



PHD STUDENT EXPERIENCES WITH THE IMPOSTOR PHENOMENON IN STEM

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ABSTRACT

Aim/Purpose	This US-based study explored various facets of impostor phenomenon experienced during PhD training in science, technology, engineering, and mathematics (STEM). Specifically, the purpose of this research was to identify certain experiences that trigger this phenomenon.
Background	Competent high-achievers who do not believe in their efforts leading to accomplishments sometimes experience the impostor phenomenon. It is characterized by the notion that one has fooled others into overestimating their ability, not attributing one's accomplishments to ability, and living with the fear of being discovered as a fraud.
Methodology	Data were collected using convenience and snowball sampling. Qualitative, semi-structured interviews from 90 PhD students were analyzed thematically.
Contribution	Study findings contribute to a less-understood area of what constitutes triggers for the impostor phenomenon among PhD students in STEM fields.
Findings	Participants described the following themes that triggered impostor phenomenon during PhD training: 1) Progress and public recognition, 2) Comparing oneself with others, 3) Developing skills: public speaking and scientific writing, 4) Application of new knowledge, and 5) Asking for help.
Recommendations for Practitioners	PhD faculty, mentors, advisers, and administrators should be cognizant of the triggers that could give rise to the impostor phenomenon among their students. Professional development activities for students could focus on earlier and more rigorous training for improving scientific communication.
Recommendations for Researchers	Future research should continue to explore if other stakeholders in academia such as postdoctoral trainees and faculty also experience similar stress due to the impostor phenomenon.

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Impact on Society	Institutes of higher education should continue to focus on improving student mental health and retention rates, alleviating some of the PhD training stressors by designing interventions that improve students' mindset and self-efficacy.
Future Research	Findings point to avenues for further research on how to support those with impostor phenomenon. Future research could explore the topic in other disciplines outside STEM and examine if long-term interventions could mitigate impostor-feelings, including the nature and length of interventions that could be helpful.
Keywords	impostor phenomenon, impostor syndrome, doctoral training, STEM training, graduate school, mindset

INTRODUCTION

“[In graduate school], I continued to break myself down. I opened up a sticky note on my computer and typed ‘stop being a worthless piece of shit’ over and over and over. I fed myself lies and I broke down because I didn’t feel good enough. Didn’t understand why I was here [in graduate school]. I can’t seem to convince myself. I never knew I was so fragile. I never knew how destructive my own thoughts were. I don’t want to give up but I can’t get myself to push forward. So I just sit on my bed, trying to do work, but end up blinded by tears every few minutes. What happened to the strength I thought I had? Why am I the only person going through this? ‘Worthless piece of shit.’ How do you make the voice inside your head stop?”

This interview quote from a PhD student in the present study reveals the nature of stress many PhD students go through due to hostile academic environment and a misplaced sense of self-worth (Levecque, Anseel, De Beuckelaer, Van der Heyden, & Gisle, 2017; Longfield, Romas, & Irwin, 2006). Graduate students pursuing PhD or master degrees are experiencing mental health issues more than ever; a survey across multiple countries and fields (including STEM) revealed that graduate students are more than six times as likely to experience mental health issues such as anxiety and depression compared to the general population (Evans, Bira, Gastelum, Weiss, & Vanderford, 2018).

Impostor phenomenon (synonyms: impostorism, imposter phenomenon, impostor/imposter syndrome) is a belief about oneself held by a subset of potentially meritorious, accomplished, and successful individuals that their success was attained by fraudulence, fooling others, and luck instead of their own hard work or ability (Clance, 1985; Clance & Imes, 1978). Such incorrect beliefs are self-handicapping because they are followed by the fear of being exposed or found out by others and feelings of incompetence and being undeserving of the very success they worked for (Harvey & Katz, 1985, p. 8). Such feelings or convictions are self-sabotaging and have become increasingly common among graduate students (Cohen & McConnell, 2019; Cope-Watson & Betts, 2010; Craddock, Birnbaum, Rodriguez, Cobb, & Zeeh, 2011; Fraenza, 2016; Gibson-Beverly & Schwartz, 2008; Jöstl, Bergsmann, Lüftenegger, Schober, & Spiel, 2012; Stone et al., 2018).

Impostor phenomenon correlates with the fear of isolation (Cohen & McConnell, 2019), lack of motivation (Vaughn, Taasobshirazi, & Johnson, 2019), questioning one’s intelligence (Stone et al., 2018), and feelings of inadequacy (Cope-Watson & Betts, 2010), among others. The impostor phenomenon is generally experienced across all genders (Burt, Knight, & Roberson, 2017; Cokley et al., 2015), although marginalized groups including women and racial/ethnic minorities are particularly vulnerable (C. C. Austin, Clark, Ross, & Taylor, 2009; Bernard, Hoggard, & Neblett, 2018; Burt et al., 2017; Ewing, Richardson, James-Myers, & Russell, 1996; Peteet, Montgomery, & Weekes, 2015) and historically underrepresented in many science, technology, engineering, and mathematics (STEM) disciplines. Those experiencing the impostor phenomenon in graduate school have attributed it to one’s good luck and ability to pretend as well as other’s kindness and poor judgment of skills (Chakraverty, 2019). Despite a growing body of research on its implications, our understanding about its triggers, typical duration, or prevalence in STEM is limited. Developing a deeper understanding of

its triggers in STEM might address some of the issues of attrition, lack of diversity, and training challenges in graduate school (Blondeau & Awad, 2018; Burt et al., 2017; Gibson-Beverly & Schwartz, 2008; Ivie & Ephraim, 2009; Villwock, Sobin, Koester, & Harris, 2016).

LITERATURE REVIEW

GRADUATE TRAINING CHALLENGES

Academic settings in higher education can trigger impostor phenomenon (Knights & Clarke, 2014). Particularly, graduate training challenges include the transition between dependent and independent phases when students shift from coursework and supervised research to working more independently (Etzkowitz, Kemelgor, & Uzzi, 2000; Lovitts, 2008). Successful graduate training involves developing higher-order thinking/reasoning and scientific communication skills that are rather complex (Lovitts, 2005). Developing these skills requires psycho-social support (Etzkowitz et al., 2000) and constructive and supportive supervisory relationships that also contribute to doctoral satisfaction (Pyhältö & Keskinen, 2012).

Other challenges include the lack of diversity and equity in many STEM fields (Leshner & Scherer, 2018), a long and undefined completion time (Pitchforth et al., 2012), first-generation status (Gardner, 2013), and maintaining a critical mass of diverse students (Allen-Ramdial & Campbell, 2014), among others. A comprehensive literature review from four decades of research identified six primary areas of challenges in doctoral training: (1) lack of teaching training for doctoral students, (2) program design issues including funding and a lack of standardized assessment policy, (3) inadequate training in academic writing and research, (4) fewer career advancement opportunities post PhD completion, (5) non-standardized supervisory practices, and (6) unwarranted experiences such as isolation, discrimination, and reduced motivation to complete doctoral training (Jones, 2013). In order to create a stronger research workforce in STEM, one needs to look at graduate training challenges from multiple perspectives. Some of the programmatic challenges include inadequate mentoring, lack of role models, and lack of professional development opportunities (Butts et al., 2012; Davidson & Foster-Johnson, 2001; Summers & Hrabowski, 2006). Other challenges could include factors like low self-confidence, isolation, and lack of belonging that are a barrier for integrating and thriving in one's department or field (Carlone & Johnson, 2007; Russell & Atwater, 2005).

The nature and number of graduate school challenges one could face are multiple, complex, and many graduate students experience mental health issues as a result during training (Evans et al., 2018; Levecque et al., 2017). The stress, burnout, and sense of not belonging in graduate school or STEM fields could manifest as the impostor phenomenon due to the perception that one lacks ability (Burt et al., 2017; Ivie & Ephraim, 2009).

To understand some of these challenges, it would be worthwhile to examine research on what motivates people to act or be a particular way. Herzberg, Mausner, and Snyderman (1959) developed a two-factor model of motivation where job satisfaction is determined by factors related to the content of the job and one's relationship to it, such as achievement, receiving recognition, the nature of work, roles and responsibilities undertaken, and advancement opportunities. However, there are other factors related to an individual's relationship with the environment (and not job content), the absence of which may create dissatisfaction but the presence of which alone may not guarantee satisfaction (such as salary, security, safe work conditions). Other research has focused on developing organizations and work relationships that focuses on the development of emotional intelligence as a way to enhance individual- and group-level well-being (Adler & Fagley, 2005; Cherniss & Adler, 2000). Organizational workplace behavior research could very well be applied in the context of the current study, examining doctoral education in STEM fields where experiences are shaped by both individual behavior/motivation as well as institutional practices. The implicit theory of intelligence or mindset, in particular, has been used to understand motivation and behavior in organizational as well as educational settings.

IMPLICIT THEORY OF INTELLIGENCE OR MINDSET

According to the implicit theory of intelligence (Dweck, 1986, 2016), those with growth mindset believe that intelligence is malleable and can be enhanced with effort rather than luck or talent, thereby showing traits like perseverance, sustained motivation, and a positive attitude towards learning despite challenges (Blackwell, Trzesniewski, & Dweck, 2007; Dweck, 1999, 2016). For them, failures are learning opportunities to become better professionally. However, those with fixed mindset are more likely to believe that their intelligence is fixed or finite and thus hold stereotypical, restrictive views on their intellectual ability. They put the onus of learning or solving complex problems on innate ability or smartness, often do not persevere when faced with difficulties, and are less likely to view rejections and failures as opportunities for growth (Blackwell, Trzesniewski, & Dweck, 2007; Dweck, 1999, 2016; Dweck, Chiu, & Hong, 1995). Those experiencing the impostor phenomenon also attribute their success to luck or talent rather than innate ability (Clance & Imes, 1978; Harvey & Katz, 1985). This could indicate an underlying assumption that those with impostor-experiences would hold a fixed mindset, with restrictive views on their ability, believing that their intelligence or ability is fixed due to which they experience the impostor phenomenon. The link between the impostor phenomenon and mindset would be important to explore.

Fewer studies have examined the impostor phenomenon among graduate students compared to undergraduates and these studies are mostly quantitative (Aubeeluck, Stacey, & Stuppel, 2016; Fraenza, 2016; Gibson-Beverly & Schwartz, 2008; Ivie & Ephraim, 2009); qualitative studies are fewer and have focused on experiences related to race (Burt et al., 2017; Craddock et al., 2011) and gender (Cope-Watson & Betts, 2010). Overall, there is a gap in the understanding of specific attributes of graduate training that could trigger impostor-feelings, especially narrated through the experiences of people. This inquiry was guided by the research question: What are the aspects of PhD training that contribute to the impostor phenomenon among PhD students in STEM?

METHODS

This investigation is a part of a larger, sequential mixed-method (Creswell, Plano Clark, Gutmann, & Hanson, 2003; Ivankova, Creswell, & Stick, 2006), US-based study to understand various unexplored facets of the impostor phenomenon in STEM. The larger study was implemented in 2017 following IRB approval at a large public university in the United States where data were collected using surveys and semi-structured, one-on-one interviews. The current study presents findings from the qualitative analysis of interviews from PhD students in STEM fields currently enrolled in a US-PhD program. All interviews were conducted on telephone by the author and each lasted 45-60 minutes.

DATA COLLECTION AND ANALYSIS

To be eligible for an interview, the individual had to (1) currently be in a STEM PhD program in the USA, (2) have a basic understanding of what the impostor phenomenon is (as verified by a short survey and the first two interview questions), and (3) have personally experienced the impostor phenomenon (as verified by the short survey and the first interview question). The study was open to STEM PhD students of all genders, race/ethnicity, age group, generation-status, geographical location, and national origin as long as they were located in the USA at the time of the interview.

Participants were selected using convenience and snowball sampling (Sadler, Lee, Lim, & Fullerton, 2010) and the study was advertised through social networks, professional networks (e.g., the Association for Faculty Women at the author's university), and listservs (e.g., Society for the Advancement of Biology Education Research). Interested participants filled out a short survey (7-8 minutes) with demographic information (current field and name of institution, year in the program, age, sex, and race/ethnicity), how did they hear about the study, if they have experienced the impostor phenomenon, and their willingness to participate in a telephone interview. Those who consented to interview in the survey were contacted by email.

The interviews were semi-structured and participants were asked open-ended questions in relation to their impostor phenomenon and PhD training. Specifically, the following questions were used as a guideline and were asked to every participant: 1. Why did you decide to participate? 2. What does feeling like an impostor mean to you? 3. Have you experienced environmental cues that contributed to your impostor phenomenon? 4. Is there something inherent to the nature of your field, PhD training, or academia that makes you feel like an impostor? 5. Does feeling like an impostor get in the way of your day-to-day activities or things you are trying to accomplish? Since this study followed a semi-structured format, other questions emerged as a result of responses to these five questions and varied based on participants' life experiences. The five basic interview questions were developed by the principal investigator and author of this manuscript based on her understanding of the gaps in the current literature.

A study webpage with the survey link was hosted by a university and indicated that the study was being conducted to expand understanding of the impostor phenomenon in STEM. No operational definition of the impostor phenomenon was provided. Data collection continued for 13 months. Those who indicated in the survey that they have never experienced the impostor phenomenon were not interviewed. To ensure that the interviewees understood the meaning of the term "impostor phenomenon," each participant was asked at the beginning of the interview what do they mean by the impostor phenomenon. Two participants shared that they did not know what it meant but wanted to interview because they were curious about the topic. Interviews were not conducted with them. The rest of the 90 participants provided an explanation that aligned with the definition provided by Clance and Imes (1978), who first coined the term.

The author conducted all the interviews. Along with a graduate trainee from a STEM field, the author open coded half the number of interviews as they were being conducted to create a codebook. The codes were developed based on the content of the interviews. For example, some of the codes pertaining to PhD training were "milestones," "adviser," "peer," "skill development," "writing," "publish," "present," "climate," "teaching," and "recognition." Other codes pertaining to the impostor phenomenon that emerged from the interviews were "self-esteem," "fear," "luck," "judgment," "underprepared," "leaning in," "evaluation," "self-doubt," "confidence," and "belonging." The author resolved disagreements about coding through discussions with the graduate trainee until both reached a consensus. The codes that were developed after conducting half the number of interviews were applied to the remaining interviews. Data saturation occurred during the first half of coding and no new codes emerged while coding the other half of the interviews. After data collection and coding were completed, the author combined codes into themes using analytic induction (Glaser & Strauss, 2017; Miles & Huberman, 1994; Pope, Ziebland, & Mays, 2000; Thomas, 2006). Both the coders were mindful of their different worldviews and their background in STEM as well as their gender that could influence this research, keeping note of any disconfirming evidences (Antin, Constantine, & Hunt, 2015) and maintaining a reflective journal.

FINDINGS

Participants came from 46 research-focused (R1) universities with high/very high research activity based on the Carnegie classification (The Carnegie Classification of Institutions of Higher Education, n.d.) from 26 US states and were between age groups 20-39 years. The sample was predominantly female and White. Demography of the sample is provided in Table 1.

Table 1. Student demographics

TOTAL	N=90
Field	Science: 65 Technology and Engineering: 21 Mathematics: 4
Sex	Male: 11 Female: 79
Race/ethnicity	White: 63 Black: 4 Hispanic: 9 Asian: 10 Multi-racial: 4
Age range (years)	20-29: 66 30-39: 24

The following themes emerged as a result of participants describing impostor-experiences in relation to their PhD training: 1) Progress and public recognition, 2) Comparing oneself with others, 3) Developing skills: public speaking and scientific writing. 4) Application of new knowledge, and 5) Asking for help. These themes are illustrated with representative quotes in the text and table 2.

Table 2. Themes that trigger the impostor phenomenon during PhD training

THEMES	QUOTES
Progress and public recognition	My department nominated me out of everyone in our incoming class [for a graduate fellowship]. I felt like the lowest performing member of the class for the first year, even though I ultimately won it over many others.
Comparing oneself with others	We were working together a lot [all the graduate students], and I had just felt comparing myself and feeling inadequate a lot, and wondering why I was here and why I deserved to be here. I very clearly remember in my proposal writing class, my cohort in that class was very clear and knew what they were doing for their PhD, and they had it all laid out. I was the only one that was still figuring out. I felt very behind compared to my peers.
Developing skills	Writing papers, actually, is where it exposes my feelings of an impostor. I'm still working on getting my thought process out on paper, whereas if I'm up in front of a class speaking, I can speak and kinda BS [lie] my way through the topic.

THEMES	QUOTES
Application of new knowledge	I struggle more when it's something new. If I'm taking a new class or I'm doing a new research technique, then it gets heightened. With coursework, it's just the constant fear that this will be the class that I can't handle; building off of the undergraduate and then the graduate school impostor syndrome that started with coursework.
Asking for help	A lot of my research will be with large datasets. And because of that, we have to use a lot of computer programs and software. I'm not very familiar with computers and it feels like most of the people in my lab are very computer competent. Or at least know more than I do at this point. So whenever I have to ask a question about something related to some computer software I'm using, that's definitely when I feel the most out of place.

PROGRESS AND PUBLIC RECOGNITION

Students felt like impostors as they progressed through PhD training and completed milestones (e.g., passing preliminary exams, qualifiers, comprehensive exams, proposal defense, or dissertation), questioning their progress and their adviser's decision to retain them. For example, a student shared, "In both cases where I have been first author on a publication, I have felt like I cheated my way through the review process. ... Since I know the work better I can see all the assumptions we've made that may be incorrect."

Students harbored negative, self-deprecation thoughts like: "I am taking up space that someone more productive or intelligent deserves" and "I'm not smart or driven enough to live up to the expectations of the program. I regularly wonder if the professors who offered me the assistantship regret their choice." With each stage of the PhD completed, students felt guilty, thinking that they still lacked content knowledge or problem-solving skills, their advisers were merely overestimating their research skills, and the dissertation committee would be soon disappointed. Students felt shame for not trying harder or being better and expressed surprise on passing PhD milestones based on self-evaluation of their performance. On passing the qualifiers, a student felt "demoralized and hopeless about my future. I don't feel that I deserved to pass," and terrified:

that I don't belong in graduate school, that I should be cast out without another thought. Each thing that I do 'right' by program standards makes me feel like I am one step closer to the edge of the cliff I will get shoved off when they figure out I am really not smart enough or cutout for this position.

Students lived in constant fear that their committee will realize that they do not know what they are doing in the program. Impostor-feelings were triggered after receiving recognition through research awards and competitive research fellowships (such as the NSF Graduate Research Fellowship or the NIH K01 award), career development awards, conference awards, and international scholarships. On receiving a research award, a student "felt that no one should trust my findings when compared to the other researchers." Students felt surprise, undeserving, fear, and discomfort with such recognition, like, "I took the award away from them [other contenders]" and "somehow I've tricked even my peers into thinking I was smarter than I really am." A student thought that she received a graduate fellowship only "as bribery to get me to join a specific research group that was desperate for students." Another student shared:

My entire graduate experience has been mediated through feelings like I shouldn't have gotten the fellowship, my original ideas were horrible, that I am incapable of doing the things I set out to do, or I'm not actually as good as I made my application seem.

COMPARING ONESELF WITH OTHERS

Students who felt like impostors tended to compare themselves unfavorably to their peers to conclude that they were not at par and thus felt inadequate. For example, a student shared, "The first year and a half of grad school I had a chronic sense of not belonging, not being worthy, not being smart enough for the program I was in, or as diligent and productive as my peers." Students considered others to be smarter and doing more important research as they undervalued their own research, expertise, and skills and considered their success as circumstantial, non-replicable, and due to luck. Students felt that while they struggled to deal with the workload and grasp the concepts taught in class, their peers in class were smarter. Students questioned if they were intelligent or hard working enough to belong in the program when others discussed research one was unfamiliar with, comparing one's lack of knowledge with that of others in the program.

Comparisons became evident in graduate school where students who felt like impostors also felt that everyone around was brilliant, pursuing more interesting research questions, progressing faster, asking better questions in class, conducting themselves in a way that they are taken seriously, and navigating PhD training with confidence. A student feared that others "perceive me not to be as technically capable as my peers" that led to fear of not belonging in graduate school. Another student added:

I didn't realize how fragile my own self-esteem was until I was directly surrounded by so many people I could compare myself to. I don't ask good questions. I don't think critically. I don't take myself seriously. I don't speak, act or think like a scientist. My proposal was shit compared to others. Everyone else had better questions and knew what they were doing. I don't.

Impostor phenomenon worsened during conferences as students found themselves surrounded by people well-known in the field and constantly comparing themselves. A student shared,

These people have this insane amount of knowledge that I just don't. I just don't know nearly enough to be competitive. You just feel so insignificant compared to these people who have just published a Nature paper, or just got some huge distinguished award. That definitely heightens it [impostor phenomenon].

Comparing other's achievements instilled negative self-worth. A student shared, "for me it was just, wow, look at what all of these people here have done and look at how far away you are from doing this." A student further added feeling "completely out of place [at conferences]. People around me were all better embedded in the culture of the conference and I felt like a complete outsider. I lacked knowledge relative to my peers." Students who felt like impostors found it more counterproductive than productive to attend conferences, even fearing networking and being introduced to others at conferences that caused anxiety. A student shared, "I actually have pretty bad bouts of depression at conferences."

DEVELOPING SKILLS

Public speaking

Those who felt like impostors during public speaking dreaded conference presentations. A student shared, "I don't always feel confident in my communication skills in terms of public speaking. I think part of that is my perception of myself that hinders my ability to present properly."

Being in the spotlight induced anxiety; students feared like they were being watched and judged. A student said:

Every word you say, you immediately are in your head going did I say that wrong? Am I going to be judged? Fighting that impostor anxiety as you are doing a task is the worst feeling in the world. Because you're so distracted that you don't feel like you're performing the way that you should. Because you're constantly overanalyzing.

Students did not feel confident to say that they don't know the answer to a particular question. Students felt like they were expected to have a certain degree of proficiency in their field, and not knowing the answer to a question asked was unacceptable. Students feared that their research and their existence in the field would be questioned if they could not answer questions during public presentations. "I just mumbled my way through some kind of answer. It was just definitely a moment where my self-confidence in my ability to present was cut down," a student shared.

Those who feared public speaking preferred academic writing as a mode of communication. Writing was more rehearsed while presentations were more extempore and unstructured. A student shared:

In a presentation, you have an audience and they're all going to be watching you. You never know what questions someone is going to ask of you and how much someone is going to challenge your ideas. That's probably where my impostor syndrome is highest.

Students who could not answer questions during a presentation automatically assumed that they did not belong in the field and were fake. A student shared that on not being able to answer questions about one's research,

People are gonna somehow sniff out that I'm actually not as knowledgeable as you would think I am. That's one of my major sources of anxiety. I don't present at as many conferences. I really don't like to hang around my poster, cuz I'm stressed about who's gonna come and talk to me about it.

Students shared that they did not know how to present research as a story and emphasized the need for more opportunities to learn story-telling in front of an audience during PhD training. "When I had my impostor tendencies very strong in me, I did not know the way I really understand a subject. I would have all the information, but I had no idea how to talk about it," a student shared. Additionally, many felt that they were not experts in their field and whatever they are speaking is already known, that they had nothing new to add to existing knowledge. Students felt self-critical about presenting research, striving for perfection and feeling judged negatively, factors that heightened impostor-feelings. They felt that they have no authority to talk about a topic because there are others who have spent longer time pursuing research in that domain and know more. As a result, "they're going to see some obvious flaw that I should have seen, and that they're just going to call me out on being a fraud, and I'm going to damage my mentor's reputation," a student shared.

Scientific writing

The process of writing and publishing induced impostor-feelings among students who questioned their contribution to writing papers and questioned their ability to publish. A student wondered if his research will be published since "I am only following the protocols invented by people who came before me and not contributing anything original" while another student expressed surprise that the reviewers understood her paper, doubting if they "thought about the basic science behind the study, were tired, or didn't spend the time to fully understand the background of the paper, therefore they didn't have many comments." Students wondered if the reviewers judged them as stupid or the readers will question the reviewers if their papers were published. Impostor feelings persisted even after publishing research papers in prestigious journals. A student shared, "My adviser will scrutinize it [the

paper] so carefully, he'll catch any little mistake, and then that little mistake would blow up into realization that I don't know what I'm talking about, and the next day, I'd be kicked out of the lab."

Another student shared that even after publishing research in the journal *Science*, "I still feel like I was given authorship as a courtesy, and not because I did any work to belong on that list. I sometimes wonder if that was just them [the co-authors] being nice to include me." A student shared not wanting to "tell people about my papers. I'm like, 'I don't want you to read this, because you're just gonna realize that I'm just a bad writer, and I don't belong here.'"

Scientific writing induced anxiety for many reasons. The process of publication was long, arduous, with frequent rejection from journals. Students expressed fear of rejection and discomfort with the subjectivity of the review process, not feeling fully prepared to deal with reviews that were harsh but not constructive. Students feared judgment from those who read their papers (including their advisers), pointing out flaws or asking questions they did know the answer to. A student shared, "Writing is something that people are going to see, that freaks me out. What if they [future employers] read that paper that I wrote and think it's stupid and already hate me?" Rather than view feedback as a constructive process, students feared how their writing and research will be criticized by others, that they had nothing new to add to the field through publications, so much that sometimes, they avoided academic writing altogether. An advanced PhD student reflected that he often procrastinated, and "my avoidance is tied to my expectation that I can't accomplish something or that I'll fail. Instead of writing a shitty draft, I just avoid it because I feel like I can't do it."

Due to the impostor phenomenon and a fear of writing, students felt unqualified and underprepared, and without enough training in academic writing; a student "felt I was just going through the motions of writing a thesis, but didn't feel qualified enough to write." Others admitted that they got very little training on scientific writing. "At the PhD level, you're supposed to write in a certain way. If you're not writing in that way, it's not scientific. You're not accepted in the field," a student shared. This was especially true for those whose first language was not English. Some students felt that their advisers treated them like employees and not mentees, not taking time out to train them to write scientifically. "They just expect you to have that innate ability, and if you don't, then you get a lot of negative comments, or they completely just write it for you, because they don't wanna deal with having to train you." Not getting formal training in writing meant that "the language becomes a barrier, so when I'm relating my science in a written form it gets harder. It prohibits me from making a good story about how I want to relay my science. That affects me," a student explained.

APPLICATION OF NEW KNOWLEDGE

The practice of applying new knowledge was challenging for those who felt like impostors. A student shared:

I think every course I take is new and different and challenging in different ways. Every single time I think this will be it. This will be the class that breaks the camel's back and reveals all the things that I cannot do, and my ambitions for a future will end with this course.

PhD students taught as teaching assistants as a part of their PhD training. Although teaching was more rehearsed and happened in front of a known audience, many experienced impostor-feelings while teaching, especially while teaching courses in a related but different department and a topic they did not specialize in (for example, a biochemistry student teaching pharmacology courses). A student shared:

I wasn't feeling like I belonged in the pharmacology program. Now I have to act as the leader in individual study sessions. That really, really made me feel like an impostor, just having to teach those students. ... It's anything new or anything I feel like I haven't had a lot of experience in, that's when I really feel like an impostor.

Like teaching, coding and data analyses were also tasks that induced impostor-feelings because one had to apply new knowledge. A student shared that while running statistical analyses on SPSS, she merely followed a laundry list of instructions, but did not know how to interpret the output. Additionally, analyzing data for research meant going a step beyond classroom learning. A student shared that she had to incorporate computer modeling for her research which she hadn't learnt in class. "I had absolutely no idea where to begin. Working through it was very difficult. It definitely highlighted my fears of 'Would I ever be able to actually do this in real life?'"

While incorporating new learning in research, a student who felt like an impostor also felt that she was very slow in learning a new protocol or solving a new problem. "I try myself to figure it out, but it doesn't work, and it takes a long time. Then I ask someone from the group to help me, and then they come up with a solution right away." Students who felt like impostors had anxieties related to applying something newly learnt, for example, adopting a different learning style through a flipped classroom where "we were expected to become masters of the content on our own accord" that induced insecurities. New coursework and learning new content also induced anxiety due to impostor phenomenon.

ASKING FOR HELP

Students who felt like impostors found it difficult to ask for help. They feared that it made them look bad, that others would judge them, their lack of knowledge would be exposed, and they should have studied better rather than ask for help. A student shared, "I just feel they [the lab members] know so much more. I feel like they're just gonna tell me that I'm wrong, or that they're not gonna buy my research. They're not gonna believe it's conducted correctly."

Students had issues with self-presentation and the way they would be perceived when asking for help. A student had "a huge hang up on doing that [admitting I don't know something] in front of faculty." Students did not even apply for opportunities in fear of getting rejected, yet felt hesitant asking for help. They didn't always understand how to run statistical analyses but felt hesitant to ask questions. Not knowing something made them feel like impostors. A student shared, "I try to play it off and try to ask intelligent questions, but I feel like they're really dumb questions. I feel, in that way, that I'm disingenuous about my research."

Another student shared that asking for help related to computer programming made her felt incompetent and out of place, although she saw her adviser and other lab members work as a team, asking help from each other, relearning their skills, and troubleshooting when codes do not run. "I'm starting to come to the realization that it's an ongoing learning and troubleshooting process for everyone, including my adviser."

As an example of negative self-talk, a student shared:

I get stuck on something that a friend of mine who has a bachelor's degree in programming, he helped me through in like 5 minutes and I just spent 6 weeks on it. That makes me think that I'm not good enough to do it. My brain is saying no you can't [get a PhD], cause look you can't even accomplish these 10 lines of code.

DISCUSSION

In this qualitative study, 90 interviews were analyzed to better understand what aspects of doctoral training contributes to the impostor phenomenon among PhD students in STEM. An analysis of the interviews revealed that impostor-feelings during PhD training were linked to the following reasons: 1. progress and public recognition, 2. comparing oneself with others, 3. developing skills (public speaking and scientific writing), 4. application of new knowledge, and, 5. asking for help. Students at all stages of training felt like impostors. This study explores themes in PhD training that prior research has not addressed.

The prevalence of the impostor phenomenon in US populations has not been examined and existing studies are geographically restricted to one or few institutions. The STEM workforce faces unique challenges such as the underrepresentation of women (especially women of color), long training time, and fewer number of students aspiring for a faculty career (Dabney, Chakraverty, Hutton, Warner, & Tai, 2016; Martinez et al., 2007; National Research Council, 2011; National Science Board, 2012; Stephan, 2012). An important factor contributing to the impostor phenomenon among some graduate students could be the nature of future job market following PhD, where training periods are long, low salaries make pursuing research a less viable option economically, and the number of scientists trained are greater than the number of research positions available (Stephan, 2012). An increasing diversity in the US population necessitates improving diversity in graduate education for many reasons (for example, improving cross-cultural competence). Yet, PhDs are increasingly getting discouraged from pursuing an academic career (J. Austin & Alberts, 2012; Fuhrmann, Halme, O'sullivan, & Lindstaedt, 2011; Sauermann & Roach, 2012) due to an extremely competitive and stressful learning environment (Alberts, Kirschner, Tilghman, & Varmus, 2014). Sustaining in such competitive environments is even more challenging for women and persons of color (Villablanca, Beckett, Nettiksimons, & Howell, 2011; Wong et al., 2001), who face greater challenges to thriving and succeeding in the field. Although not examined yet, the same challenges could be creating heightened impostor-feelings among some PhD students, especially women/persons of color. Factors related to future job prospects could possibly impact anxiety levels, impostor phenomenon in graduate school, and the overall ability to visualize oneself as a future researcher in the field (belonging); however, this assertion would need more research.

By its very definition, those who feel like impostors do so following an achievement, success, or recognition in some form (Clance & Imes, 1978; Harvey & Katz, 1985). Study findings not only confirm the same, but also catalog the various kinds of situations that made PhD students vulnerable to this phenomenon. Each of the five themes uncovered portray some of the essential aspects of doctoral training. In the first theme, impostor-feelings increased as one progressed through doctoral training, attained milestones, and achieved public recognition. Performance-based student assessments examining their research skill development in the doctoral journey could be beneficial; to better enhance research skill development during PhD would require developing instruments that measure skill development over time (Feldon, Maher, & Timmerman, 2010). In the past, Individual Development Plans have been successfully developed and implemented where students self-assess their skills and interests along with faculty mentors to track their career development (Vanderford, Evans, Weiss, Bira, & Beltran-Gastelum, 2018). The second theme uncovered how the impostor phenomenon is further aggravated when students constantly compared themselves unfavorably with others who were perceived as more intelligent, questioning why they are pursuing PhD and if they got into the program by luck. This could be tied to several traits characteristic of this phenomenon, like lower self-esteem, lack of belonging, self-doubt, academic under-preparedness, and inadequacy (Cisco, 2020; Cope-Watson & Betts, 2010; Neureiter & Traut-Mattausch, 2016; Stone et al., 2018; Yaffe, 2020).

The third theme focused on communication skill development and how the impostor phenomenon increased during conference presentations and publications. Effective verbal and written communication are considered among the core competencies that should be developed during doctoral training (Durette, Fournier, & Lafon, 2016; Larkin & Morris, 2015). In this study, participants shared their anxiety about publishing, having already published successfully in peer-reviewed journals, yet it is this very success in publishing that triggered impostor-feelings. Similar findings were reported among 11 postgraduate students interviewed who revealed that the impostor phenomenon occurs during training due to a combination of unpreparedness related to academic reading and writing, class conversations, and in the process of comparing oneself to peers (Cisco, 2020). While the current study confirms some of these findings from a larger sample of interviewees (e.g., comparing oneself, public speaking and scientific writing), it also documented additional situations like progress and public

recognition, application of new knowledge, and asking for help that made students feel like impostors and undervalue their potential as contributing members of academia.

Anxiety continued as students struggled to apply their knowledge in new settings in the fourth theme, be it teaching, analyzing data, or incorporate new learning in their research. On a related note, students also hesitated asking for help (theme 5) as they feared that their vulnerabilities would be exposed. Since those with the impostor phenomenon have difficulty internalizing success and tend to attribute achievement to luck, error, or external factors, it could also be a reflection of a fixed mindset in assessing one's intelligence and capability due to self-handicapping beliefs. Students experiencing the impostor phenomenon struggled to notice or feel proud of their achievements and recognize their competency. On a related note, the way we view failure in academia needs larger-level reflection. Students who felt like impostors were also afraid of being wrong or not knowing the answer to a question and felt judged and criticized themselves for being wrong. This could explain why they were reluctant to apply new knowledge or ask for help.

Schwartz (2008), in his essay, "The importance of stupidity in scientific research," talks about research being "immersion in the unknown," a phenomenon that is time-intensive, without assured or immediate results. A productivity-driven culture in academia could create anxiety among PhD students who are not always well-equipped to cope with academic stress (Barry, Woods, Warnecke, Stirling, & Martin, 2018), especially stress due to failing or being wrong (Mortenson, 2006). It would be valuable to re-examine academic power structures that contribute to this stress, and how PhD training can be tailored academically and culturally so that at-risk students can develop a stronger mindset, sense of belonging, and find support among their peers and mentors (Sanford, Ross, Blake, & Cambiano, 2015), transitioning from the fixed mindset to growth mindset and enculturating values such as grit and resilience (Dweck, 2006). Having more open dialogues among those who grapple with the impostor phenomenon could help manage it by developing a sense of community and connection, thereby normalizing impostor-feelings and making them less stigmatic.

Prior literature has reiterated the constant tension between the social construction of gender identity for women and their STEM identity (e.g., Ahlqvist, London, & Rosenthal, 2013; Powell, Bagilhole, & Dainty, 2009; Rhoton, 2011; Tate & Linn, 2005); research also shows that the impostor phenomenon is more common among women (Clance & Imes, 1978; Cohen & McConnell, 2019). Although women were overrepresented in this study, the author did not see any trend or difference between the themes based on gender.

Prior research shows links between growth mindset and academic motivation (Dweck, 2006; Grant & Dweck, 2003), learning outcomes and achievements (Blackwell et al., 2007; Claro, Paunesku, & Dweck, 2016; Paunesku et al., 2015). Based on years of research, Dweck (2016) concluded that success is hinged on self-belief about ability and effort spent on improving ability more than just possessing the ability. Those who experience the impostor phenomenon, by definition, are successful, yet may not have positive self-views about ability and possess fixed mindset (Dweck, 2012). Prior research shows that people can hold mixed mindset under different settings (Dweck, 2006; Quihuis, Bempechat, Jimenez, & Boulay, 2002).

Alternatively, based on this study, mindset could be viewed as something more fluid rather than categorical (growth or fixed). In other words, students can have fixed mindset in one domain and growth mindset in a different domain, depending on situation and context. For example, a student could feel like an impostor in public speaking but might be comfortable with scientific writing or the application of new knowledge. However, this would need more research. Additionally, those who feel like impostors are sometimes averse to risk-taking, do not seek growth and learning opportunities, and are not open to implementing creative ideas in research due to constantly feeling judged and threatened. Future interventions emphasizing the development of growth mindset could potentially help in addressing impostor-feelings and beliefs about oneself. However, understanding the connection between the impostor phenomenon and mindset needs more research.

Is there something in the academic environment that triggers impostor-feelings despite, or due to, success? The importance of professional and academic support to improve doctoral student persistence have been expounded in prior research (e.g., Chakraverty, Jeffe, & Tai, 2018; Greene, 2015; Ruud, Saclarides, George-Jackson, & Lubienski, 2018). Institutions might consider addressing what supports are necessary for those vulnerable to or already experiencing the impostor phenomenon. Can early intervention and support for students potentially prevent impostor-feelings to develop later in one's career? One of the simpler interventions, as pointed out by Cisco (2020), is helping students identify and be aware of their impostor-feelings. This is possible through honest conversations and developing relationships with peers and mentors.

Early support during graduate training, as early as PhD orientation, might help identify and manage impostor-feelings while seeking support groups. Novel mentoring approaches should address how to work with trainees who experience this phenomenon, where successes and achievements can also become triggers. Mentors and advisers could mindfully learn to have more open conversations and interact with the trainees vulnerable to the impostor phenomenon. Both individual and institutional research productivity is measured using parameters like the ability to publish peer-reviewed, empirical research in high-impact journals (Wootton, 2013). Professional development and mentor support should start early and continue throughout training, with avenues of receiving constructive, performance-based feedback. The importance of formulating individual development plans along with faculty mentors, as discussed above, would be important.

Developing a sense of belonging as well as the skills to thrive in academia (publishing papers, and presenting for academic audiences) take time and continuous effort, and mentors play a crucial role in both. Graduate training is complex, lengthy, and students often interact with a network of faculty mentors and advisers as well as peers during their training (Kong, Chakraverty, Jeffe, Andriole, Wathington, & Tai, 2013), developing their identity as researchers while integrating in their respective fields (Baker & Pifer, 2014; Baker, Pifer, & Griffin, 2014). Those who experience the impostor phenomenon are more likely to experience isolation and not seek academic collaborations or ask for help due to perceived lack of support or belonging, as shown in this study. The impostor phenomenon could adversely affect mental health and well-being (Cokley, McClain, Enciso, & Martinez, 2013; Cokley et al., 2017; McClain et al., 2016), which can affect graduate students experiencing depression, stress, and suicidal ideation (Eisenberg, Gollust, Golberstein, & Hefner, 2007; Hyun, Quinn, Madon, & Lustig, 2006; McGregor, Gee, & Posey, 2008), making it an important topic of study.

LIMITATIONS

This study used a purposeful, non-random sampling method, increasing the possibility of selection bias (Patton, 2015). At 12 per cent, males were underrepresented in the study. The study sample is not nationally representative and the findings should not be generalized across the US population. Since interviews were conducted once, we do not know if the impostor phenomenon continued over time, and for how long. The study did not use validated measures of mindset, so a quantitative exploration of the impostor phenomenon and mindset is beyond the scope of this research. Despite these limitations, the current study contributes to a less understood area of professional development among PhD students in STEM who feel like impostors.

FUTURE DIRECTIONS

In this study, the impostor phenomenon was seen in STEM students across departments, universities, fields, and ages. The study highly recommends future initiatives to examine the impostor phenomenon longitudinally, its relationship with mindset, and if long-term interventions could address, mitigate, or normalize impostor-feelings, including the nature and length of interventions that could be helpful. Further research could also explore the nature and extent of the impostor phenomenon outside STEM fields, and among other marginalized groups, for example, international doctoral stu-

dents who may not be as familiar with the academic culture, system, and language and may be rendered invisible or more vulnerable to experiencing impostor phenomenon due to academic challenges, transition difficulties, economic hardship, language and cultural barriers, and social exclusion (Laufer & Gorup, 2019; Smith & Khawaja, 2011). Future research could also examine how impostor phenomenon can impact individual development plans where students self-assess themselves. The experience of impostor phenomenon could possibly impact how successful students view themselves in the field and as a result, how do students self-assess, and develop their career plans thereof. The impostor phenomenon could possibly impact how and what students define their career goals following PhD, although this assertion needs research.

CONCLUSION

This study examined what aspects of PhD training could be contributing to the impostor phenomenon in STEM fields. Study findings revealed that students could be experiencing the impostor phenomenon as they progress through their PhD, attain milestones, and are publicly recognized for their progress (for example, through receiving awards or fellowships). The phenomenon could further occur when one constantly compares oneself (unfavorably) with their peers, does not feel confidence in certain aspects of their skill development required for doctoral completion (for example, mastering public speaking in conferences and academic writing through scientific publications), and faces challenges in applying new knowledge (for example, applying knowledge gained through coursework in their research or teaching). Students who felt like impostors were also reluctant to ask for help as they perceived being viewed negatively if they would do so. This study encourages readers to reflect on the way academics are trained to view failure. Although usually viewed as an internal phenomenon, the impostor phenomenon could be very well rooted in explicit, external cues such as a stressful, chilly academic environment. Universities, STEM departments, administrators, advisers/mentors, and PhD students may find this study useful, especially to understand how institutions and individuals could work together to help PhD students and create support systems for those who experience/are at risk of experiencing the impostor phenomenon that could affect student mental health and well-being. Such initiatives will be useful not only for successful PhD completion, but also for better transition into career pathways and job attainment post-PhD.

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BIOGRAPHY



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