IMPOSTOR FEELINGS AND CAREER OUTCOMES AMONG STEM WOMEN: THE ROLES OF ENCOURAGEMENT AND RESEARCH SELF-EFFICACY

by

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Abstract

Despite women's increased representation overall in higher education, women still earn fewer doctoral degrees than men in many STEM (science, technology, engineering, and mathematics) fields, particularly in those fields that are math-intensive (i.e., mathematics, engineering, computer science, and physical sciences). Lower levels of self-efficacy in women have been identified as one critical barrier that may explain the underrepresentation of women in math-intensive STEM fields. The impostor phenomenon (IP) may contribute to differences in self-efficacy as well as negatively impact STEM women's interest in research and expectations for a career in STEM. Using the interest model of social cognitive career theory (SCCT) as a theoretical framework, the study examined research self-efficacy (RSE) as a mediator and encouragement as a moderator in the relationships between impostor feelings and interest in research and expectations for a STEM career. Participants were 167 STEM women in doctoral programs in the math-intensive fields. Results indicated that RSE partially mediated the relationships between impostor feelings and interest in research as well as impostor feelings and expectations for a STEM career. In addition, encouragement moderated the relationship between impostor feelings and RSE. These findings suggest that building research self-efficacy in and providing encouragement to STEM doctoral programs may reduce the negative impacts of impostor feelings.

Keywords: impostor phenomenon, STEM women, encouragement, social cognitive career theory, research self-efficacy, interest in research, expectations for a STEM career

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CHAPTER ONE

STUDY OVERVIEW

Gender Disparities in STEM Doctoral Programs

The term "STEM" was first introduced in the early-2000s by the National Science Foundation (Sanders, 2009). Science, technology, engineering, and mathematics (STEM) represent a wide-ranging group of disciplines. STEM has been recognized as an important group of fields for job opportunities, technological advancement, and national security (Committee on STEM Education, 2018; Hill et al., 2010) and increasing the STEM workforce and improving STEM education has been a focus of both the Obama (Handelsman & Smith, 2016) and Trump (Camera, 2018) presidential administrations.

Over the past 50 years, women's representation in math-intensive STEM fields (i.e., engineering, computer science, mathematics, and physical sciences) has increased overall (Ceci et al., 2014). Despite this increase, however, women continue to be underrepresented (i.e., earning less than 50% of degrees awarded) in math-intensive STEM fields (National Science Foundation, 2019b), particularly at the bachelor's and doctoral level. For example, in 2016, women earned only 20% of doctoral degrees in computer science, 23.5% of doctoral degrees in engineering, 28.5% of doctoral degrees in mathematics, and 19.3% of doctoral degrees in physics (National Science Foundation, 2019b).

While women are underrepresented particularly at the bachelor's and doctoral level, the current study focused on doctoral students. Some researchers consider doctoral training to be a critical period in which individuals often solidify their career intentions (Cabay et al., 2018). However, many studies have focused on undergraduate STEM students, and limited research has examined doctoral STEM students, which presents a gap in the current literature (Wilkins-Yel et

al., 2021). The current study focused on women in math-intensive STEM doctoral programs as a research population to address this gap.

Impostor Feelings and STEM Women in Doctoral Programs

Impostor phenomenon (IP) refers to an "internal experience of intellectual phoniness," and a belief that one is not as intelligent or capable as others perceive them to be (Clance & Imes, 1978, p. 241). Those experiencing IP (i.e., those with impostor feelings) see themselves as frauds, believing they have deceived those around them into thinking they are more competent or intelligent than they truly are (Clance, 1985; Clance & Imes, 1978; Clance & O'Toole, 1987). Impostor feelings have been found to be prevalent in STEM doctoral students (Chakraverty, 2019, 2020b, 2020a; Ivie & Ephraim, 2009; Stachl & Baranger, 2020), specifically female doctoral students (Tao & Gloria, 2019). Recent research has suggested that women in disciplines that strongly value talent and/or innate intellectual abilities (e.g., STEM fields) may be more significantly impacted by impostor feelings than their male counterparts (Muradoglu et al., 2021).

Exploring the impacts of impostor feelings on STEM women in doctoral programs is important because impostor feelings have been seen as an internal barrier for academic and professional success (Neureiter & Traut-Mattausch, 2016a). The self-doubt associated with impostor feelings may inhibit individuals from reaching their full potential, as they may turn down opportunities for advancement because they do not believe they are qualified or capable (Clance & O'Toole, 1987). Additionally, impostor feelings have been associated with lower academic self-efficacy and more negative attitudes towards persisting in STEM in female STEM doctoral students (Tao & Gloria, 2019). Impostor feelings have also been negatively associated with research self-efficacy (RSE) in doctoral students (Jöstl et al., 2012). Lower self-efficacy is

believed to contribute to the underrepresentation of women in STEM (Cheryan et al., 2017) and thus it is possible that impostor feelings may contribute to women's underrepresentation in STEM through their impact on self-efficacy.

Social Cognitive Career Theory

Social cognitive career theory (SCCT; Lent et al., 1994) is the primary vocational theory used to explore the underrepresentation of women in STEM fields (Fouad & Santana, 2017). SCCT aims to provide a framework for understanding important processes in career development (e.g., developing interests, choosing a career, persisting in that career) and the impact that supports and barriers have on these process (Lent et al., 1994). SCCT originally proposed a framework consisting of three interlocking models focused on vocational interest, choice, and persistence (Lent et al., 1994). The interest model, which the current study focused on, explores the associations among self-efficacy, interest, and outcome expectations. This model proposes that an individual's self-efficacy in a subject or field predicts their interest in that field and the outcomes that they expect to receive from pursuing that field (Lent et al., 1994). The current study focused on RSE, interest in research, and expectations for a STEM career (i.e., outcome expectations).

RSE is defined as an individual's belief in their own ability to successfully conduct research (Forester et al., 2004). RSE is particularly important for doctoral students, as conducting research and completing a dissertation or thesis is an important part of most doctoral training programs (Ampaw & Jaeger, 2012; Litson et al., 2021). In doctoral students, RSE has been associated with increased interest in research (Lambie et al., 2014; Livinţi et al., 2021; Morrison & Lent, 2014) and positive expectations for a career conducting research (Livinţi et al., 2021). Interest in research, which refers to an individual's interest in conducting research as part of their

post-doctoral career, is important for women in STEM doctoral programs because research is a key component of doctoral programs. Additionally, approximately 41% of individuals with STEM doctoral degrees conduct research as a primary activity in their career (Opsomer et al., 2021). Outcome expectations, or one's beliefs about the potential outcomes of pursuing a certain field or activity (Bandura, 1986), are important for this population as well. Specifically, positive expectations related to earning a doctoral degree (e.g., the value that one prescribes to earning a doctoral degree) are important motivating factors for STEM doctoral students (London et al., 2014). Additionally, outcome expectations have been found to play an important role in women's decisions to stay within the field of professional engineering; those with more positive expectations about their career were more likely to remain in engineering (Fouad et al., 2011).

The SCCT interest model has received meta-analytic support in undergraduate STEM women population (e.g., Lent et al., 2018; Sheu et al., 2010; Sheu et al., 2018). Positive associations have been established between self-efficacy in STEM and outcome expectations in STEM through meta-analysis (Lent et al., 2018; Sheu et al., 2018). Additionally, positive correlations have been established between self-efficacy in STEM and interest in STEM via meta-analysis as well (Lent et al., 2018). The proposed relationships of the SCCT interest model have also been supported via meta-analysis in a population of primarily doctoral students. In particular, positive relationships between RSE and interest in research as well as RSE and expectations for a career in research were supported by meta-analysis (Livinţi et al., 2021).

RSE as a Mediator

A negative association has been revealed between impostor feelings and academic self-efficacy among women in STEM doctoral programs (Tao & Gloria, 2019). Among doctoral students, impostor feelings have been found to negatively impact RSE (Jöstl et al., 2012).

Relationships between RSE and interest in research and outcome expectations have been established by a recent meta-analysis (Livinţi et al., 2021). Specifically, a positive association was found between RSE and interest in research and expectations for a career in research (Livinţi et al., 2021). However, few studies have examined RSE in the context of STEM doctoral students (Livinţi et al., 2021), which presents a gap in the literature. Therefore, the current study aimed to address this gap by focusing on RSE in women in STEM doctoral programs. Given the established negative relationship between impostor feelings and RSE, and the positive relationships between RSE and interest in research and career expectations, RSE was examined as a mediator in the current study. Specifically, the current study investigated whether RSE mediates the relationship between impostor feelings and interest in research and between impostor feelings and expectations for a STEM career.

Encouragement as a Moderator

Encouragement is defined as "the expression of affirmation through language or other symbolic representations to instill courage, perseverance, confidence, inspiration, or hope in a person(s) within the context of addressing a challenging situation or realizing a potential," (Wong, 2015, p. 182). According to Wong's (2015) tripartite encouragement model, there are two possible foci of encouragement: challenge focused and potential focused (Wong, 2015). Challenge-focused encouragement is intended to help an individual persist in a difficult situation while potential-focused encouragement is intended to help an individual realize what they can achieve and pursue their potential (Wong, 2015). An exploration of encouragement in the academic setting supported the distinction between potential-focused and challenged-focused encouragement through factor analysis (Wong et al., 2019), and thus they were considered as distinct foci of encouragement in the current study.

Conceptually, encouragement can be thought of as a form of positive verbal persuasion (Hsu et al., 2021; Wong, 2015). It is through this connection to verbal persuasion that encouragement becomes an important factor to explore in women in STEM. Professional women in STEM have reported that receiving encouragement from family members, teachers/professors, peers, and supervisors/bosses was very influential in their decision to pursue STEM careers (Zeldin & Pajares, 2000). Encouragement has been shown to positively contribute to these women's confidence in their ability to successfully pursue STEM careers (i.e., self-efficacy; Zeldin & Pajares, 2000). Additionally, encouragement has been connected to SCCT through this conceptualization of encouragement as a form of positive verbal persuasion (Hsu et al., 2021). Using the SCCT interest model as a framework, encouragement from faculty specifically has been found to be positively associated with self-efficacy in STEM students (Hsu et al., 2021). In the current study, both potential-focused and challenge-focused encouragement were explored as a moderator of the relationship between impostor feelings and RSE.

Theoretically, both potential-focused and challenge-focused encouragement confront the self-doubt that is characteristic of impostor feelings. Receiving potential-focused encouragement (e.g., messages from one's advisor that highlight their strengths in conducting research, remind them that they have the ability to be a successful researcher, and encourage them to continue to set new research goals for themselves, etc.) or challenge-focused encouragement (e.g., messages from one's advisor that instill hope, encourage them to believe in themselves, and express confidence in their abilities as they encounter difficulty time in their research, etc.) may counteract the negative impact of impostor feelings on RSE. Therefore, the current study hypothesized that those who perceive lower levels of encouragement from their advisor would be more vulnerable to the negative impact of impostor feelings on RSE. Conversely, for those who

perceive higher levels of encouragement from their advisor, it is hypothesized that they would be less vulnerable to the impact of impostor feelings and the association between impostor feelings and RSE will not be significant.

In addition to moderating the relationship between impostor feelings and RSE, it is hypothesized that the moderation effects of encouragement can be extended to the mediation model. Specifically, the current study predicted that both potential-focused and challenge-focused encouragement would moderate the indirect effect of RSE on the relationships between impostor feelings and interest in research and impostor feelings and expectations for a STEM career. Similar to the above rationale, individuals who perceive low levels of encouragement from their advisors may be more vulnerable to the negative impacts of IP, which may decrease their RSE and in turn may result in lower interest in research or career expectations.

If a doctoral student is experiencing impostor feelings and does not receive much encouragement (potential-focused or challenge-focused) from her advisor, the negative relationship between impostor feelings and RSE may be stronger. Thus, this student likely doubts their ability to be successful, particularly in conducting research. The combination of high impostor feelings and low RSE, which may be strengthened by a lack of encouragement, may make a student less interested in pursuing STEM research as a career and have lower or less positive expectations for a career in STEM. Overall, the negative mediation effects from imposter feelings, through RSE, to interest in research or expectations for a career in STEM is expected to be stronger when students experience less encouragement from their advisor.

Hypotheses

In sum, the current study sought to examine the following hypotheses.

Hypothesis 1: Mediation

H_{1A}: Research self-efficacy would mediate the relationship between impostor feelings and interest in research.

H_{1b}: Research self-efficacy would mediate the relationship between impostor feelings and expectations for a STEM career.

Hypothesis 2: Moderation

H_{2A}: Challenge-focused encouragement would moderate the relationship between impostor feelings and research self-efficacy. Specifically, the negative relationship between impostor feelings and research self-efficacy would be stronger for individuals who experienced less potential-focused encouragement from their advisor than individuals who perceived greater potential-focused encouragement.

H_{2B}: Potential-focused encouragement would moderate the relationship between impostor feelings and research self-efficacy. Specifically, the negative relationship between impostor feelings and research self-efficacy would be stronger for individuals who received less challenge-focused encouragement from their advisor than individuals who perceived greater challenge-focused encouragement.

Hypothesis 3: Moderated Mediation

H_{3A}: Challenge-focused encouragement would moderate the mediation effects of research self-efficacy on the relationship between impostor feelings and interest in research. It was hypothesized that the mediation effect would be more negative (i.e., stronger) for individuals who perceived lower levels of challenge-focused encouragement from their advisor than for individuals who perceived higher levels of challenge-focused encouragement from their advisor.

H_{3B}: Challenge-focused encouragement would moderate the mediation effects of research self-efficacy on the relationship between impostor feelings and expectations for a STEM career. It was hypothesized that the mediation effect would be more negative (i.e., stronger) for individuals who perceived lower levels of challenge-focused encouragement from their advisor than for individuals who perceived higher levels of challenge-focused encouragement from their advisor.

H_{3C}: Potential-focused encouragement would moderate the mediation effects of research self-efficacy on the relationship between impostor feelings and interest in research. It was hypothesized that the mediation effect would be more negative (i.e., stronger) for individuals who perceived lower levels of potential-focused encouragement from their advisor than for individuals who perceived higher levels of potential-focused encouragement from their advisor.

H_{3D}: Potential-focused encouragement would moderate the mediation effects of research self-efficacy on the relationship between impostor feelings and expectations for a STEM career. It was hypothesized that the mediation effect would be more negative (i.e., stronger) for individuals who perceived lower levels of potential-focused encouragement from their advisor than for individuals who perceived higher levels of potential-focused encouragement from their advisor.

Methods

This study received approval from the Radford University Institutional Review Board (IRB #2021-447).

Participants

An a priori power analysis was conducted using G*Power 3.1.9.7 online software (Faul et al., 2007, 2009). This analysis determined that, for a power of .8 and a significance level of .05 ($\alpha = .05$), 550 participants would be required for a small effect size ($f^2 = .02$), 77 participants for a medium effect size ($f^2 = .15$), and 36 participants for a large effect size ($f^2 = .35$). The current

study aimed to recruit approximately 200 participants in order to achieve a small to medium effect size.

Participants were recruited via emails to professional organizations within math-intensive STEM fields (i.e., engineering, computer science, mathematics, and physical sciences). These organizations included the Association for Women in Science, Society of Women Engineers, National Society of Black Engineers, American Physical Society, Institute of Electrical and Electronics Engineers, National Society of Black Physicists, Association of Environmental and Engineering Geologists, American Association for the Advancement of Science, Association of Women in Mathematics, Graduate Women in Science, Association for Women in Computing, Association for Women Geoscientists, Society of Asian Scientists and Engineers, Society of Hispanic Professional Engineers, Out in STEM, and more. If applicable, sections and student chapters were contacted as well. Chain sampling was also utilized to recruit participants, as participants were asked to forward the recruitment request to others they knew who may have been eligible for the study. The survey was administered online via Qualtrics (www.qualtrics.com).

In the recruitment request, potential participants were informed in the recruitment request that they needed to (a) identify as a woman, (b) be 18 years or older, (c) be currently enrolled in a doctoral program in the United States, (d) work with an advisor, and (e) be pursuing a degree in physical sciences, engineering, computer science, and mathematics in order to be eligible for the study. Potential participants were also informed that if they completed the survey, they could choose to enter their name and email address to win one of five $20 Amazon gift cards. After completing the survey, participants who were interested in entering to win a gift card were re-

directed to a separate survey, thus not linking any identifying information (i.e., name and email address) to their survey responses.

A total of 281 responses were recorded in Qualtrics. During the data cleaning process, 80 responses were excluded because they did not respond to any study questions and/or were not eligible for the study. An additional 34 responses were removed because they failed to respond to any items on at least one of the measures. The final sample consisted of 167 participants. The average age of participants was 26.84 years old (*SD* = 3.74, range = 21 to 45 years). Participants worked with their advisor for an average of 32.38 months (*SD* = 20.10, range = 2 to 107 months). Other demographic information about the participants can be found in Table 1.

Instruments

The complete survey can be found in Appendix A.

Eligibility Screening. Before completing the study measures, participants completed a forced-answer eligibility screening to ensure that participants met the qualifications for the study. Participants were asked to affirm that they were 18 years or older, to indicate their gender, to identify whether or not they were a doctoral student, to indicate whether they were studying one of the math-intensive STEM fields (i.e., engineering, computer sciences, physical sciences, and earth sciences), and indicate whether or not they were working with an advisor. Only participants who were 18 years or older, identified as a woman, worked closely with an advisor, and were currently enrolled in a doctoral program in math-intensive STEM fields were allowed to participate in the study. Those participants who passed the eligibility screening were given informed consent and the option to continue participating in the study. Those participants who did not meet the study inclusion criteria were thanked for their participation and not allowed to proceed further in the study.

Demographics. Participants were asked to complete a self-report demographic questionnaire that included the following: age, gender identity, sexual orientation, race and ethnicity, what year they were in their program, how long they had been working with their current advisor, their advisor's gender, and what math-intensive STEM field they were studying. Demographic information was collected at the end of the survey.

Impostor Feelings. Impostor feelings were measured using the Clance Impostor Phenomenon Scale (CIPS; Clance, 1985). The CIPS measures an individual's impostor feelings and contains 20 items. Participants indicated how true each statement was of them using a 5-point scale ranging from 1 (*Not at all true*) to 5 (*Very true*). A sample item is "I can give the impression that I'm more competent than I really am." The coefficient alpha was .93 among female STEM doctoral students (Tao & Gloria, 2019). The coefficient alpha for this study was .91.

Research Self-Efficacy. Research self-efficacy was measured using the short form of the Self-Efficacy in Research Measure (SERM-S; Kahn & Scott, 1997). The SERM-S is a 12-item short-version of the Self-Efficacy in Research Measure developed by Phillips and Russell (1994). Participants indicated how confident they are in their ability to complete different research tasks on a nine-point scale ranging from 1 (*No confidence*) to 9 (*Total confidence*). Higher scores indicated higher self-efficacy in research. A sample item is "writing the introduction and literature review for a dissertation" (Kahn & Scott, 1997). The coefficient alpha was .89 among doctoral students (Morrison & Lent, 2014). The coefficient alpha for this study was .85.

Expectations for a Career in STEM. Expectations for a career in STEM was measured using a four-item scale developed by Stake and Mares (2001). This measure has been slightly

modified by other researchers by changing references to "science" to "STEM" (Findley-Van Nostrand & Pollenz, 2017), and this modified version was used in the current study. Participants were asked to rate how true each statement was for them using a seven-point scale from 1 (*Not at all true*) to 7 (*Very true*). A sample item is "I would enjoy a career in STEM" (Stake & Mares, 2001). Higher scores on this measure indicated more positive expectations for a career in the STEM field. The coefficient alpha for this measure was .96 in STEM undergraduate students (Findley-Van Nostrand & Pollenz, 2017). The coefficient alpha for this study was .91.

Interest in Research. Interest in research was measured using a modified version of the 16-item Interest in Research Questionnaire (IRQ; Bishop & Bieschke, 1994, 1998). This measure was originally designed to be used with counseling/clinical psychology populations. To modify it for the non-counseling/clinical psychology population, one item that referred specifically to counseling was removed. This modified 15-item version has been used before with doctoral student populations (e.g., Morrison & Lent, 2014). Participants were asked to indicate their degree of interest in various research activities using a 5-point Likert scale ranging from 1 (*Very disinterested*) to 5 (*Very interested*). A sample item is "conceptualizing a research study" (Bishop & Bieschke, 1994, 1998). Higher scores on this measure indicated stronger interests in research in the participant's professional career. Coefficient alpha values have ranged from .89 to .92 among doctoral student populations (Bishop & Bieschke, 1994; Morrison & Lent, 2014). The coefficient alpha for this study was .84.

Encouragement. Encouragement was measured using the Academic Encouragement Scale (AES; Wong et al., 2019). The AES measures an individual's perception of the encouraging messages they may have received from someone they respect. The AES is a multidimensional measure that contains 10 items, five of which comprise the challenge-focused

subscale and five of which comprise the potential-focused subscale. Each scale item typically begins with the words “someone I respect.” However, for the purposes of this study, this phrase was changed to “my advisor.” A sample item from the challenge-focused subscale is “my advisor encouraged me to believe in myself when I doubted my academic abilities” (Wong et al., 2019). A sample item from the potential-focused subscale is “my advisor explained why I had the skills to succeed in school at an advanced level” (Wong et al., 2019). Participants were asked to rate how true statements were to them using a six-point scale ranging from 1 (*Very untrue of me*) to 6 (*Very true of me*). Higher scores on each subscale indicated that individuals perceived more encouragement (challenge-focused or potential-focused) from their advisor. The coefficient alpha was .93 for the challenge-focused subscale and .90 for the potential-focused subscale in a sample of undergraduate students (Wong et al., 2019). In this study, the coefficient alpha for the challenge-focused subscale was .92 and for the potential-focused subscale was .88. The coefficient alpha for the overall scale was .93.

Procedure

After receiving approval from the Radford University Institutional Review Board (IRB# 2022-147), recruitment requests were sent via email to professional organizations in math-intensive STEM fields. Those who were eligible for the study (i.e., were 18 years of age or older, identified as a woman, were currently enrolled in a doctoral program in a math-intensive STEM field, and worked with an advisor) were given informed consent and allowed to proceed with the survey. Those who did not pass the eligibility criteria were thanked for their participation and not allowed to further participate in the survey. Participants were notified in the informed consent about the option to enter a raffle to win one of five $20 Amazon gift cards after completing the study. After data was collected, each participant who provided information to enter the gift card

raffle was given an ID number. Research randomizer (www.randomizer.org; Urbaniak & Plous, 2013) was used to randomly select five numbers. Those participants whose ID numbers corresponded to the randomly generated numbers were the winners of the raffle and notified via the email they provided. They received the Amazon gift card via email to that same email address.

Results

Preliminary Analysis

A total of 281 responses were collected for the current study. After removing participants who did not meet the eligibility criteria, did not respond to any survey items, or did not respond to any items within one of the survey questionnaires, 167 participants remained and were used for data analysis in this study. The Expectation Maximization algorithm (Schafer & Graham, 2002) was used to replace missing data within the questionnaire. Means, standard deviations, zero-order correlations, and internal consistency reliability estimates of the study variables can be found in Table 2.

Covariate Analysis. Multiple analysis of variance (MANOVA) was conducted to determine if the dependent variables (i.e., interest in research, expectations of a STEM career, and research self-efficacy) varied significantly as a function of the categorical demographic variables (i.e., year in program, gender identity, sexual orientation, field of study, race/ethnicity, and the gender of their advisor).

There was marginally significant variance among the dependent variables based on the participants' field of study (Wilks' $\Lambda = .90$, $F = 1.91$, $p = .05$, partial $\eta^2 = .03$). However, results for tests of between-subjects effects were not significant [research self-efficacy - $F(3,162) = 2.12$, $p = .10$; interest in research - $F(3, 162) = 2.49$, $p = .06$; expectations for a STEM career -

$F(3, 162) = 2.00$, $p = .12$]. Therefore, field of study was not considered as a covariate in the current study.

There was also significant variance among the dependent variables based on participants' year in program (Wilks' $\Lambda = .82$, $F = 1.84$, $p = .02$, partial $\eta^2 = .07$). Results of between-subjects effects indicated that participants' year in program had a significant impact on RSE [$F(3, 160) = 3.11$, $p = .01$)] but not interest in research [$F(3,160) = 0.64$, $p = .08$], or expectations for a STEM career [$F(3, 160) = 0.44$, $p = .85$]. Several previous studies have found positive associations between one's year in their doctoral program and research self-efficacy (Bishop & Bieschke, 1998; Cobb et al., 2020; Livinţi et al., 2021; Morrison & Lent, 2014; Phillips & Russell, 1994). Thus, participants' year in their program was considered a covariate in the current study.

No significant variance was found for the gender of participants' advisors (Wilks' $\Lambda = .97$, $F = .90$, $p = .49$, partial $\eta^2 = .02$), participants' gender identity (Wilks' $\Lambda = .99$, $F = .71$, $p = .55$, partial $\eta^2 = .01$), participants' sexual orientation (Wilks' $\Lambda = .92$, $F = .71$, $p = .80$, partial $\eta^2 = .03$), or participants' race/ethnicity (Wilks' $\Lambda = .88$, $F = 1.11$, $p = .34$, partial $\eta^2 = .04$).

Correlation analyses were conducted to determine covariance between the continuous demographic variables (i.e., age and length of time with advisor) and the dependent variables. Age was significantly correlated with research self-efficacy ($r = .17$, $p < .05$). Previous studies using the SCCT framework have found the age of participants to be related to differences in self-efficacy with older participants tending to have higher levels of self-efficacy than younger participants (Multon & Brown, 1991). This may be because participants who are older have more experience and more accurate perceptions of their abilities (Multon & Brown, 1991). Because of this pre-existing relationship in the literature, age will be considered a covariate for the current study.

Participants' length of time working with their advisor was also significantly correlated with research self-efficacy ($r = .25$, $p < .01$). Length of time working with their advisor was not expected to be a covariate in this study as this author was not able to find empirical support for a relationship between time working with one's advisor and research self-efficacy. Given the lack of support in the literature, this variable will not be considered a covariate in the current study.

Exploratory Factor Analysis

Encouragement is conceptualized to have two components or foci: challenge-focused and potential-focused encouragement (Wong, 2015). However, this two-factor solution has not been consistently found in the literature (e.g., Hsu et al., 2021). Exploratory factor analysis (EFA) was conducted to determine whether a one-factor or two-factor model was the best fit for encouragement in this study. A principal axis factor was conducted on the 10 items that composed the encouragement measure. A parallel analysis was first conducted to determine the number of possible factors (Kahn, 2006; Russell, 2002), as factors extracted from the real data set have to account for more variance than those extracted from the random data set created through parallel analysis (Brown, 2006).

After computing 1,000 random data sets, the eigenvalues for the first two factors in the random data set were 1.41 and 1.28, respectively. The eigenvalues for the first two factors in the real data set were 6.25 and 1.08, respectively. Because the second eigenvalue from the real data set was smaller than the second eigenvalue from the random data set, a one-factor model for encouragement is a better fit for the data. Therefore, a general encouragement score was calculated (i.e., challenge-focused and potential-focused encouragement) and was used in the moderation and moderated mediation analyses.

Mediation Analysis

The mediation hypotheses predicted that research self-efficacy would mediate the relationship between IP and interest in research (hypothesis 1A) as well as between IP and expectations for a STEM career (hypothesis 1B). The PROCESS model (Hayes, 2013), 10,000 bootstrap samples, and a 95% confidence interval (Mallinckrodt et al., 2006; Preacher & Hayes, 2008) were used to examine the mediation hypotheses. Year in program and age were considered covariates.

The results supported both hypotheses 1A and 1B. The indirect effect of impostor feelings on interest in research was significant (*ab* = -0.07, *SE* = .03, 95% CI [-0.12, -0.02]) while the direct effect of impostor feelings on interest in research was not significant (*c'* = 0.04, *p* = .59). This suggests that research self-efficacy partially mediated the relationship between impostor feelings and interest in research, supporting hypothesis 1A (see Figure 9).

The indirect effect of impostor feelings on expectations for a STEM career was also significant (*ab* = -0.06, *SE* = .03, 95 CI [-0.14, -0.004]). The direct effect of impostor feelings on expectations for a STEM career was not significant (*c'* = 0.07, *p* = .56). This suggests that research self-efficacy partially mediated the relationship between impostor feelings and expectations for a career in STEM, supporting hypothesis 1B (see Figure 10).

An alternative mediation model was also examined. Mediation analyses were conducted using RSE as the independent variable and impostor feelings as the mediator. The indirect effect of RSE on interest in research (*ab* = -0.004, *SE* = .01, 95% CI [-0.02, 0.02]) and expectations for a STEM career (*ab* = -0.008, *SE* = .02, 95% CI [-0.04, 0.02]) were not significant. These findings provide further support for the role of RSE as a mediator.

Moderation Analysis

The moderation hypotheses predicted that challenge-focused (hypothesis 2A) and potential-focused encouragement (hypothesis 2B) would moderate the relationship between IP and research self-efficacy. Because EFA suggested a one-factor model for the current data set, an overall score of encouragement was examined as a moderator as well. The moderation hypotheses were examined using the PROCESS software (Hayes, 2013) and an alpha level of .05 was used to determine significance. Using the pick-a-point approach, the current study probed the interaction with moderator variables that were equal to ±1 *SD* from the mean of the moderator.

The moderation effect of challenge-focused encouragement was not significant (B = 0.27, SE = .14, p = 0.06, 95% CI [-0.01, 0.54]) nor was the moderation effect of potential-focused encouragement significant (B = 0.25, SE = .13, p = .06, 95% CI [-0.01, 0.51]). However, the moderation effect of encouragement was significant (B = 0.30, SE = .15, p = .04, 95% CI [0.02, 0.59]). Probing the interaction revealed that the relationship between impostor feelings and RSE was significantly negative for individuals who received low levels of encouragement (B = -0.85, SE = .24, 95% CI [-1.32, -0.38]). The relationship between impostor feelings and RSE was not significant, however, for individuals who received high levels of encouragement (B = -0.22, SE = .21, 95% CI [-0.64, 0.20]) (see Figure 11).

Moderated Mediation Analysis

The moderated mediation analysis predicted that challenge-focused encouragement would moderate the indirect effect of RSE on the relationship between impostor feelings and interest in research (hypothesis 3A) and expectations for a STEM career (hypothesis 3B). It was also hypothesized that potential-focused encouragement would moderate the indirect effect of

RSE on the relationship between impostor feelings and interest in research (hypothesis 3C) and expectations for a STEM career (hypothesis 3D). An overall score of encouragement (i.e., general encouragement) was examined as a moderator as well based on the results of EFA.

This analysis was also conducted using the PROCESS model (Hayes, 2013) and an alpha level of .05 was used to determine significance. The results did not support the moderated mediation hypotheses. Neither challenge-focused encouragement (*B* = 0.04, *SE* = .02, 95% CI [-0.01, 0.08]), potential-focused encouragement (*B* = 0.03, *SE* = .02, 95% CI [-0.01, 0.07]), nor general encouragement (*B* = 0.04, *SE* = .02, 95% CI [-0.01, 0.09]) moderated the indirect effect of RSE on the relationship between impostor feelings and interest in research. Similarly, neither challenge-focused encouragement (*B* = .03, *SE* = .02, 95% CI [-.01, .08]), potential-focused encouragement (*B* = .03, *SE* = .02, 95% CI [-.01, .08]), nor general encouragement (*B* = .04, *SE* = .03, 95% CI [-.01, .09]) moderated the indirect effect of RSE on the relationship between impostor feelings and expectations for a STEM career. Overall, none of the moderated mediation hypotheses were supported.

Discussion

The current study examined the role of research self-efficacy as a mediator of the relationships between impostor feelings and both interest in research and expectations for a STEM career. The current study also examined the role of encouragement (potential-focused, challenge-focused, and general encouragement) as a moderator of the above-described mediation relationship (i.e., moderated mediation) and as a moderator of the relationship between impostor feelings and RSE. The results supported the mediation hypotheses and moderation hypotheses; the moderated mediation hypotheses were not supported by the data. Implications of these findings are discussed as well as limitations of the study and directions for future research.

Research Self-Efficacy as a Mediator

Hypotheses 1A and 1B were supported as the indirect effect of RSE on the relationship between impostor feelings and interest in research (hypothesis 1A) and impostor feelings and expectations for a STEM career (hypothesis 1B) were significant. These findings suggested that STEM women who experienced more impostor feelings had lower RSE and, in turn, lower interest in research and lower expectations for a career in STEM. These results support previous findings in the literature of a negative relationship between IP and RSE (Jöstl et al., 2012; Tao & Gloria, 2019) and positive relationships within the SCCT interest model (Lent & Brown, 2019). Overall, these results suggest that impostor feelings negatively impact interest and expectations through RSE.

The findings highlight the importance of building RSE in women in math-intensive STEM doctoral programs as a way of reducing the impact of impostor feelings on interest in research and expectations for a STEM career. Mental health providers and STEM faculty and advisors may consider building RSE in STEM doctoral women through the four sources of self-efficacy: verbal persuasion (i.e., messages of support such as encouragement), mastery experiences (i.e., previous successes and failures), vicarious experiences (i.e., social comparison, seeing similar others succeed), and physiological and affective states (i.e., arousal experienced when attempting tasks where their self-efficacy is challenged; Bandura, 1997). Mental health providers in particular may focus on helping their clients manage physiological and affective states and provide verbal persuasion, while STEM faculty may focus on building mastery experiences throughout the doctoral program and incorporating examples of STEM women into the curriculum to build up vicarious experiences.

Contributions. These findings are important as they integrate the SCCT and IP literatures. Understanding a common experience for STEM women in doctoral programs (i.e., impostor feelings) within the context of the most widely used vocational framework for examining the underrepresentation of women in STEM (i.e., SCCT) may ultimately help us to better understand the experiences of women in math-intensive STEM programs and other vocational impacts of impostor feelings. These findings also help to fill a gap in the literature by focusing on the experiences of STEM women in doctoral programs, as much of the previous literature has focused on undergraduate women (Wilkins-Yel et al., 2021).

Encouragement as a Moderator

Hypotheses 2A and 2B proposed that challenge-focused encouragement and potential-focused encouragement would moderate the relationship between impostor feelings and RSE. General encouragement (i.e., challenge-focused and potential-focused encouragement) was also examined as a moderator, as EFA suggested a one-factor model for encouragement for the current study. The results suggested that general encouragement moderated the relationship between impostor feelings and RSE for STEM women who perceived low levels of encouragement from their advisors.

These results suggest that encouragement may reduce the impact of impostor feelings on RSE. Mental health providers and STEM faculty advisors may consider providing encouragement to their clients and advisees. Providing encouragement could look like reminding advisees/clients of times in which they have succeeded or gotten through difficult experiences in the past (i.e., challenge-focused encouragement; Wong, 2015). Advisors and mental health providers could also highlight areas in which their advisees/clients are passionate and/or have strengths and work with their advisees/clients to help them focus on these strengths more (i.e.,

potential-focused encouragement; Wong, 2015). Given that a score of overall encouragement moderated the relationship between impostor feelings and RSE, mental health providers and STEM faculty advisors should aim to incorporate both challenge-focused and potential-focused encouragement into their feedback to their STEM women clients/advisees.

To increase the effectiveness of these encouraging messages, mental health providers should focus on building the therapeutic alliance, as those who have a strong therapeutic alliance with their clients are often perceived as more genuine and credible, two important features that impact the effectiveness of encouragement (Wong, 2015). Faculty advisors may focus on building their advisory working alliance with their advisees to increase the effectiveness of their encouragement messages. Both mental health providers and STEM faculty advisors may focus their messages of encouragement on effort and progress, as this is theorized to provide the most effective encouragement (Wong, 2015).

Hypotheses 3A, B, C, and D proposed challenge-focused and potential-focused encouragement as moderators of the indirect effect of RSE on the relationship between impostor feelings and both interest in research and expectations for a STEM career. General encouragement was also examined as a moderator in these moderated mediation analyses. Unfortunately, none of the moderated mediation analyses were significant. This may be because the moderated mediation model utilized in the current study is not complex enough to understand the interactions between encouragement and the mediation model. Though bootstrapping was applied in the analyses, the sample size may not have been sufficient to capture the potentially complex moderated mediation interactions. Additionally, unexamined variables, such as the advisory working alliance, may have impacted the strength of encouragement to moderate the mediation effects.

Contributions. The results of the moderation analyses are important as they integrate the encouragement literature, and positive psychology literature more broadly, with the IP literature. The IP literature has often focused on the negative impacts of impostor feelings, such as anxiety (Clance, 1985; Clance & O'Toole, 1987), feelings of self-doubt (Chakraverty, 2019; Jacobs et al., 2020), or low self-efficacy (Jöstl et al., 2012; Tao & Gloria, 2019). Positive psychology tends to focus on building positive qualities and helping individuals flourish (Seligman & Csikszentmihalyi, 2000). Continuing to integrate positive psychology into the IP literature may help us identify more ways in which we can help individuals experiencing IP improve their well-being.

Limitations

There are several limitations in the current study that should be considered in interpretation of the results. One limitation is self-selection bias, which refers to differences between the target group (i.e., women in doctoral programs in math-intensive STEM fields) and those who participated in the study (i.e., the participants; Alarie & Lupien, 2021). It is possible that the women who chose to participate in the study may have had different characteristics than the women who did not, such as more experiences with IP, for example. This could bias the results and possibly limit the generalizability of the current study. Finally, the lack of representation of women in computer science in the current study is another limitation and may reduce the generalizability of the results. Only 1.2% of participants endorsed studying computer science, while 32.9% endorsed engineering, 34.1% endorsed mathematics, and 31.3% endorsed physical sciences as their field of study. Though women are most underrepresented in computer science (National Science Foundation, 2019a), they are more underrepresented in the current study than nationally and thus the results of the study may not generalize to the computer science

population. Finally, the cross-sectional design of the study presents a limitation, as causational inferences were not able to be established among the study variables.

Directions for Future Research

The current study provides several directions for future research. First, future studies should aim to recruit a more representative sample of STEM women, specifically recruiting more participants from the computer science field. This would increase the generalizability of the results. Second, future research may also consider utilizing more complex moderated mediation models when examining the role of encouragement as a moderator of the indirect effect of RSE on relationships between impostor feelings and interest and expectations. Specifically, future researchers may want to further investigate the role of the advisory working alliance in the moderated mediation model. The advisory working alliance may impact the effectiveness of messages of encouragement, as advisors who have a stronger working alliance with their advisees may be perceived as more genuine and credible, thereby increasing the effectiveness of messages of encouragement (Wong, 2015).

Third, future research should continue to explore the structure of encouragement and whether a one-factor or two-factor model is a better fit for the variable. Fourth, future studies should consider longitudinal design in order to better understand the impacts of impostor feelings and encouragement over time. The cross-sectional design utilized by the current study does not allow causal inferences to be made. Researchers may also consider utilizing an experimental design, such as the one employed by Wong and colleagues (2020). An experimental design may allow increased understanding of the role of encouragement by controlling the encouragement that participants are receiving.

CHAPTER TWO

LITERATURE REVIEW

This literature review discusses the proportion of degrees earned by women in math-intensive science, technology, engineering, and mathematics (STEM) fields at various levels (i.e., bachelor's, master's, and doctoral) and highlighted the underrepresentation that women face in specific STEM domains. Explanations for women's underrepresentation in math-intensive STEM fields are explored, with particular emphasis given to research self-efficacy.

Impostor feelings were introduced as a factor that may contribute to women's lower self-efficacy in STEM fields. Research self-efficacy (RSE), interest in research, and outcome expectations were then introduced through the social cognitive career theory (SCCT) interest model framework. In addition, RSE was introduced as a possible mediator for the association between imposter feelings and interest in research, and between imposter feelings and outcome expectations. Also, encouragement was introduced as a possible moderator for the association between imposter feelings and RSE and a moderator on the mediation effects of RSE.

Gender Disparities in STEM Doctoral Programs

What is STEM?

STEM represents a wide-ranging group of disciplines. The term "STEM" was first introduced in the early-2000s by the National Science Foundation (Sanders, 2009). STEM has been recognized as an important group of fields for job opportunities, technological advancement, and national security (Committee on STEM Education, 2018; Hill et al., 2010), and increasing the STEM workforce and improving STEM education has been a focus of both the Obama (Handelsman & Smith, 2016) and Trump (Camera, 2018) presidential administrations. Though STEM fields represented 6.2% of U.S. employment in 2015 within the

United States (Fayer et al., 2017), the number of jobs in STEM fields in the United States has grown rapidly. Between 2009 and 2015, STEM jobs grew by 10.5% compared to the average job growth rate of 5.2% and STEM jobs represented approximately 8.6 million jobs in 2015 (Fayer et al., 2017). Almost all of these STEM jobs had wages above the national average as well (Fayer et al., 2017), highlighting that the importance of STEM in our economy continues to grow (Hill et al., 2010).

Women's Representation in STEM

Despite the fact that women's representation in math-intensive STEM fields (i.e., engineering, mathematics, computer sciences, and physical sciences and earth sciences) has generally increased over time (Ceci et al., 2014), women are still underrepresented in the math-intensive STEM fields (Ceci et al., 2014; National Science Foundation, 2019a, 2019b). Men tend to outnumber women three to one in doctoral degrees earned in math-intensive STEM fields (Miller & Wai, 2015). In mathematics and physical sciences, women were most underrepresented at the doctoral level in 2016 (National Science Foundation, 2019b). In computer science and engineering, women earned a slightly lower proportion of degrees at the bachelor's level but still earned less than half of degrees awarded at all levels (National Science Foundation, 2019b). In 2019, women earned only 25.8% of doctoral degrees in mathematics and computer science, 24% in engineering, and 33.6% in physical sciences and earth sciences (National Science Foundation, 2019a).

Women's representation in these math-intensive STEM fields (i.e., engineering, computer science, mathematics, and physical and earth sciences) continues to be a concern. In the literature, most studies have focused on undergraduate STEM women as opposed to graduate STEM women, creating a gap in the literature (Wilkins-Yel et al., 2021). In recent years,

women's experiences in graduate STEM programs have become a growing interest and focus within the literature (Cabay et al., 2018). Some researchers argue that future research should focus on factors impacting the persistence of women in graduate STEM education (Fouad & Santana, 2017).

There are several reasons why it is important to focus on doctoral STEM women. First, some authors have argued that the doctoral program is a "critical phase in the STEM career trajectory," as it is where women solidify their career intentions (Cabay et al., 2018). However, the career intentions and trajectory of STEM women in doctoral programs received limited attention in the existing literature. For example, SCCT (Lent et al., 1994) is the theoretical framework most commonly used to examine the underrepresentation of women in STEM (Fouad & Santana, 2017). Yet most studies utilizing the SCCT theoretical framework focus on STEM undergraduate students and only few focus on STEM doctoral students, presenting a gap in the current literature (Wilkins-Yel et al., 2021).

Second, impostor feelings have been found to be prevalent among STEM women in doctoral programs and negatively related to their persistence in STEM and self-efficacy (Tao & Gloria, 2019). Only few studies have examined the role of impostor feelings in STEM doctoral students (e.g., Chakraverty 2019, 2020a, 2020b), with even fewer focusing on STEM women in doctoral programs (Tao & Gloria, 2019). This study focused on STEM women in the math-intensive fields' doctoral programs because women are still underrepresented in these fields. There is a need for an increased understanding of STEM women's experiences in doctoral programs (e.g., impostor feelings) and how these experiences impact their career trajectory and intentions.

Impostor Feelings and STEM Women

The impostor phenomenon (IP) is a commonly experienced phenomenon that serves as a barrier to vocational development (Neureiter & Traut-Mattausch, 2016a, 2016b). The term "impostor phenomenon" was first coined in 1978 by Dr. Pauline Rose Clance and Dr. Suzanne Imes after observing that many of their successful female clients were struggling to internalize their successes (Clance & Imes, 1978). In the academic literature, this is most commonly referred to as "impostor phenomenon," while in the lay literature (e.g., social media, internet articles, blogs, websites, etc.), the term "imposter syndrome" is primarily used (Bravata et al., 2020). IP has also been referred to as the impostor experience, perceived fraudulence, and fraud syndrome (Bravata et al., 2020).

These differences in terminology are important. The words "phenomenon" and "syndrome" can express very different meanings. For example, syndrome is defined as "a group of signs and symptoms that occur together and characterize a particular abnormality or condition" (Merriam-Webster, 2021b), while phenomenon is defined as "an observable fact or effect" (Merriam-Webster, 2021a). The use of "syndrome" to describe can suggest that impostor feelings are the result of "dysfunction within the individual" (Feenstra et al., 2020, p. 2). Some have argued that this use of "syndrome" blames the individual for their impostor feelings and does not fully consider the important interpersonal and social contexts that contribute to these impostor feelings (Feenstra et al., 2020). The term impostor phenomenon or impostor feelings was used throughout the current study.

What are Impostor Feelings?

At its core, IP describes an "internal experience of intellectual phoniness" (Clance & Imes, 1978, p. 241) and a belief that one is "less competent and less intelligent than they

appeared to be" (Clance et al., 1995, p. 79). Individuals experiencing IP (i.e., individuals with impostor feelings) see themselves as frauds and believe they have fooled those around them (Clance, 1985; Clance & Imes, 1978; Clance & O'Toole, 1987). They often fear that their "true" intelligence will be discovered, and others will see them as they see themselves, as an impostor (Clance, 1985; Clance & Imes, 1978; Clance & O'Toole, 1987). Those with impostor feelings often do not believe they deserve or have truly earned the success they have achieved (Clance & Imes, 1978). They may also attribute their successes or accomplishments to luck or to others making a mistake and may perceive any failure as further evidence that they have deceived those around them and do not belong (Clance & Imes, 1978; Harvey & Katz, 1985). Individuals with impostor feelings may also hold themselves to very high standards (Clance, 1985; Clance & Imes, 1978; Clance & O'Toole, 1987) and experience frustration when they cannot meet these standards (Clance & Imes, 1978).

A key characteristic of IP is the impostor cycle (Clance, 1985; Clance & O'Toole, 1987). This cycle begins with strong feelings of self-doubt and fear that cannot replicate previous success or live up to others' expectations (Clance, 1985; Clance & O'Toole, 1987). As a result, when an individual is faced with a task or a project, they typically experience significant anxiety (Clance, 1985; Clance & O'Toole, 1987). Sometimes, this anxiety causes procrastination and other times it leads to over-preparing (Clance, 1985; Clance & O'Toole, 1987). Once the task, assignment, or project is complete, the individual may receive praise for their efforts, which may cause temporary relief and pride. However, the next time that they are given an assignment to complete, their previous success is typically forgotten and the cycle of anxiety, procrastination or over-preparation, and temporary relief is repeated (Clance, 1985; Clance & Imes, 1978; Clance & O'Toole, 1987).

There are several other common characteristics of impostor feelings. First, many individuals with impostor feelings have a history of being "the best," and may find it difficult to realize that they cannot always be the best at everything (Clance, 1985; Clance & Imes, 1978). Individuals with impostor feelings tend to also have a strong fear of failure and often strive for perfection, making them particularly vulnerable to significant distress when they make a mistake or experience a setback or failure (Clance, 1985; Clance & O'Toole, 1987). Additionally, those with impostor feelings also tend to have difficulties internalizing positive feedback, often finding ways to undermine or discount positive feedback and thereby continuing to fuel their impostor feelings (Clance, 1985; Clance & O'Toole, 1987). This may contribute to self-doubt and an overall lack of self-confidence that is common with impostor feelings (Clance, 1985; Clance & Imes, 1978). Finally, those with impostor feelings may feel guilty or uncomfortable with the success that they have achieved (Clance, 1985; Clance et al., 1995). For example, individuals, particularly women, may receive messages that they will be rejected or disliked if they are too successful (Clance, 1985; Clance et al., 1995).

Gender Differences in Impostor Feelings

Impostor feelings were originally observed in highly successful women and thought to primarily exist in this population (Clance & Imes, 1978). Research has supported high rates of impostor feelings in women, as a recent meta-analysis also found impostor feelings to be common in women (Bravata et al., 2020). Additionally, several studies have found differences in the prevalence of impostor feelings between men and women with women experiencing more impostor feelings than men (e.g., Cokley et al., 2015; Henning et al., 1998; Jöstl et al., 2012; King & Cooley, 1995; Kumar & Jagacinski, 2006; McGregor et al., 2008; Muradoglu et al., 2021). The emphasis on brilliance, talent, or innate intellectual abilities in the STEM fields may

make women particularly more susceptible to impostor feelings than men (Muradoglu et al., 2021). Specifically, in one study, the more that women (i.e., graduate students, faculty members, postdoctoral researchers, and medical students) perceived their field to emphasize brilliance, the more likely they were to experience more significant impostor feelings (Muradoglu et al., 2021).

There is also evidence that men and women experience impostor feelings differently. For example, compared to men, women with impostor feelings are less likely to set goals based on mastery of a topic or task (i.e., learning goals) and more likely to set goals based on outperforming others (i.e., performance goals; Dweck, 1986; Kumar & Jagacinski, 2006). Women with impostor feelings are also more likely to believe that intelligence is fixed and cannot be changed very much (i.e., entity theory of intelligence; Dweck, 1986) while no associations between intelligence beliefs and impostor feelings were found in men (Kumar & Jagacinski, 2006).

Experience and Impact of IP in STEM Women Doctoral Students

Compared to men in the STEM fields, women are more likely to experience impostor feelings due to a lack of belongingness to the STEM fields (Muradoglu et al., 2021). Feeling like one does not belong may increase their vulnerability to impostor feelings (Ivie & Ephraim, 2009; Tao & Gloria, 2019) and contribute to the underrepresentation of women in STEM fields (Cheryan et al., 2017). Many empirical studies have documented that impostor feelings exist in STEM women in doctoral programs (Chakraverty, 2019, 2020a, 2020b; Ivie & Ephraim, 2009; Tao & Gloria, 2019). For women in STEM doctoral programs, impostor feelings tend to show up in specific ways. Many STEM doctoral students report feeling unworthy and unprepared to start their doctoral programs (Chakraverty, 2019), and experience self-doubt (Chakraverty, 2019; Jacobs et al., 2020). Some were surprised that they were even accepted in their program, feeling

less qualified than their peers (Chakraverty, 2019), and others felt that they were admitted solely to increase the diversity of their program (Chakraverty, 2019, 2020a). Throughout their programs, many STEM doctoral students continue to experience impostor feelings particularly when completing milestones in their program (e.g., submitting their work for publication). Many doctoral students also reported experiencing impostor feelings when they compared themselves to their classmates, asked for help, and tried new skills (Chakraverty, 2020b). They feared that they had fooled their advisor, dissertation committee, professors, classmates, and so on into overestimating their skills (Chakraverty, 2020b). Many STEM women often felt that their peers were more successful and more deserving (Chakraverty, 2020b) and that they did not belong in their respective programs (Jacobs et al., 2020).

Impacts of Impostor Feelings on STEM Women's Professional and Career Development

Impostor feelings may inhibit individuals from reaching their full potential, as they may doubt their abilities and turn down opportunities for advancement (Clance & O'Toole, 1987). Individuals with impostor feelings often do not have an accurate view of their own abilities (Clance & O'Toole, 1987) and perceive themselves as incompetent (Vaughn et al., 2020). Unsurprisingly, impostor feelings have been linked to lower self-efficacy among STEM women doctoral students (Tao & Gloria, 2019) and lower RSE among doctoral students more broadly (Jöstl et al., 2012).

Impostor feelings have also been linked to more negative views of one's research environment (e.g., fewer perceived opportunities to collaborate with faculty, develop personal research interests, or develop meaningful relationships with advisors) and more negative attitudes towards persisting in STEM for women doctoral students (Tao & Gloria, 2019). In the academic environment specifically, women with impostor feelings may be inclined to perceive a

higher cost and lower value to their work (Vaughn et al., 2020). They may not experience the same amount of joy or sense of reward when achieving a goal or completing a task as individuals who are not as impacted by impostor feelings (Clance & O'Toole, 1987). Individuals with impostor feelings may also feel less connected to the academic community (Vaughn et al., 2020). These impacts of impostor feelings may contribute to lower motivation (Vaughn et al., 2020), which could contribute to reduced job satisfaction and performance.

Summary

To summarize, the impostor phenomenon refers to an "internal experience of intellectual phoniness" (Clance & Imes, 1978, p. 241) often accompanied by self-doubt and a lack of self-confidence (Clance, 1985; Clance & Imes, 1978; Clance & O'Toole, 1987). Individuals with impostor feelings often believe they have fooled others into perceiving them as competent and fear others discovering that they are an impostor (Clance, 1985; Clance & Imes, 1978; Clance & O'Toole, 1987). They also often have difficulties internalizing their successes (Clance & Imes, 1978; Harvey & Katz, 1985) and hold themselves to high standards (Clance, 1985; Clance & Imes, 1978; Clance & O'Toole, 1987). There is evidence that women in STEM may be more vulnerable to experiencing impostor feelings than men in STEM (Muradoglu et al., 2021). Impostor feelings have been found to have a negative impact on career and vocational development, particularly through the negative relationship between impostor feelings and self-efficacy, views of the research environment, and persistence in women in STEM doctoral programs (Tao & Gloria, 2019). Impostor feelings have also been related to a lack of belonging, lower motivation, and less perceived value of one's work (Vaughn et al., 2020).

Social Cognitive Career Theory

Social cognitive career theory (SCCT; Lent et al., 1994) is a well-supported vocational framework through which to consider the associations among impostor feelings, research self-efficacy, interest in research, and expectations for a STEM career. SCCT is built upon Hackett and Betz's (1981) work on career self-efficacy and decision-making as well as Bandura's social cognitive theory (Bandura, 1986). SCCT aims to provide a unifying framework for understanding important relationships in career development: forming career-related interests, choosing academic and vocational foci, and persisting and succeeding in those endeavors (Lent et al., 1994). This theory strives to understand how academic and career development occurs when individuals' choices are restricted (Lent, 2016; Lent et al., 1994) and addresses the impact of personal factors (e.g., gender, socioeconomic status, culture, etc.), learning experiences (e.g., gender role socialization), and environmental barriers and supports on one's vocational and academic development (Lent, 2016; Lent & Brown, 2019; Lent et al., 1994). SCCT has been used to examine educational and vocational development of diverse populations, such as women in STEM (Byars-Winston et al., 2010; Lent et al., 2000, 2005, 2013, 2015, 2016; Navarro et al., 2014), and is the major vocational framework used to explore the underrepresentation of women in STEM fields (Fouad & Santana, 2017).

SCCT is comprised of three interlocking models: interest development, choice-making, and performance (Lent et al., 1994). The current study focused on the interest development (i.e., interest) model of SCCT. The interest model focuses primarily on the relationships between three variables: self-efficacy, outcome expectations, and interest (Lent et al., 1994). SCCT uses Bandura's (1986) definition of self-efficacy, which describes self-efficacy as "people's judgments of their capabilities to organize and execute courses of action required to attain

designated types of performances" (p. 391). In other words, self-efficacy refers to an individual's beliefs in their own ability to successfully complete a certain task. It is important to emphasize that self-efficacy reflects one's belief in their own ability and not necessarily an accurate representation of their ability. Outcome expectations refer to one's beliefs regarding the consequences of engaging in a specific behavior of completing an action (Bandura, 1986). These expectations can involve self-evaluations (e.g., satisfaction), physical (e.g., salary), and social (e.g., the opinions of others; Bandura, 1986). Finally, interest refers to "patterns of likes, dislikes, and indifferences regarding career-relevant activities and occupations" (Lent et al., 1994, p. 88). The interest model proposes that individuals with higher self-efficacy for a specific domain (e.g., STEM) will have more interest in that domain (Lent et al., 1994). In other words, those who have believe they have the ability to be successful in STEM are more likely to be interested in pursuing a STEM career. Additionally, individuals tend to expect more positive outcomes when engaging in tasks that they are confident they can successfully complete (Lent et al., 1994; Lent et al., 2018). In other words, individuals who believe they have the ability to be successful in STEM are more likely to perceive positive outcomes from pursuing a career in STEM. To summarize, the SCCT interest model proposes positive relationships between self-efficacy and outcome expectations as well as between self-efficacy and interest.

Empirical Support of the Interest Model

In the more than 20 years since SCCT was formally introduced to the literature, a significant amount of research has been conducted in support of SCCT and the interest model (Lent, 2016). The SCCT interest model has been supported in STEM populations (Lent et al., 2018; Sheu et al., 2018). Several meta-analytic reviews revealed a medium effect size for the positive correlation between self-efficacy and interest and between self-efficacy and outcome

expectations among STEM population (Lent et al., 2018; Sheu et al., 2018). These relationships held true in STEM women as well (Lent et al., 2018; Sheu et al., 2018).

Many SCCT studies have focused on younger students (e.g., high school students) and undergraduate students (Fouad & Santana, 2017), while only few studies have focused on graduate students, particularly doctoral students. Researchers have called for more studies that focus on the experiences of women in STEM doctoral programs (e.g., Cabay et al., 2018; Fouad & Santana, 2017). Therefore, the current study aimed to extend the SCCT literature by focusing on women in the math-intensive STEM doctoral programs.

Self-Efficacy in Research

Self-efficacy refers to one's belief in their own competency and ability to complete a certain task or achieve a certain goal (Bandura, 1986). Generally, if an individual believes they are capable of doing something, they will do it (Bandura, 1986). An important form of self-efficacy in doctoral programs is RSE, which refers to an individual's beliefs in their ability to successfully conduct research (Forester et al., 2004). RSE has been viewed as a key component of most doctoral programs (Ampaw & Jaeger, 2012; Litson et al., 2021) and has been associated with several important vocational outcomes. According to the SCCT interest model, self-efficacy is positively related to an individual's interest in a subject or domain as well as the outcomes they expect to encounter as a result of pursuing that domain (e.g., salary, prestige, enjoyment, etc.; Lent et al., 1994).

As previously stated, the interest model of SCCT has received substantial support in the literature and the predicted relationships between self-efficacy, interest, and outcome expectations have been supported (Lent, 2016). Similar relationships have been found specific to RSE. For example, RSE has been positively associated with interest in research (Lambie et al.,

2014; Livinţi et al., 2021; Morrison & Lent, 2014) and more positive expectations for a career in research (Livinţi et al., 2021). Doctoral students with higher RSE are also more likely to complete their doctoral degree (Lambie et al., 2014; Litalien & Guay, 2015; Varney, 2010), and submit more research publications (Brown et al., 1996; Lambie et al., 2014; Livinţi et al., 2021). RSE has also been related to more positive attitudes toward research, a stronger identity as a researcher, and stronger intentions to pursue a career in research (Livinţi et al., 2021).

Much of the literature on research self-efficacy in doctoral students has focused on students in psychology and education fields such as clinical or counseling psychology, education, rehabilitation, and others (Livinţi et al., 2021), and there is limited information on RSE in math-intensive STEM fields. Additionally, Fouad and colleagues (2013) have called for further investigation into the role of self-efficacy in underrepresented graduate students' decisions to remain in or leave STEM. RSE is a relevant form of self-efficacy for graduate students given the importance of research in doctoral education. Therefore, the current study aimed to contribute to the literature by increasing our understanding of the role of RSE in math-intensive STEM doctoral programs.

Expectations for a Career in STEM

Outcome expectations represent personal beliefs about potential outcomes of specific behaviors (Bandura, 1986). These expectations are conceptualized as falling into three different classes: physical, social, and self-evaluative (Bandura, 1986). Physical outcome expectations include stimulating or positive sensory experiences, positive physical experiences (i.e., physical and sexual health), and physical discomfort (i.e., pain, discomfort, and aversive sensory experiences; Bandura, 1986). Social outcome expectations revolve around either approval or disapproval from others (Bandura, 1986). Finally, self-evaluative outcome expectations result

from an individual's own appraisal of their performance or progress towards goals (Bandura, 1986).

In the SCCT interest model, outcome expectations are predicted by self-efficacy (Lent et al., 1994). For example, those who believe they are able to successfully conduct STEM research typically perceive the outcomes of pursuing a STEM career to be more positive. Positive outcome expectations can lead individuals to approach rather than avoid challenging tasks, according to SCCT (Brown et al., 2008; Lent et al., 1994). If an individual believes they are capable of something but perceives it to have negative consequences, they may not pursue it. On the other hand, if an individual expects positive outcomes from engaging in a task, they will be more likely to pursue that task. With regard to math-intensive STEM fields, social outcome expectations may revolve around stereotypes that persist about individuals in those fields (e.g., that they are masculine, socially awkward, and/or "nerdy"; Cheryan et al., 2017). These negative stereotypes may contribute to women's underrepresentation in STEM by decreasing the likelihood that they will pursue those math-intensive STEM fields (Cheryan et al., 2017). Additionally, self-evaluative outcome expectations, such as not seeing themselves as capable of finding a work-life balance in STEM (Ceci et al., 2014; Fouad & Santana, 2017), may influence women's decisions to pursue STEM as well.

Outcome expectations have been found to be important motivating factors in STEM doctoral students. For example, the outcomes associated with earning a doctoral degree and the value that the doctoral degree adds have been found to be important motivating factors in pursuing and obtaining a doctoral degree in engineering (London et al., 2014). Specifically, the opportunity to enter higher education/academia and to become an expert in an area of interest are two of the most important reasons why individuals pursue a PhD in engineering (London et al.,

2014). Many individuals who earned a PhD in engineering also reported that a doctoral degree allowed them to do scientific work (i.e., design research projects, collect data, develop solutions to problems), increase their knowledge, and provide them with access to more opportunities (London et al., 2014). Additionally, a study of female engineering professionals found outcome expectations to play an important role in women's decisions to stay within the field (Fouad et al., 2011).

Interest in Research

Interest is another key variable in the SCCT model (Lent et al., 1994). According to SCCT, interest in a field influences the vocational goals that an individual sets, the choices they make, and their persistence in those fields (Lent et al., 1994). In SCCT, interests are influenced by self-efficacy (Lent et al., 1994). That is, individuals who believe they are capable of completing a certain task or being successful in a certain field (i.e., have high self-efficacy) are more likely to be interested in pursuing that field. The current study focused on doctoral students' interest in conducting research and having a research career, which may be particularly important for doctoral students.

Conducting research is an important component of doctoral education (Ampaw & Jaeger, 2012) and an area in which doctoral students and early-career scientists are expected to demonstrate competency (Verderame et al., 2018). Many doctoral students are required to complete a dissertation, thesis, or other type of research project to earn their doctorate degree, and doctoral students often complete or work on various research projects throughout their graduate training as well. Additionally, many individuals with doctorate degrees in STEM fields will conduct research and develop new products as the primary activity of their career. A recent survey found that approximately 41% of all individuals who hold a doctorate degree in a STEM

field in the United States and 48% outside of the United States engage in research and development as their primary work activity (Opsomer et al., 2021). Therefore, whether an individual chooses to work in higher education or in the private sector, a significant proportion of STEM doctoral degree holders engage in research in their career.

At the doctoral level, women may question their interest in pursuing a more research-intensive STEM career (Cabay et al., 2018). For example, in a qualitative study of advanced female doctoral students (e.g., doctoral students in their third or fourth year), more than one-third of participants reported planning on pursuing careers outside of academia and careers that were not research-focused (Cabay et al., 2018). Other studies have supported this finding that women shift away from academic STEM careers more often than men (Goulden et al., 2009). This shift in career intentions may be important for future generations of STEM women as it could limit the availability of faculty and research mentors for other STEM women (Cabay et al., 2018).

Research Self-Efficacy as a Mediator

In the literature, a negative relationship has been found between impostor feelings and self-efficacy in women in math-intensive STEM doctoral programs (Tao & Gloria, 2019). Several meta-analyses of the SCCT interest model have found self-efficacy to be positively associated with interest and outcome expectations (Lent et al., 2018; Rottinghaus et al., 2003; Sheu et al., 2010). Additionally, a recent meta-analysis focused on RSE specifically has also found support for positive associations between RSE, research interest, and outcome expectations (Livinţi et al., 2021). Specifically, large associations were found between RSE and interest in research while moderate associations were found between RSE and outcome expectations (Livinţi et al., 2021). While not all participants in the studies included in the meta-

analysis were doctoral students, the majority were (Livinți et al., 2021), and thus the findings are relevant for the current study.

Given the previously established relationships between impostor feelings and self-efficacy as well as between self-efficacy, interest, and outcome expectations, the current study predicted that RSE would mediate the relationship between impostor feelings and both interest in research and expectations for a career in STEM. Specifically, this study predicted that impostor feelings would have a negative relationship with RSE. Those experiencing impostor feelings often do not believe that they are deserving of their accomplishments and doubt their own abilities. Given that research is a key component of doctoral education, RSE may be one area where the self-doubt of impostor feelings specifically manifests. In other words, those experiencing impostor feelings likely have low RSE and doubt their abilities to successfully conduct research. Based on the SCCT literature, this study predicts that RSE would in turn have a positive correlation with interest in research and outcome expectations (i.e., expectations for a STEM career). If an individual does not believe they are capable of conducting research, they may be likely less interested in pursuing research and may see less benefits of a STEM career, given that research is often a key component of STEM jobs, particularly those in academia.

To summarize, the current study predicted that RSE would mediate the relationship between impostor feelings and interest in research and outcome expectations. Individuals who feel like impostors in their doctoral programs likely doubt their ability to successfully conduct research, which in turn may reduce their interest in research and their expectations for a career in STEM.

Encouragement

Encouragement can be defined as "the expression of affirmation through language or other symbolic representations to instill courage, perseverance, confidence, inspiration, or hope in a person(s) within the context of addressing a challenging situation or realizing a potential" (Wong, 2015, p. 182). According to the tripartite encouragement model, encouragement is thought to have two foci: challenge focused and potential focused (Wong, 2015). Challenge-focused encouragement aims to help individuals persist and persevere in difficult situations and is thought to be most helpful for individuals that are struggling (Wong, 2015). Potential-focused encouragement aims to help individuals realize what they might be capable of and is thought to be most helpful for individuals who may not fully realize their potential (Wong, 2015). The current study will focus specifically on encouragement received from one's advisor within the academic context.

This conceptualization of encouragement is relatively new and has not been heavily studied yet. One study has examined the impact of an encouragement intervention in doctoral students (Wong et al., 2020). In this study, doctoral students' advisors wrote the students a letter of encouragement (Wong et al., 2020). Those doctoral students who received a letter of encouragement had significantly stronger interest in research than those who did not receive a letter of encouragement (Wong et al., 2020). The authors of this study hypothesized that receiving a letter of encouragement from an advisor may help the doctoral student feel cared for, which may increase their motivation (Wong et al., 2020). Another study has examined the role of encouragement in STEM undergraduate students (Hsu et al., 2021). Hsu and colleagues (2021) utilized the SCCT choice model as their theoretical framework and examined the impact of encouragement from faculty members on undergraduate engineering students' self-efficacy,

outcome expectations, and intentions to continue pursuing their engineering degree (i.e., choice). Overall, Hsu et al. (2021) found positive relationships between faculty encouragement and both self-efficacy and outcome expectations. The relationship between encouragement and persistence intentions was mediated by self-efficacy (Hsu et al., 2021). Self-efficacy also had a positive relationship with outcome expectations in their study (Hsu et al., 2021).

Recently, researchers have called for additional investigation into for whom encouragement is effective and how encouragement benefits its recipients (Wong et al., 2020). Researchers have also called for additional investigation into the role of moderators within the SCCT model (Brown & Lent, 2019). Therefore, the current study hoped to answer these calls by exploring whether or not encouragement is effective for STEM women in doctoral programs and if one of the ways in which encouragement may benefit STEM women is through moderating the impact of impostor feelings on RSE.

Encouragement as a Moderator

In the present study, it was hypothesized that both challenge-focused and potential-focused encouragement would moderate the relationship between impostor feelings and RSE. There are several reasons to support these moderation hypotheses. First, in Wong's (2015) conceptualization of encouragement, encouragement is likened to verbal persuasion. Verbal persuasion is one of the four sources of self-efficacy and refers to the messages an individual receives regarding what others believe they can or cannot do (Bandura, 1997). Several studies have examined the role of encouragement as verbal persuasion in STEM students (Byars-Winston et al., 2017; Sheu et al., 2018; Usher & Pajares, 2008; Zeldin & Pajares, 2000). Overall, these studies found verbal persuasion to be associated with increased self-efficacy (Byars-Winston et al., 2017; Sheu et al., 2018; Usher & Pajares, 2008; Zeldin & Pajares, 2000) and

outcome expectations (Sheu et al., 2018) in STEM students. Additionally, women engineers who persisted in engineering reported perceiving more support from their workplaces (e.g., more opportunities for advancement, more understanding regarding work-life balance, etc.) than those who left the field of engineering (Fouad et al., 2016). Overall, these studies suggest that encouragement generally may increase self-efficacy in STEM students and STEM women.

Second, encouragement may theoretically challenge the self-doubt that is characteristic of impostor feelings. As previously mentioned, challenge-focused encouragement is thought to be most helpful to individuals who are struggling (Wong, 2015). Examples of challenge-focused encouragement may include encouraging an individual to believe in themselves when they doubt their own abilities, instilling hope in an individual after they want to give up, reminding or assuring another individual of their competence, reminding another individual of their strengths, and expressing confidence in another's abilities even when the task is hard (Wong et al., 2019). Those experiencing impostor feelings also often struggle with frequent self-doubt and a lack of confidence (Clance, 1985). Receiving messages of challenge-focused encouragement from their advisor, a faculty member whom they work closely with, may counteract or buffer against the self-doubt caused by impostor feelings. Challenge-focused encouragement may be particularly important in situations where they are struggling to accomplish certain tasks (e.g., proposing a thesis or dissertation) because of a lack of confidence in their abilities. Overall, those who perceive higher levels of challenge-focused encouragement from their advisor may be less vulnerable to the negative effect of impostor feelings on RSE. Conversely, those who perceive less challenge-focused encouragement from their advisor may be more vulnerable to the negative impact of impostor feelings on their RSE.

Following the same logic, individuals experiencing impostor feelings may benefit from potential-focused encouragement as well. Potential-focused encouragement, as previously noted, is thought to be most helpful for individuals who have not fully realized their potential (Wong, 2015). Examples of potential-focused encouragement include pointing out strengths, encouraging an individual to continue to set goals and high standards for themselves because they can achieve them, explaining why an individual has the skills to succeed, and giving the individual a positive message to motivate them to continue setting new goals (Wong et al., 2019). Providing potential-focused encouragement may help an individual continue to fulfill their research potential. Being encouraged to utilize their potential and having someone close to them believe in their ability to reach even higher goals and meet higher standards may increase their belief in their own abilities and challenge the self-doubt caused by impostor feelings. Against this backdrop, those who perceive higher levels of potential-focused encouragement from their advisor may be less vulnerable to the negative effect of impostor feelings on RSE, while those who perceive less potential-focused encouragement from their advisor may be more vulnerable to the negative impact of impostor feelings on RSE.

In addition to moderating the relationship between impostor feelings and RSE, the moderation effects of encouragement could be extended to the mediation model, and encouragement could moderate the indirect effect of research self-efficacy on the relationship between interest in research and expectations for a STEM career. Using a similar rationale as above, compared to individuals who received high levels of academic encouragement (challenge-focused or potential-focused), individuals who perceive low levels of encouragement may be more vulnerable to the negative impacts of impostor feelings and thus may decrease their RSE and in turn may have less interest in research or outcome expectancy. Overall, the mediation

effect of research self-efficacy on the relationship between impostor feelings and interest in research as well as expectations for a STEM career would be more negative for individuals who perceive low levels of academic encouragement.

Hypotheses

The current study sought to examine the following three main hypotheses.

Hypothesis 1: Mediation

H_{1A}*:* Research self-efficacy would mediate the relationship between impostor feelings and interest in research.

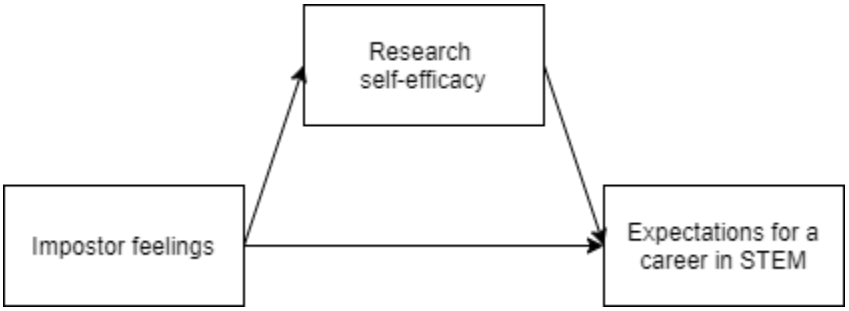
Figure 1

The Conceptual Model for the Mediation Hypothesis: Research Self-Efficacy as a Mediator Between Imposter Feelings and Interest in Research

H_{1b}*:* Research self-efficacy would mediate the relationship between impostor feelings and expectations of a STEM career.

Figure 2

The Conceptual Model for the Mediation Hypothesis: Research Self-Efficacy as a Mediator Between Impostor Feelings and Expectations for a Career in STEM

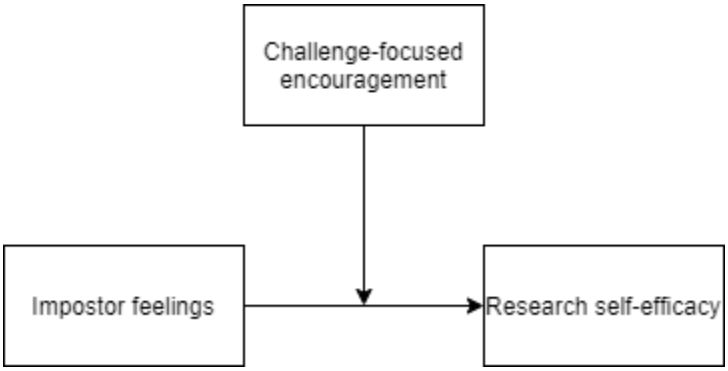


Hypothesis 2: Moderation

H_{2A}: Challenge-focused encouragement would moderate the relationship between impostor feelings and research self-efficacy. Specifically, the negative relationship between impostor feelings and research self-efficacy would be stronger for individuals who perceived less challenge-focused encouragement from their advisor than individuals who perceived greater challenge-focused encouragement.

Figure 3

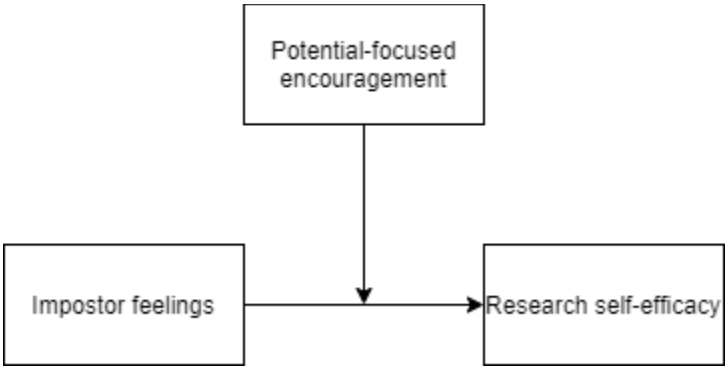
The Conceptual Model for the Moderation Hypothesis: Challenge-Focused Encouragement as a Moderator for the Relationship Between Impostor Feelings and Research Self-Efficacy



H_{2B}: Potential-focused encouragement would moderate the relationship between impostor feelings and research self-efficacy. Specifically, the negative relationship between impostor feelings and research self-efficacy would be stronger for individuals who perceived less potential-focused encouragement from their advisor than individuals who perceived greater potential-focused encouragement.

Figure 4

The Conceptual Model for the Moderation Hypothesis: Potential-Focused Encouragement as a Moderator for the Relationship Between Impostor Feelings and Research Self-Efficacy

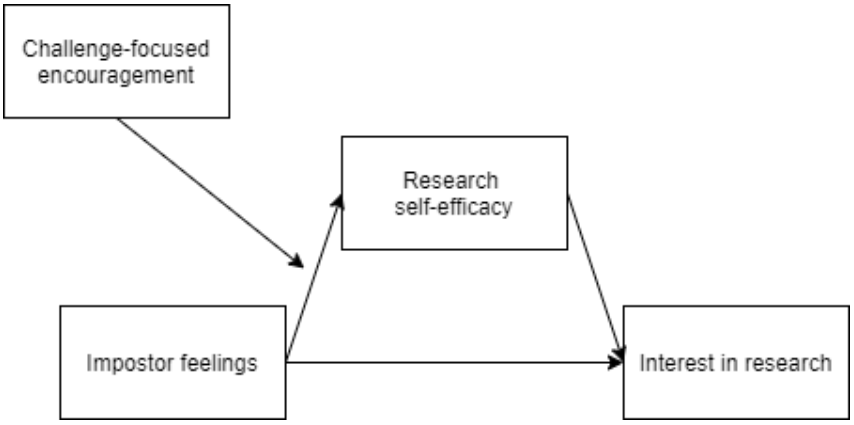


Hypothesis 3: Moderated Mediation

H_{3A}: Challenge-focused encouragement would moderate the mediation effects of research self-efficacy on the relationship between impostor feelings and interest in research. It was hypothesized that the mediation effect would be more negative (i.e., stronger) for individuals who perceived lower levels of challenge-focused encouragement from their advisor than for individuals who perceived higher levels of challenge-focused encouragement.

Figure 5

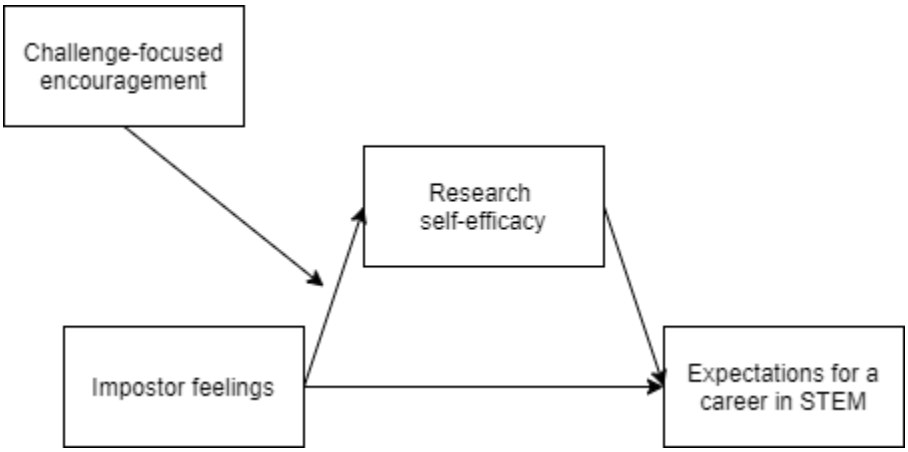
The Moderated Mediation Hypothesis: Challenge-Focused Encouragement would Moderate the Mediation of Research Self-Efficacy on the Relationship Between Impostor Feelings and Interest in Research



H_{3B}: Challenge-focused encouragement would moderate the mediation effects of research self-efficacy on the relationship between impostor feelings and expectations for a career in STEM. It was hypothesized that the mediation effect would be more negative (i.e., stronger) for individuals who perceived lower levels of challenge-focused encouragement from their advisor than for individuals who perceived higher levels of challenge-focused encouragement.

Figure 6

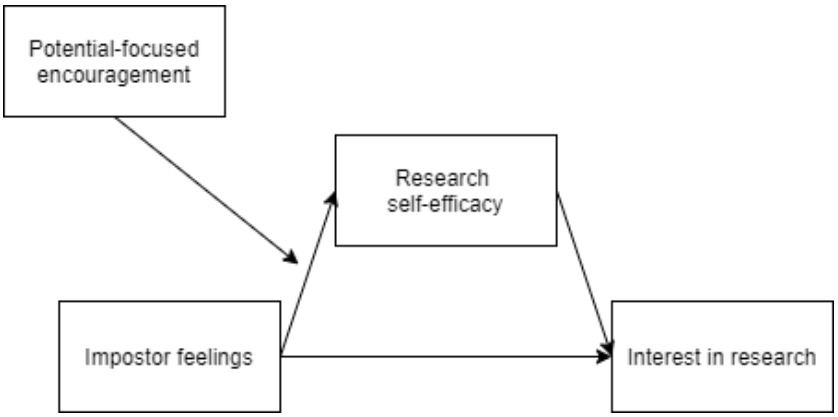
The Moderated Mediation Hypothesis. Challenge-Focused Encouragement would Moderate the Mediation of Research Self-Efficacy on the Relationship Between Impostor Feelings and Expectations for a Career in STEM



$H_{3C:}$ Potential-focused encouragement would moderate the mediation effects of research self-efficacy on the relationship between impostor feelings and interest in research. It was hypothesized that the mediation effect would be more negative (i.e., stronger) for individuals who perceived lower levels of potential-focused encouragement from their advisor than for individuals who perceived higher levels of potential-focused encouragement.

Figure 7

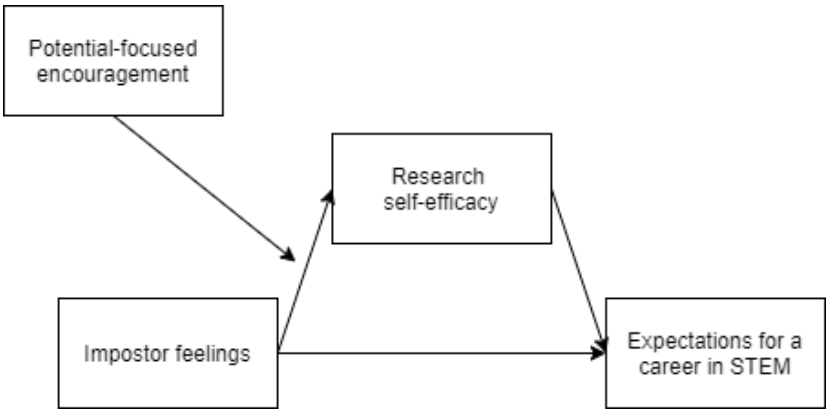
The Moderated Mediation Hypothesis: Potential-Focused Encouragement would Moderate the Mediation of Research Self-Efficacy on the Relationship Between Impostor Feelings and Interest in Research



$H_{3D:}$ Potential-focused encouragement would moderate the mediation effects of research self-efficacy on the relationship between impostor feelings and expectations for a career in STEM. It was hypothesized that the mediation effect would be more negative (i.e., stronger) for individuals who perceived lower levels of potential-focused encouragement from their advisor than for individuals who perceived higher levels of potential-focused encouragement.

Figure 8

The Moderated Mediation Hypothesis: Potential-Focused Encouragement would Moderate the Mediation of Research Self-Efficacy on the Relationship Between Impostor Feelings and Expectations for a Career in STEM



CHAPTER THREE

METHODS

Power Analysis

To estimate the necessary sample size for significant and meaningful results for the moderation analysis, an a priori power analysis was conducted using G*Power 3.1.9.7 online software (Faul et al., 2007, 2009). This decision was based on the recommendations made by Cohen's (1988) research regarding the importance of determining and achieving adequate power for a study. For the following analyses, a power of .8 and a significance level of .05 ($\alpha = .05$) is used. For a small effect size ($f^2 = .02$), 550 participants are required. For a medium effect size ($f^2 = .15$), 77 participants are required. For a large effect size ($f^2 = .35$), 36 participants are required. The current study aimed to recruit approximately 200 participants to achieve a small to medium effect size.

Participants

This study received approval from the Radford University Institutional Review Board (IRB #2021-447). Participants were recruited from approximately 47 STEM professional organizations (e.g., Association for Women in Science, Society of Women Engineers, National Society of Black Engineers, American Physical Society, Institute of Electrical and Electronics Engineers, National Society of Black Physicists, Association of Environmental and Engineering Geologists, American Association for the Advancement of Science, Association of Women in Mathematics, Graduate Women in Science, Association for Women in Computing, Association for Women Geoscientists, Society of Asian Scientists and Engineers, Society of Hispanic Professional Engineers, Out in STEM, etc.) and their student chapters. Given that the current study is focused on women in math-intensive STEM doctoral programs, professional

organizations representing math-intensive STEM fields (i.e., engineering, mathematics, computer science, and physical sciences) were targeted. Emails were sent to each organization and any chapters/sections for which email addresses could be retrieved, particularly student chapters. In the recruitment emails, potential participants were informed of the eligibility criteria for the study (i.e., participants need to identify as a woman, be at least 18 years of age, be currently enrolled in a doctoral program in a math-intensive field, and work with an advisor). Participants were also informed of the opportunity to win one of five $20 Amazon gift cards after completing the study.

A total of 281 responses were collected via Qualtrics, an online survey platform. Eighty responses were excluded from the study because they did not respond to any study questions and/or were not eligible for the study (i.e., did not identify as a woman, as 18 years of age or older, as being enrolled in a doctoral program in a math-intensive STEM field, or working with an advisor). An additional 34 responses were excluded from the study because these respondents failed to answer any items on at least one of the questionnaires. The final sample consisted of 167 participants. The average age of the participants was 26.84 years old (*SD* = 3.74, range = 21 to 45 years). The average length of time that participants worked with their advisor was 32.38 months (*SD* = 20.10, range = 2 to 107 months). Other demographic information can be found in Table 1.

Table 1

Participant Demographic Information

Variable	*n*	%
Gender Identity		
Cisgender woman	162	97.0%
Transgender woman	2	1.2%
No response	3	1.8%
Sexual Orientation		
Heterosexual/Straight	123	73.7%
Gay/Lesbian/Same Gender	7	4.2%
Bisexual	20	12%
Pansexual	7	4.2%
Queer	4	2.4%
Demisexual	1	0.6%
Other[a]	2	1.2%
No response	3	1.8%
Race/Ethnicity		
Asian or Asian American	23	13.8%
Latino/a or Hispanic	11	6.6%
Middle Eastern or North African	2	1.2%
Black or African American	3	1.8%
White/Caucasian or European American	120	71.9%
Biracial or Multi-racial	4	2.4%
No response	4	2.4%
Area of Study		
Engineering	55	32.9%
Computer Science	2	1.2%
Mathematics	57	34.1%
Physical Sciences	52	31.1%
No response	1	0.6%
Year in Program		
1st year	29	17.4%
2nd year	29	17.4%
3rd year	33	19.8%
4th year	40	24.0%
5th year	25	15.0%
6th year	6	3.6%
Other[b]	5	3.0%

[a]all participants who responded “other” to sexual orientation described their sexual orientation as asexual.

[b]all participants who responded “other” to year in program reported being in their 7th year

Instruments

The complete survey can be found in Appendix A.

Eligibility Screening

To be eligible to complete this study, participants need to identify as a woman, be 18 years of age or older, currently be enrolled in a doctoral program in a math-intensive STEM field, and work with an advisor. Before completing the measures and providing demographic information, individuals interested in participating in the study completed a forced-answer eligibility screening to ensure that they met the previously stated eligibility criteria. Those who did not meet these criteria were thanked for their participation and were not allowed to proceed further in the study. Those who were eligible for the study were presented with informed consent and given the option to continue participating in the study.

Demographics

Participants were asked to self-report the following demographic information: age, gender identity (i.e., cisgender woman vs. transgender woman), sexual orientation, race/ethnicity, their year in program, how long they had been working with their current advisor, their advisor's gender, what specific field they were currently studying, and the type of doctoral degree they were pursuing (e.g., PhD, D.Sc, etc.).

Impostor Phenomenon

Impostor feelings were measured using the Clance Impostor Phenomenon Scale (CIPS; Clance, 1985). The CIPS contains 20 items. Sample items are "I'm afraid people important to me may find out that I'm not as capable as they think I am" and "at times, I feel my success has been due to some kind of luck." Participants were asked to indicate how true each statement was of them using a five-point scale ranging from 1 (*Not at all true*) to 5 (*Very true*). The CIPS has been

found to be a unidimensional measure in STEM doctoral students (Simon & Choi, 2018) and thus participants' responses were summed to create a total score. Higher scores on this measure indicated that impostor feelings more frequently interfered with the participant's life. Validity evidence of the CIPS was demonstrated through positive associations with depression and social anxiety as well as negative associations with self-esteem and self-monitoring among undergraduate college students (Chrisman et al., 1995). The coefficient alpha was .93 among female doctoral STEM students (Tao & Gloria, 2019). The coefficient alpha for this study was .91.

Research Self-Efficacy

Research self-efficacy was measured using the short-form of the Self-Efficacy in Research Measure (SERM-S; Kahn & Scott, 1997). The SERM-S (Kahn & Scott, 1997) is a 12-item shortened version of the Self-Efficacy in Research Measure developed by Phillips and Russell (1994). Participants were asked to indicate how confident they are in their ability to complete different research tasks on a nine-point scale ranging from 1 (*No* confidence) to 9 (*Total* confidence). Higher scores on this measure indicated higher levels of self-efficacy in research. A sample item includes "defending a thesis or dissertation." Validity of the SERM-S has been demonstrated through positive correlations with interest in research and a more positive research training environment in doctoral students (Kahn & Scott, 1997). The coefficient alpha for the SERM-S was .89 among doctoral students (Morrison & Lent, 2014). The coefficient alpha for this study was .85

Expectations for a STEM Career

Expectations for a career in STEM (i.e., outcome expectations) were measured using a four-item scale developed by Stake and Mares (2001). Participants were asked to rate how true

each statement was for them using a seven-point scale from 1 (*Not at all true*) to 7 (*Very true*). Findley-Van Nostrand and Pollenz (2017) modified this measure by changing references to "science" to "STEM." Sample items are "I would enjoy a career in STEM" and "I have good feelings about a career in STEM." Higher scores on this measure indicated greater positive expectations for a career in the STEM field. Validity evidence for the STEM career expectancy measure has been demonstrated through positive correlations with self-efficacy in STEM, scientist identity, and sense of belonging in STEM (Findley-Van Nostrand & Pollenz, 2017). It has also been negatively correlated with intention to leave the STEM field (Findley-Van Nostrand & Pollenz, 2017). In U.S. undergraduate STEM students, a coefficient alpha was .96 among this population (Findley-Van Nostrand & Pollenz, 2017). The coefficient alpha in this study was .91.

Interest in Research

Interest in research was measured using a modified version of the 16-item Interest in Research Questionnaire (IRQ; Bishop & Bieschke, 1994, 1998). To accommodate this sample, one item that referred specifically to counseling was removed, and thus a 15-item version of this measure was used in the study. This 15-item altered measure has been used in previous research and found to have acceptable internal reliability ($\alpha = .89$; Morrison & Lent, 2014). Participants were asked to indicate their degree of interest in engaging in various research activities after they complete their doctorate degree. Participants responded using a five-point Likert scale ranging from 1 (*Very disinterested*) to 5 (*Very interested*). Higher scores on this measure indicated stronger interests in research in the participant's professional career. Validity evidence for the IRQ has been demonstrated through positive correlations with the investigative scale of the Vocational Preference Inventory (VPI; Holland, 1985) and self-efficacy in research and outcome

expectations related to research (Bischop & Bieschke, 1998). The coefficient alpha value for the modified version of the IRQ was .89 with female doctoral students (Morrison & Lent, 2014). The coefficient alpha for this study was .84.

Encouragement

Encouragement was measured using the Academic Encouragement Scale (AES; Wong et al., 2019). The AES measures an individual's perception of the encouraging messages they may have received from someone they respect in an academic setting. Participants were instructed to rate how true statements were to them using a six-point scale ranging from 1 (*Very untrue of me*) to 6 (*Very true of me*). Each scale item typically begins with the words "someone I respect." However, for the purposes of this study, this phrase was changed to "my advisor" to reflect the emphasis of this study on the advisor-advisee relationship. The AES contains 10 items, five of which comprise the challenge-focused subscale and five of which comprise the potential-focused subscale. A sample item of the challenge-focused subscale is "my advisor encouraged me to believe in myself when I doubted my academic abilities" and a sample item of the potential-focused subscale is "my advisor expressed confidence in me and told me to keep trying in school even though it was difficult." Higher scores on this measure indicated that individuals perceived greater encouragement (challenge-focused and/or potential-focused) from their advisor. The construct validity of both the potential-focused and challenge-focused encouragement subscale was supported by a positively correlation with hope, academic self-efficacy, and campus connectedness as well (Wong et al., 2019). The coefficient alpha was .93 for the challenge-focused subscale and .90 for the potential-focused subscale among United States undergraduate students (Wong et al., 2019). The coefficient alpha was .92 for the challenge-focused subscale and .88 for the potential-focused subscale. The coefficient alpha for the entire scale was .93.

Procedure

After receiving approval from the Radford University Institutional Review Board (IRB# 2022-147), recruitment requests were sent out via email to identified professional organizations in math-intensive STEM fields (e.g., Association for Women in Science, Society of Women Engineers, National Society of Black Engineers, American Physical Society, Institute of Electrical and Electronics Engineers, National Society of Black Physicists, Association of Environmental and Engineering Geologists, American Association for the Advancement of Science, Association of Women in Mathematics, Graduate Women in Science, Association for Women in Computing, Association for Women Geoscientists, Society of Asian Scientists and Engineers, Society of Hispanic Professional Engineers, Out in STEM, etc.). Chain sampling was utilized as well, as participants were asked to forward the recruitment information to others they knew who may have been eligible for the current study.

The survey was distributed through Qualtrics (www.qualtrics.com), an online survey software. To be eligible for the study, participants need to be 18 years of age or older, identify as a woman, be currently enrolled in a doctoral program in a math-intensive STEM field, and work with an advisor. Participants first affirmed their eligibility for the study by answering questions related to the above-described inclusion criteria before being able to access the remainder of the study. Those who did not meet the inclusion criteria were thanked for their participation and not allowed to further participate in the survey. Those who were eligible for the study were directed to a page containing information on informed consent. Information was provided about the risks and benefits of participating in the study, requirements to participate in the study, the purpose of the study, their rights as participants (e.g., the right to leave the study at any time and the right to skip any questions on the survey), and the confidentiality they can expect regarding their

responses. Participants were also informed about the option to enter a raffle to win one of five $20 Amazon gift cards after completing the study and the approximate odds of winning a gift card. After reading the informed consent, participants who were interested in participating in the study were able to continue on to the questionnaire and those who no longer wanted to participate were instructed to close the webpage.

The survey consisted of demographic questions, the CIPS, the SERM-S, the STEM Career Expectancy measure, the IRQ, and the AES. After completing the survey, participants were redirected to a separate survey where they were able to voluntarily enter into a raffle for a chance to receive one of five $20 Amazon gift cards. Participants were asked to provide their name and email address if they wanted to enter the raffle. Using a separate survey to obtain this information ensured that no identifying information was associated with the participants' responses to the study questionnaire.

A total of 161 participants entered the raffle. After data was collected, each participant who provided information to enter the survey was given an ID number from 1 to 161. Research randomizer (www.randomizer.org) was used to select five random numbers between 1 and 161 (Urbaniak & Plous, 2013). The participants whose numbers corresponded to the randomly generated numbers were the winners of the raffle. Participants were notified via email that they had won the raffle and would receive an Amazon gift card via the email address they provided.

CHAPTER FOUR

RESULTS

The current study collected data from women in math-intensive STEM doctoral programs across the United States regarding their experiences of the impostor phenomenon, self-efficacy in research, interest in research, expectations for a career in STEM, and perceived encouragement from their advisor. The results of data cleaning procedures, covariate analyses, mediation analyses, moderation analyses, and moderated mediation analyses are provided.

Data Exclusion and Missing Responses

A total of 281 responses were collected for this study. Eighty responses were removed because they did not respond to any study questions and/or were not eligible for the study. An additional 34 responses were removed because they failed to respond to any items on at least one of the questionnaires. The final sample consisted of 167 participants. The average age of the participants was 26.84 years old (*SD* = 3.74, range = 21 to 45 years) and participants worked with their advisor for 32.38 months on average (*SD* = 20.10, range = 2 to 107 months).

The percentage of missing responses were calculated for each survey item to ensure that the percentage of missing responses was low enough that the Expectation Maximization algorithm could be used to replace missing values (Schafer & Graham, 2002). The percentage of missing responses for each measure are as follows: 0.06% missing (CIPS), 0.24% missing (AES), 0% missing (STEM Career Expectancy), 3.29% missing (SERM-S), and 4.87% missing (IRQ). EM was utilized to impute the missing data for the subsequent analyses. Means, standard deviations, zero-order correlations, and internal consistency reliability estimates of the study variables can be found in Table 2.

Table 2

Means, Standard Deviations, and Zero-Order Correlations

	1	2	3	4	5	6	7
1. Impostor feelings	--------						
2. Research self-efficacy	-.22**	--------					
3. Interest in research	.03	.35**	--------				
4. Expectations for a STEM career	.02	.14	.31**	--------			
5. Challenge-focused encouragement	.09	-.03	.15	.19*	--------		
6. Potential-focused encouragement	-.02	.06	.17*	.22**	.75**	--------	
7. Encouragement	.03	.02	.17*	.22**	.93**	.94**	--------
Mean	3.68	5.43	3.72	6.10	4.26	3.81	4.04
SD	0.67	1.43	0.59	0.92	1.15	1.21	1.10
α	.91	.85	.84	.91	.92	.88	.93

Note. $N = 167$. * $p < .05$, ** $p < .01$

Covariate Analysis

Multivariate analysis of variance (MANOVA) was conducted to determine if dependent variables (i.e., interest in research, expectations of a STEM career, and research self-efficacy) varied as a function of the categorical demographic variables (i.e., year in program, gender identity, sexual orientation, field of study, race/ethnicity, and the gender of their advisor). No significant variance was found for the gender of participants' advisors (Wilks' $\Lambda = .97$, $F = .90$, $p = .49$, partial $\eta^2 = .02$), participants' gender identity (Wilks' $\Lambda = .99$, $F = .71$, $p = .55$, partial $\eta^2 = .01$), participants' sexual orientation (Wilks' $\Lambda = .92$, $F = .71$, $p = .80$, partial $\eta^2 = .03$), or participants' race/ethnicity (Wilks' $\Lambda = .88$, $F = 1.11$, $p = .34$, partial $\eta^2 = .04$).

There was a marginal significant difference based on participants' field of study (Wilks' $\Lambda = .90$, $F = 1.91$, $p = .05$, partial $\eta^2 = .03$). However, there were not significant results for tests of between-subjects effects (research self-efficacy: $F(3,162) = 2.12$, $p = .10$; interest in research: $F(3, 162) = 2.49$, $p = .06$; expectations for a STEM career: $F(3, 162) = 2.00$, $p = .12$). Therefore, field of study was not considered as a covariate in the current study. There was also a significant difference based on participants' year in program (Wilks' $\Lambda = .82$, $F = 1.84$, $p = .02$, partial $\eta^2 = .07$). Results for tests of between-subjects effects indicated that year in program has a statistically significant effect on research self-efficacy [$F(3, 160) = 3.11$, $p = .01$], but not on interest in research [$F(3,160) = 0.64$, $p = .08$], or expectations for a STEM career[$F(3, 160) = 0.44$, $p = .85$]. Several studies have found that the longer a student is in their doctoral training program, the higher research self-efficacy they have (Bishop & Bieschke, 1998; Cobb et al., 2020; Livinţi et al., 2021; Morrison & Lent, 2014; Phillips & Russell, 1994). As a result, year in program was considered as a covariate in the current study.

Correlation analyses were conducted for the continuous demographic variables (i.e., age and length of time working with advisor). Age was significantly correlated with research self-efficacy ($r = .17$, $p < .05$). Previous studies using the SCCT framework have found the age of participants to be significantly correlated with self-efficacy (Multon & Brown, 1991). Specifically, the literature suggests that self-efficacy may increase with age as individuals have more experience and potentially more accurate perceptions of their own abilities (Multon & Brown, 1991). Given this pre-existing relationship in the literature, age was considered as a covariate in the current study.

Length of time working with their advisor ($r = .25$, $p < .01$) was also significantly correlated with research self-efficacy. This author has not been able to find empirical support for

a relationship between how long an individual has worked with their advisor and their research self-efficacy. Given this lack of support in the literature, length of time working with one's advisor was not considered a covariate in this study.

Exploratory Factor Analysis

Encouragement is conceptualized to have two different foci, challenge-focused encouragement and potential-focused encouragement (Wong, 2015). However, other researchers such as Hsu and colleagues (2021) have found challenge-focused and potential-focused research to be highly correlated with one another, bringing concerns of multicollinearity, and instead utilized an overall measure of encouragement. Exploratory factor analysis was conducted in the current study to explore whether a two-factor or one-factor model was a better fit for encouragement scale in this study.

A principal axis factor analysis was conducted on 10 items of encouragement measure. A parallel analysis was utilized to determine the number of possible factors (Kahn, 2006; Russell, 2002). Specifically, factors extracted from a real data set have to account for more variance than factors extracted from a random data set (Brown, 2006). After computing 1,000 random data sets through parallel analysis, the eigenvalues of the first two factors in the random data sets are 1.41 and 1.28 respectively. In the real data from the current study, the eigenvalues of the first two factors are 6.25 and 1.08 respectively. Because the second eigenvalue from the current study data set is smaller than the second eigenvalue extracted from the random data sets in the parallel analysis, it is suggested that a one-factor model is a better fit for the data. Because the factor analysis suggests a one-factor model, an overall mean score was created for encouragement and was utilized in the following moderation and moderated mediation analyses.

Mediation Analysis

The mediation hypotheses predicted that RSE would mediate the relationship between impostor feelings and interest in research (hypothesis 1A) as well as impostor feelings and expectations for a career in STEM (hypothesis 1B). Both age and year in program were treated as covariates for the mediation analyses.

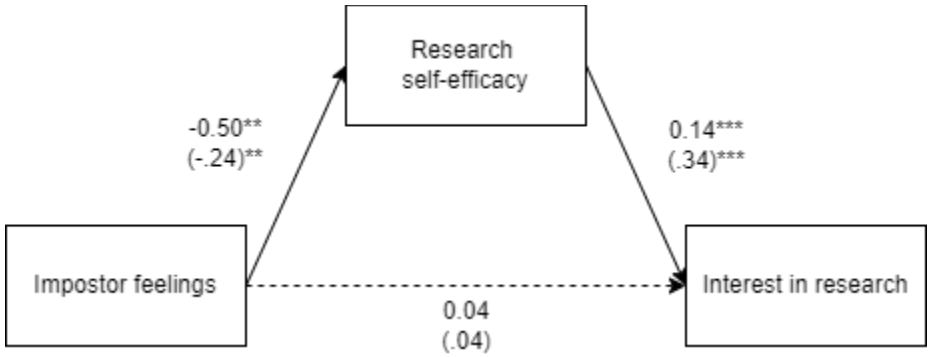
These hypotheses were examined using the PROCESS model, developed by Hayes (2013). PROCESS is a computational tool that can be used with statistical analysis software such as SPSS to conduct path-analysis based moderation and mediation analyses. A total of 10,000 bootstrap samples were selected and a 95% confidence interval (CI) was used (Mallinckrodt et al., 2006; Preacher & Hayes, 2008). Bootstrapping is a sampling approach in which a large number of random samples are drawn from the research sample (Mallinckrodt et al., 2006). The random samples are drawn using continuous replacement, so the probability of being selected remains the same for each case (Mallinckrodt et al., 2006). Bootstrapping allows for an estimation of the sampling distribution based on the sampling data and is recommended for testing the indirect effect of mediation (Hayes & Rockwood, 2017). If the 95% CI did not include zero, this indicated that the indirect effect of the mediation is significant at the .05 alpha level (Shrout & Bolger, 2002). Analysis of the mediation effects focused on the indirect mediation effects, as recommended by Hayes and Rockwood (2017). Specifically, the significance of the product of pathways *a* and *b* would be tested rather than following the traditional causal steps approach created by Baron and Kenny (1986).

Both age and year in program were viewed as covariates in the mediation analyses. The indirect effect of impostor feelings on interest in research through research self-efficacy was significant (*ab* = -0.07, *SE* = .03, 95% CI [-0.12, -0.02]). The direct effect of impostor feelings

on interest in research was not significant (*c'* = 0.04, *p* = .59). This suggests that research self-efficacy partially mediated the relationship between impostor feelings and interest in research, supporting hypothesis 1A (see Figure 9).

Figure 9

Unstandardized Regression Coefficients for the Mediation of Research Self-Efficacy Between Impostor Feelings and Interest in Research



Note. Standardized regression coefficients are provided in parentheses.

***p* < .01, ****p* < .001

The indirect effect of impostor feelings on expectations for a STEM career through research self-efficacy was also significant (*ab* = -0.06, *SE* = .03, 95 CI [-0.14, -0.004]). The direct effect of impostor feelings on expectations for a STEM career was not significant (*c'* = 0.07, *p* = .56). This suggests that research self-efficacy partially mediated the relationship between impostor feelings and expectations for a career in STEM, supporting hypothesis 1B (see Figure 10).

Figure 10

Unstandardized Regression Coefficients for the Mediation of Research Self-Efficacy Between Impostor Feelings and Expectations for a Career in STEM

Note. Standardized regression coefficients are provided in parentheses.

***p* < .01, ****p* < .001

The current study also tested an alternative mediation model. Specifically, mediation analyses were also conducted using RSE as the independent variable and impostor feelings as the mediator. The indirect effect of RSE on interest in research through impostor feelings was not significant (*ab* = -0.004, *SE* = .01, 95% CI [-0.02, 0.02]). The indirect effect of RSE on expectations for a STEM career through impostor feelings was not significant either (*ab* = -0.01, *SE* = .02, 95% CI [-0.04, 0.02]). These findings provide further support for the role of RSE as a mediator.

Moderation Analysis

The moderation hypotheses predicted that both challenge-focused (hypothesis 2A) and potential-focused encouragement (hypothesis 2B) would moderate the relationship between impostor feelings and RSE. Specifically, for individuals who receive greater encouragement from their advisor, it is expected that the negative relationship between impostor feelings and RSE would be weaker than for those who perceive lesser encouragement from their advisor.

Because exploratory factor analysis suggested a one-factor model for encouragement in this study, an overall mean score for encouragement was used as a moderator as well. Both age and year in program were treated as covariates for the moderation analyses.

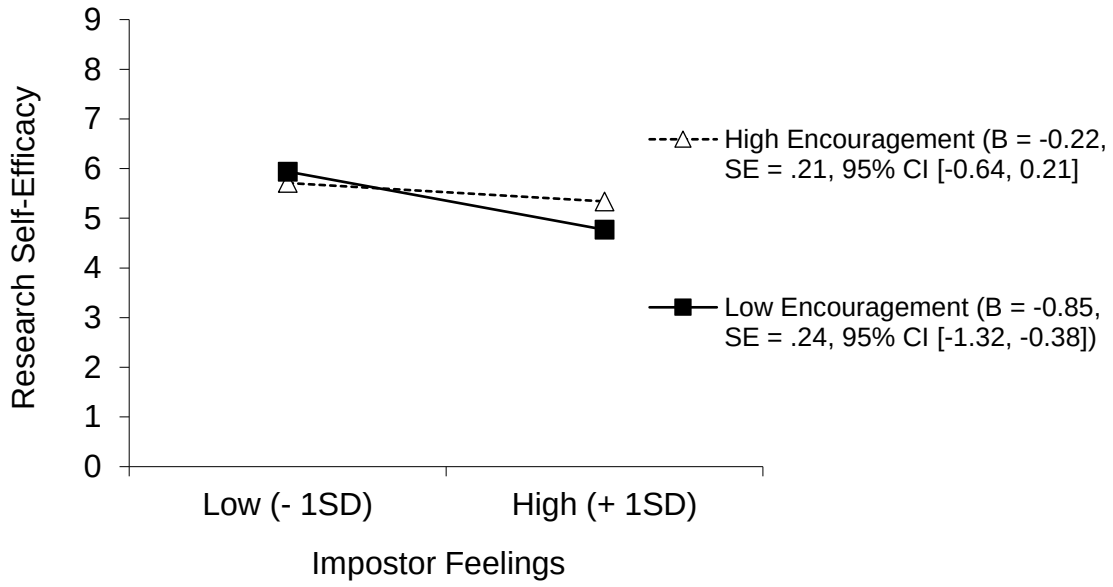
The moderation hypothesis was examined using the PROCESS software as well (Hayes, 2013). If the 95% CI of the interaction term did not include zero, it indicated a significant moderation effect (Aiken & West, 1991). The "pick-a-point" approach was used to determine which levels of the moderator should be used to probe the interaction (Rogosa, 1980). PROCESS allows researchers to examine conditional effects, which demonstrate changes in the relationship between the independent and dependent variable (Hayes, 2013), at any level of the moderator variable and automatically generates this output (Hayes, 2013; Hayes & Rockwood, 2017). The current study probed the interaction with moderator values equal to the ±1 *SD* from the mean of the moderator (i.e., academic encouragement).

The moderation effect of challenge-focused encouragement on the relationship between impostor feelings and RSE was not significant as the 95% CI of the interaction term included zero (*B* = 0.27, *SE* = .14, *p* = .06, 95% CI [-0.01, 0.54]). The moderation effect of potential-focused encouragement was also not significant as the 95% CI of the interaction term included zero (*B* = 0.25, *SE* = .13, *p* = .06, 95% CI [-0.01, 0.51]). However, the moderation effect of general encouragement was significant, as the 95% CI did not include zero (*B* = 0.30, *SE* = .15, *p* = .049, 95% CI [0.02, 0.59], $\Delta R^2 = .02$). To understand the nature of the moderation, I probed the interaction with moderator values equal to the ±1 *SD* from the mean of the moderator (i.e., academic encouragement). The simple effects analyses from PROCESS revealed that the association between impostor feelings and research self-efficacy was significantly negative for STEM women who received low levels of academic encouragement (*B* = -0.85, *SE* = .24, 95%

CI [-1.32, -0.38]). However, for STEM women who received high levels of academic encouragement, the association between impostor feelings and research self-efficacy was not significant (*B* = -0.22, *SE* = .21, 95% CI [-0.64, 0.20]) (see Figure 11).

Figure 11

The Effect of Impostor Feelings on Research Self-Efficacy at High vs. Low Levels of Encouragement



Moderated Mediation Analysis

The moderated mediation analysis examined whether or not challenge-focused encouragement moderated the indirect effect of RSE on the relationship between impostor feelings and interest in research (hypothesis 3A) and expectations for a STEM career (hypothesis 3B). This analysis also examined if potential-focused encouragement moderated the indirect effect of RSE on the relationship between impostor feelings and interest in research (hypothesis 3C) and expectations for a STEM career (hypothesis 3D). We hypothesized that the indirect

mediation effect of RSE on the relationships between impostor feelings and interest in research and outcome expectations would be stronger (i.e., more negative) at lower levels of both challenge-focused and potential-focused encouragement. Because EFA suggested a one-factor model for encouragement scale in this study, we also explored the role of general encouragement as a moderator of the indirect effect of RSE on the relationship between impostor feelings and both interest in research and expectations for a STEM career.

The moderated mediation analysis (also called conditional process analysis; Hayes & Rockwood, 2017) was conducted using PROCESS. PROCESS automatically produces an index of moderated mediation. If the 95% CI did not include zero, it suggested that the indirect mediation effect is significantly different at different levels of the moderator. Results indicated that none of the moderated mediation analyses were significant. Challenge-focused (*B* = 0.04, *SE* = .02, 95% CI [-0.01, 0.08]), potential-focused (*B* = 0.03, *SE* = .02, 95% CI [-0.01, 0.07]), and general encouragement (*B* = 0.04, *SE* = .02, 95% CI [-0.01, 0.09]) did not significantly moderate the indirect effect of RSE on the relationship between impostor feelings and interest in research, as the 95% CI included zero in all three analyses. These results do not support hypotheses 3A and 3C.

Challenge-focused (*B* = 0.03, *SE* = .02, 95% CI [-0.01, 0.08]), potential-focused (*B* = 0.03, *SE* = .02, 95% CI [-0.01, 0.08]), and general encouragement (*B* = 0.04, *SE* = .03, 95% CI [-0.01, 0.09]) did not moderate the indirect effect of RSE on the relationship between impostor feelings and expectations for a STEM career either, as all three 95% CIs included zero. These results do not support hypotheses 3B and 3D. Overall, none of the moderated mediation hypotheses were supported.

CHAPTER FIVE

DISCUSSION

The current study broadly aimed to examine the relationships between impostor feelings and career-related outcomes in women enrolled in doctoral programs in math-intensive STEM fields. Specifically, for the mediation hypotheses, the study examined whether research self-efficacy would serve as a mediator for the relationship between impostor feelings and career-related outcomes (i.e., interest in research and expectations for a STEM career). Regarding moderation hypotheses, encouragement was hypothesized to be a moderator for the relationship between impostor feelings and research self-efficacy. Pertaining to moderated mediation hypotheses, encouragement was examined as a moderator for the mediation effect of impostor feelings through research self-efficacy to career outcomes (i.e., interest in research and expectations for a STEM career). The previous chapter (chapter four) detailed the statistical analyses used to examine these hypotheses and indicated that several hypotheses were supported by the data. This chapter further discusses the findings, particularly their implications for mental health providers, STEM doctoral programs, and future research.

Research Self-Efficacy as a Mediator

Hypotheses 1A and 1B proposed that research self-efficacy would mediate the relationship between impostor feelings and interest in research (hypothesis 1A) and expectations for a STEM career (hypothesis 1B). Both of these hypotheses were supported by the results of this study. The results suggested that STEM women who struggled with impostor feelings had less research self-efficacy, which in turn was associated with less interest in research and lower expectations for a STEM career. These findings aligned with previous research indicating that there are negative relationships between impostor feelings and RSE in doctoral students (Jöstl et

al., 2012; Tao & Gloria, 2019). In addition, these findings confirmed the positive relationships between self-efficacy, interest, and outcome expectations in the interest model of SCCT (Lent, 2016).

Implications for Mental Health Providers

The results of hypotheses 1A and 1B suggest that individuals with greater impostor feelings had less RSE and in turn had less interest in research and lower expectations for a career in STEM. These findings highlight the importance of building RSE in women in math-intensive STEM doctoral programs, as lower RSE partially explained the impact of impostor feelings on participants' interest in research and expectations for a STEM career. Self-efficacy theory suggests four primary sources of self-efficacy: verbal persuasion, mastery experiences, vicarious experiences, and physiological and affective states (Bandura, 1997). Verbal persuasion refers to receiving messages from important others regarding how an individual's competence is perceived or what others believe the individual is capable of doing (Bandura, 1997). Mastery experiences refer to previous successes and failures (Bandura, 1997). Vicarious experiences refer to seeing the success of similar others and having role models, which provide a point of social comparison and may foster self-efficacy through providing examples of what is possible (Bandura, 1997). Finally, physiological and affective states refer to the arousal an individual experiences when attempting tasks where their self-efficacy is challenged, with more arousal often internally interpreted as a sign of distress and/or dysfunction, typically lowering self-esteem (Bandura, 1997).

Mental health providers working with women in math-intensive STEM doctoral programs as well as administrators, faculty, and advisors in these programs could help increase the RSE of their doctoral students by utilizing these four sources of self-efficacy. For example,

mental health providers could work with women in these programs to develop coping skills to reduce physiological and affective arousal by utilizing therapeutic approaches such as cognitive behavioral therapy (A. T. Beck, 1979; J. S. Beck, 2011), dialectical behavioral therapy (Linehan, 1993), and acceptance and commitment therapy (Hayes et al., 1999), for example. Other therapeutic approaches could be used as well. Mental health providers could also provide encouragement to their women in STEM clients, targeting verbal persuasion (the role of encouragement will be further discussed later in this chapter). For example, mental health providers could utilize challenge-focused encouragement by highlighting instances in which their client has persevered through difficult situations in the past and emphasize the client's abilities to get through their current difficult situation or resolve their current problem as well (e.g., a client's self-care habits and ability to cognitively re-frame situations; Wong, 2015). Mental health providers could also utilize potential-focused encouragement by emphasizing a strength that they have observed in their client that their client may want to continue to develop for personal growth or overall improved well-being (e.g., a client's value of social justice and actions to help marginalized communities; Wong, 2015).

Implications for STEM Doctoral Programs

These findings have important implications for STEM faculty, advisors, and administrators as well. Faculty could work to increase mastery experiences in their doctoral students by creating a curriculum where doctoral students complete smaller research projects with appropriate support and scaffolding from their advisors, building mastery experiences in research before embarking on a large thesis or dissertation project. Advisors could also provide encouragement as verbal persuasion and acknowledge their advisees' research abilities and achievement. Finally, STEM programs could also work to highlight women in math-intensive

STEM fields through creating a more gender-diverse faculty, emphasizing the contributions of women in coursework, creating a speaker series, and so on, to increase vicarious experiences in their women doctoral students.

Contributions

The support of the mediation hypotheses has several implications for the literature. First, the findings help to close the gap in the literature regarding graduate women's experiences in STEM programs. Though women earn significantly fewer doctoral degrees in math-intensive STEM fields than men, and there is a growing interest in the experiences of graduate women in STEM (Cabay et al., 2018; Fouad & Santana, 2017), most previous research has focused on undergraduate STEM women (Wilkins-Yel et al., 2021). By focusing on the experience of doctoral women through the theoretical lens of SCCT, the current study provides support for the applicability of the SCCT interest model in the graduate women in STEM population.

Additionally, the current study incorporates impostor phenomenon (IP) into the SCCT literature. Integrating the extensive literatures of IP and SCCT is particularly important for the women in STEM literature as IP can have negative impacts on vocation (Tao & Gloria, 2019; Vaughn et al., 2020) and SCCT is the most commonly used vocational theoretical framework to study the STEM women population (Santana & Fouad, 2017). Incorporating IP into the SCCT literature opens up many future research directions that may increase our understanding of the vocational impacts resulting from the impostor feelings as well as avenues through which to reduce those impacts (i.e., increasing RSE).

Encouragement as a Moderator

Hypotheses 2A and 2B proposed that challenge-focused and potential-focused encouragement would moderate the relationship between impostor feelings and RSE. A score of

general encouragement was also examined as a moderator, as exploratory factor analysis showed that a one-factor model was a better fit for the data in the current study. The results showed that general encouragement moderated the relationship between impostor feelings and RSE. Specifically, there was a negative association between impostor feelings and research self-efficacy for STEM women doctoral students who perceived low levels of encouragement from their advisors. As hypothesized, encouragement may have moderated this relationship due to its similarity to verbal persuasion, a source of self-efficacy, which may help challenge the self-doubt created by impostor feelings. These findings suggest that providing encouragement may be an important way to reduce the negative impact of impostor feelings on the RSE of women in math-intensive STEM doctoral programs.

Hypotheses 3A, 3B, 3C, and 3D proposed challenge-focused and potential-focused encouragement as moderators of the previously described mediation model. These moderated mediation analyses were also conducted using a general encouragement score given the results of factor analysis. The results did not support these hypotheses. In other words, a participant's level of perceived encouragement did not significantly impact the strength of the indirect effect of RSE on the relationship between impostor feelings and both interest in research and expectations for a STEM career. It is possible that the proposed moderated mediation model did not capture the potential complex interactions between encouragement and the mediation model or other variables may be contributing to these relationships. For example, perhaps advisory working alliance may impact the strength of encouragement to moderate these mediation effects.

Implications for Mental Health Providers

The results of the moderation analyses suggest that STEM women in doctoral programs who perceived low levels of academic encouragement from their advisors would be more

vulnerable to the negative impact of impostor feelings. Mental health providers may provide encouragement to their STEM women clients to combat the negative impacts of impostor feelings. According to the tripartite encouragement model, encouragement is most effective when the individual providing the encouragement is perceived as trustworthy and credible (Wong, 2015). Encouragement is also more effective when the encouraging message is focused on the individual's progress or effort (Wong, 2015). To increase the effectiveness of their encouragement messages, mental health providers may focus on building the therapeutic alliance with their clients. The therapeutic alliance refers to the feelings that the client and clinician have towards one another (Gelso & Carter, 1985) and is an important mechanism of change in psychotherapy (Castonguay et al., 2006). Messages of encouragement from mental health providers whom the client has a strong therapeutic alliance with may be perceived as more effective as the provider may be seen as more trustworthy and credible (Wong, 2015).

Implications for STEM Doctoral Programs

The result of the moderation has important implications for STEM doctoral programs as well. Those in advisory relationships with STEM women may consider working to incorporate encouragement into their advisory style. Specifically, advisors may highlight their advisee's strengths, particularly in areas in which the advisor may be perceived as particularly credible (i.e., research, coursework, etc.). Advisors should also consider framing their encouragement on their advisee's effort and progress in order for the encouragement to be most effective (Wong, 2015). Receiving this encouragement from their advisor may, as the results of the current study suggest, reduce the negative impact of impostor feelings on RSE.

Contributions

In the existing research literature, relationships between IP and positive psychology concepts (i.e., encouragement) have not been examined. The current study helped to close this gap in the literature by integrating these two fields. Integrating these literatures is important as much of the IP literature has focused on the negative impacts of IP such as symptoms of anxiety (Clance, 1985; Clance & O'Toole, 1987), feelings of self-doubt (Chakraverty, 2019; Jacobs et al., 2020), or reduced RSE (Jöstl et al., 2012; Tao & Gloria, 2019). Positive psychology, on the other hand, focuses on building positive qualities and helping individuals thrive rather than just survive (Seligman & Csikszentmihalyi, 2000). The integration of positive psychology, specifically encouragement, and IP in the current study was promising, as general encouragement was found to mitigate the negative impact of impostor feelings on doctoral women's RSE.

Limitations

There are several limitations of the current study that should be considered in the interpretation of the results. One limitation is the design of the study. Because the study utilized a cross-sectional design, causal inferences were not able to be established among the variables. Another limitation in the current study is self-selection bias or self-selection effect. Self-selection bias can occur when participants have to actively choose to participate in a study and refers to differences between those individuals who choose to participate and those who do not (Alarie & Lupien, 2021). This can reduce the representativeness and generalizability of the findings (Braver & Bay, 1992). In the current study, individuals interested in participating in the study may have different characteristics than those who did not choose to participate. For example, individuals who have experienced impostor feelings during their doctoral program may have

been more interested in participating in the current study than individuals who did not feel like impostors in their program, which could potentially bias the results.

A final limitation may be the lack of representation of women in computer science doctoral programs in the current study. The percentage of participants who indicated they were studying computer science (1.2%) was significantly lower than the percentage of participants studying engineering (32.9%), mathematics (34.1%), or physical sciences (31.3%). Computer science is the math-intensive STEM field in which women earned the fewest percentage of doctoral degrees in 2016 (National Science Foundation, 2019a), which may partially explain why so few women studying computer science responded to the study. However, because the percentage of women in computer science was significantly lower than the other fields, the results of the current study may not generalize to the computer science population.

Directions for Future Research

The present study offers many suggestions for future research. First, future research may also aim to recruit a more representative sample with regard to the math-intensive STEM fields that participants are studying. As previously stated, computer science was underrepresented in this study, with only 1.2% of participants indicating that they were studying computer science. A more representative sample would increase the generalizability of the results.

Second, future research may also consider examining more complex moderated mediation models. The moderated mediation hypotheses were not supported, which may be due to unexamined potential variables that may interact with encouragement to impact the mediation effect. For example, the advisory working alliance between the advisor and advisee may interact with academic encouragement in predicting the association between impostor feelings and research self-efficacy. As previously mentioned, encouragement is more effective when the

individual providing the encouragement is perceived to be more credible and genuine (Wong, 2015). Just as encouragement can contribute to a stronger relationship between a clinician and client, and a stronger relationship can make encouragement more effective (Wong, 2015), the same may be true for the relationship between an advisor and advisee. Future research may utilize more complex moderated mediation models and explore the potential impact of the advisory working alliance on encouragement as a moderator.

Third, future research should continue to explore the underlying factorial structure of encouragement. While conceptualized as a two-factor variable (Wong, 2015), other researchers have utilized a one-factor approach, considering high correlations among the foci of encouragement (Hsu et al., 2021). Exploratory factor analysis in the current study suggested a one-factor model as well. Future research utilizing encouragement should continue exploring whether encouragement is better explained as one factor or two factors.

Fourth, the current study utilized a cross-sectional, correlational design and thus causation was not able to be established in the current study. Future research may consider using a longitudinal design to better understand the impact of impostor feelings on RSE, interest in research, and expectations for a STEM career over time. Finally, future research may also consider employing an experimental design such as the one utilized in Wong et al. (2020). Using an experimental design may allow us to better understand the role of encouragement in moderating the impact of impostor feelings by controlling how doctoral STEM women are receiving encouragement and comparing between control and experimental groups.

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Appendix A: Measures

Eligibility Screening

1. Do you identify as a woman?
    a. Yes
    b. No
2. Are you at least 18 years old?
    a. Yes
    b. No
3. Are you currently enrolled in a doctoral program (e.g., PhD program)?
    a. Yes
    b. No
4. Are you enrolled in a doctoral program in one of the following fields? Engineering, computer science, mathematics, or physical sciences (e.g., chemistry, physics, astronomy, Earth sciences, or atmospheric sciences)?
    a. Yes
    b. No
5. Do you work with an advisor?
    a. Yes
    b. No

Demographic Information

1. What type of degree (e.g., Ph.D, D.Sc., etc.) are you pursuing?
    a. Ph.D.
    b. DSc or ScD
    c. DEng or DESc or DES
    d. Other ____
2. What year are you in the current doctoral program?
    a. 1st year
    b. 2nd year
    c. 3rd year
    d. 4th year
    e. 5th year
    f. 6th year
    g. Other _____
3. What is your area of study?
    a. Engineering
    b. Computer science
    c. Mathematics
    d. Physical sciences (e.g., chemistry, Earth sciences, astronomy, geology, etc.)
    e. Other _____
4. Age?
    a. _____ years
5. What is your gender identity?
    a. Cisgender woman (gender identity and sex assigned at birth are the same)
    b. Transgender woman (gender identity and sex assigned at birth are different)
6. Which of the following best describes your sexual orientation?

   a. Heterosexual/Straight
   b. Gay/Lesbian/Same-Gender
   c. Bisexual
   d. Pansexual
   e. Queer
   f. Asexual
   g. Demisexual
   h. Other: _____
7. Which of the following best describes your ethnicity?
   a. Alaska Native or American Indian
   b. Asian or Asian American
   c. Latino/a or Hispanic
   d. Middle Eastern or North African
   e. Black or African American
   f. Native Hawaiian or Pacific Islander
   g. White/Caucasian or European American
   h. Bi-racial or multi-racial
   i. Other:_____
8. How long you have been working with your current advisor?
   _____year(s)_____month(s)
9. What is your advisor's gender identity?
   a. Man
   b. Woman
   c. Unsure/don't know

Academic Encouragement Scale

The following statements refer to experiences that may or may not have happened in your life. Please rate the extent to which the statements are true for you.

Very untrue of me	Untrue of me	Somewhat untrue of me	Somewhat true of me	True of me	Very true of me
1	2	3	4	5	6

1. My advisor encouraged me to believe in myself when I doubted my academic abilities.
2. My advisor instilled hope in me when I felt like giving up on an academic task.
3. My advisor reminded me of my strengths when I was discouraged about a challenging academic task.
4. My advisor assured me that I was competent in dealing with my academic difficulties.
5. My advisor expressed confidence in me and told me to keep trying in school even though it was hard.
6. My advisor pointed out my strengths when they suggested I pursue a new academic opportunity.
7. My advisor noticed I was doing well in school and encouraged me to dream bigger and aim higher.
8. My advisor insisted that I should strive for higher academic standards because I was capable.
9. My advisor explained why I had the skills to succeed in school at an advanced level.
10. My advisor said something positive to motivate me to consider a new academic goal.

Reference:

Wong, Y. J., Cheng, H. L., McDermott, R. C., Deng, K., & McCullough, K. M. (2019). I believe in you! Measuring the experience of encouragement using the academic encouragement scale. *The Journal of Positive Psychology*, *43*(2), 178-216. https://doi.org/10.1177/0011000014545091.

Clance IP Scale

For each question, please select the number the best indicates how true the statement is of you. It is best to give the first response that enters your mind rather than dwelling on each statement and thinking about it over and over.

Not at all True	Rarely	Sometimes	Often	Very True
1	2	3	4	5

1) I have often succeeded on a test or task even though I was afraid that I would not do well before I undertook the task.
2) I can give the impression that I'm more competent than I really am.
3) I avoid evaluations if possible and have a dread of others evaluating me.
4) When people praise me for something I've accomplished, I'm afraid I won't be able to live up to their expectations of me in the future.
5) I sometimes think I obtained my present position or gained my present success because I happened to be in the right place at the right time or knew the right people.
6) I'm afraid people important to me may find out that I'm not as capable as they think I am.
7) I tend to remember the incidents in which I have not done my best more than those times I have done my best.
8) I rarely do a project or task as well as I'd like to do it.
9) Sometimes I feel or believe that my success in my life or in my job has been the result of some kind of error.
10) It's hard for me to accept compliments or praise about my intelligence or accomplishments.
11) At times, I feel my success has been due to some kind of luck.
12) I'm disappointed at times in my present accomplishments and think I should have accomplished much more.
13) Sometimes I'm afraid others will discover how much knowledge or ability I really lack.
14) I'm often afraid that I may fail at a new assignment or undertaking even though I generally do well at what I attempt.
15) When I've succeeded at something and received recognition for my accomplishments, I have doubts that I can keep repeating that success.
16) If I receive a great deal of praise and recognition for something I've accomplished, I tend to discount the importance of what I've done.
17) I often compare my ability to those around me and think they may be more intelligent than I am.
18) I often worry about not succeeding with a project or examination, even though others around me have considerable confidence that I will do well.
19) If I'm going to receive a promotion or gain recognition of some kind, I hesitate to tell others until it is an accomplished fact.
20) I feel bad and discouraged if I'm not "the best" or at least "very special" in situations that involve achievement.

Reference:

Clance, P.R. (1985) *The imposter phenomenon: When success makes you feel like a fake.* Bantam Books.

Expectancy for a STEM Career

Please think about yourself and rate how true the following statements are:

Not at all True	Untrue	Somewhat Untrue	Neither True nor Untrue	Somewhat True	True	Very True
1	2	3	4	5	6	7

1) I would enjoy a career in STEM.
2) I have good feelings about a career in STEM.
3) Having a STEM career would be interesting.
4) I would like to have a career in STEM.

Reference:

Stake, J. E., & Mares, K. R. (2001). Science enrichment programs for gifted high school girls and boys: Predictors of program impact on science confidence and motivation. *Journal of Research in Science Teaching, 38*(10), 1065–1088. https://doi.org/10.1002/tea.10001

Self-Efficacy in Research Measure

The following items are tasks related to research. Please indicate your degree of confidence in your ability to successfully accomplish each of the following tasks on a scale from 0-9 with 0 representing no confidence and 9 representing total confidence.

No Confidence									Total Confidence
0	1	2	3	4	5	6	7	8	9

1) Keeping records during a research project
2) Designing an experiment using traditional methods (e.g., experimental, quasi-experimental designs)
3) Writing the introduction and literature review for a dissertation
4) Writing the introduction and discussion sections for a research paper for publication
5) Formulating hypotheses
6) Writing the method and results sections of a thesis
7) Utilizing resources for needed help
8) Understanding computer printouts
9) Defending a thesis or dissertation
10) Using multivariate statistics (e.g., multiple regression, factor analysis, etc.)
11) Using statistical packages (e.g., SPSS, SAS, R, etc.)
12) Operationalizing variables of interest

Reference:

Kahn, J. H., & Scott, N. A. (1997). Predictors of research productivity and science-related career goals among counseling psychology doctoral students. *The Counseling Psychologist, 25*(1), 38–67. https://doi.org/10.1177/0011000097251005

Interest in Research Questionnaire

Using the 5-point scale provided, please indicate the degree of interest you have in the activities listed as part of **your professional (post-Ph.D.) career**. Please remember that the term research encompasses both quantitative and qualitative approaches.

Very Disinterested		Indifferent		Very Interested
1	2	3	4	5

1. Reading a research journal article.
2. Being a member of a research team (remember, the term **research** encompasses both quantitative and qualitative approaches).
3. Conceptualizing a research study.
4. Conducting a literature review.
5. Developing funding proposals.
6. Having research activities as part of every work week.
7. Taking a research design course.
8. Taking a statistics course.
9. Developing a data analysis.
10. Analyzing data.
11. Discussing research findings.
12. Writing for publication/presentation.
13. Leading a research team.
14. Designing a study.
15. Collecting data.

Reference:

Bishop, R. M., & Bieschke, K. J. (1994). *Interest in Research Questionnaire*. Unpublished scale.

Bieschke, K. J., Bishop, R. M., & Herbert, J. T. (1995). Research interest among rehabilitation doctoral students. *Rehabilitation Education, 9,* 51–66.

Bishop, R. M., & Bieschke, K. J. (1998). Applying social cognitive theory to interest in research among counseling psychology doctoral students: A path analysis. *Journal of Counseling Psychology, 45,*182–187.