior studies cited primarily focused on race-based experiences of impostor phenomenon (Burt et al., 2017; McGee et al., 2019, 2021) as well as documented, through a survey at one US institution, that women in computer science experienced impostor phenomenon more than men (Rosenstein et al., 2020). Although these studies examined why engineers experienced impostor phenomenon, focusing on its implication in STEM fields, the reasons engineering education researchers experience this phenomenon have not been studied. Three of the four studies had only Black participants (undergraduates, PhD students, and post doctorates), which explained their findings. The current

study unraveled aspects of impostor phenomenon not described before, using a combination of surveys and interviews for eleven participants across the US (primarily White and female). This exploratory study found that engineering education researchers narrated impostor experiences through a lens of "othering," primarily due to two reasons. First, there were constant comparisons between engineering and engineering education, both by participants and their peers/colleagues, that made them feel like engineering and engineering education were two separate worlds and engineering education was the lesser of the two. The way one communicated in these two fields, including the vocabulary used, popularly used research methodologies, and even the identities people held were different. The hierarchical nature of engineering made participants feel like their research was not as impactful or even methodologically sound. Secondly, women struggled to develop an engineering educator identity due to gendered experiences (including lack of recognition) where they struggled to be visible. The findings should be interpreted with caution, given that the sample predominantly consisted of White women; voices from male participants were minimally represented and that from racial/ethnic minorities including Black, Hispanic/Latinx, and Native American participants were not represented. Future research should try to incorporate voices from diverse demographics and could examine, in detail, aspects of engineering education research training that could contribute to impostor phenomenon, poor belonging, lack of identity, and othering experiences. This would be important in developing strategies to reduce alienation, improve belongingness, and to strengthen the engineering education workforce.

ACKNOWLEDGMENTS

The author would like to thank all those who participated in the study, Drs Teresa Zhang and Brittany Leaf for co-analyzing interview data, and Washington State University's New Faculty Seed Grant and Faculty Research Funding Award (College of Education) for generously funding this study.

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