WOMEN'S UNDER-REPRESENTATION IN THE ENGINEERING AND COMPUTING PROFESSIONS: FRESH PERSPECTIVES ON A COMPLEX PROBLEM

EDITED BY: Kathleen Buse, Catherine Hill and Romila Singh
PUBLISHED IN: Frontiers in Psychology

frontiers Research Topics

ISSN 1664-8714
ISBN 978-2-88945-493-8
DOI 10.3389/978-2-88945-493-8

About Frontiers

Frontiers is more than just an open-access publisher of scholarly articles: it is a pioneering approach to the world of academia, radically improving the way scholarly research is managed. The grand vision of Frontiers is a world where all people have an equal opportunity to seek, share and generate knowledge. Frontiers provides immediate and permanent online open access to all its publications, but this alone is not enough to realize our grand goals.

Frontiers Journal Series

The Frontiers Journal Series is a multi-tier and interdisciplinary set of open-access, online journals, promising a paradigm shift from the current review, selection and dissemination processes in academic publishing. All Frontiers journals are driven by researchers for researchers; therefore, they constitute a service to the scholarly community. At the same time, the Frontiers Journal Series operates on a revolutionary invention, the tiered publishing system, initially addressing specific communities of scholars, and gradually climbing up to broader public understanding, thus serving the interests of the lay society, too.

Dedication to quality

Each Frontiers article is a landmark of the highest quality, thanks to genuinely collaborative interactions between authors and review editors, who include some of the world's best academicians. Research must be certified by peers before entering a stream of knowledge that may eventually reach the public - and shape society; therefore, Frontiers only applies the most rigorous and unbiased reviews.
Frontiers revolutionizes research publishing by freely delivering the most outstanding research, evaluated with no bias from both the academic and social point of view.
By applying the most advanced information technologies, Frontiers is catapulting scholarly publishing into a new generation.

What are Frontiers Research Topics?

Frontiers Research Topics are very popular trademarks of the Frontiers Journals Series: they are collections of at least ten articles, all centered on a particular subject. With their unique mix of varied contributions from Original Research to Review Articles, Frontiers Research Topics unify the most influential researchers, the latest key findings and historical advances in a hot research area! Find out more on how to host your own Frontiers Research Topic or contribute to one as an author by contacting the Frontiers Editorial Office: researchtopics@frontiersin.org

WOMEN'S UNDER-REPRESENTATION IN THE ENGINEERING AND COMPUTING PROFESSIONS: FRESH PERSPECTIVES ON A COMPLEX PROBLEM

Topic Editors:
Kathleen Buse, Case Western Reserve University, United States
Catherine Hill, American Association of University Women, United States
Romila Singh, University of Wisconsin - Milwaukee, United States

Women continue to be under-represented in the engineering and computing professions, comprising about 1 in 10 of the engineering workforce and about 1 in 4 of those working in technology and computer sciences worldwide. An intentional, international effort is needed to accelerate the rate of achievement for women in these important professions. This eBook includes studies related to career choice, academic success, workplace recruitment, retention, and advancement. Included are articles that aid in understanding the many complexities that frame this under-representation and lead to effective interventions.

Citation: Buse, K., Hill, C., Singh, R., eds. (2018). Women's Under-Representation in the Engineering and Computing Professions: Fresh Perspectives on a Complex Problem Lausanne: Frontiers Media. doi: 10.3389/978-2-88945-493-8

Table of Contents

CHAPTER 4
CASE STUDIES OF SUCCESSFUL INTERVENTION STRATEGIES

frontiers in Psychology

EDITORIAL
published: 24 April 2018
doi: 10.3389/fpsyg.2018.00595

Check for updates

Editorial: Women's Under-representation in Engineering and Computing: Fresh Perspectives on a Complex Problem

*Kathleen Buse**

Case Western Reserve University, Cleveland, OH, United States

Keywords: women in STEM, engineering, computing, women, under-representation

Editorial on the Research Topic

Women's Under-representation in Engineering and Computing: Fresh Perspectives on a Complex Problem

Understanding the many complexities that define gender inequality has been described by researchers as a grand challenge (Joshi et al., 2015). Novel insights, innovation, a broader community to conduct research and to ascertain effective interventions are essential in the challenge to create organizations that are gender equal. As such, this research topic in Frontiers in Psychology addresses the underrepresentation of women in engineering and computing as a complex, but solvable problem. The special issue seeks to inform the global community about advances in understanding the underrepresentation of women in engineering and computing with a focus on what enables change. Further this issue promotes fresh perspectives, innovative methodologies, and mixed method approaches important to accelerating the pace of change.

Despite more than 40 years of research attempting to explain the gender gap (Kanny et al., 2014) the engineering and computing professions continue to be dominated by men. In 2015 women comprised 12% of the engineers and 25% of computer professionals in the USA (US Bureau of Labor Statistics, 2015). This is at a time when women comprise 47% of the total labor force and 52% of managers and professionals. The numbers are similar in Europe, India, and Australia, but slightly higher in China (The Association of German Engineers, 2010; Catalyst, 2012, 2015; Engineers Australia, 2017).

An intentional, international effort is essential to accelerate the rate of achievement for women in engineering and computing. As such this special research topic includes 13 papers that employ empirical methodologies studying adolescents, students in 2-year colleges, undergraduate and graduate programs, and women in the workplace. The full body of work includes studies related to career choice, academic success, workplace recruitment, retention, and advancement. Methodologies employed include qualitative, quantitative, longitudinal, ethnographic, case studies, and mixed methods. The papers span the development of theoretical concepts through effective interventions and suggestions on future research.

Several of the contributions leverage empirical methods to describe interventions. Adolescents are the focus of the longitudinal study by Riegle-Crumb and Morton that explores the impact of messages from peers within science classrooms on girls' career choice in the science, technology, engineering, and math (STEM) professions. Results reveal that a higher percentage of 8th grade male peers in the classroom who endorsed explicit gender/STEM stereotypes significantly and negatively predicted girls' later intentions to pursue engineering or computer science. Yet results also reveal that exposure to a higher percentage of confident female peers in the science classroom positively predicted such intentions. These results were specific to engineering and computer science, suggesting that peers are an important source of messages regarding girls' career choice to pursue non-traditional STEM fields.

OPEN ACCESS

Edited and reviewed by:
Richard Eleftherios Boyatzis, Case Western Reserve University, United States

****Correspondence:***
Kathleen Buse
krb50@case.edu

Specialty section:
This article was submitted to Organizational Psychology, a section of the journal Frontiers in Psychology

Received: *12 February 2018*
Accepted: *09 April 2018*
Published: *24 April 2018*

Citation:
Buse K (2018) Editorial: Women's Under-representation in Engineering and Computing: Fresh Perspectives on a Complex Problem. Front. Psychol. 9:595. doi: 10.3389/fpsyg.2018.00595

Women's educational pathways and success in STEM through 2-year colleges were explored by Wang et al. Specifically they studied the relationship between the intent to transfer and a set of motivational, contextual, and socio-demographic background factors. Six hundred and ninety-six female students from 2-year colleges in the USA were surveyed as they began studies in STEM programs or courses. The survey data and administrative records were used to complete a multinomial logistic regression analysis. Findings revealed that students' math and science self-efficacy beliefs, as well as transfer-oriented interaction, were significant and positive predictors for their intent to transfer into STEM fields. The association between transfer intent and motivational and contextual factors was moderated by students' racial/ethnic backgrounds, marital status, and childcare obligations. These findings have important and nuanced implications for policymakers, educators, and researchers and support the case for women to consider 2-year colleges as pathways to success in STEM fields.

An innovative approach was used by Milesi et al. employing Experience Sampling Method (ESM) to evaluate, in real-time, the engagement of college students. 165 students majoring in computer science at two Research I universities were "beeped" several times a day via a smartphone app prompting them to provide information. The responses were paired with data provided by the institutions. Mean comparisons and logistic regression analysis were used to compare enrollment and persistence patterns. Results suggest that women are more likely to continue taking computer science courses when they felt challenged and skilled in their initial computer science classes. This promising study was the first using this method. The authors suggest expanding the study across different types of institutions and over a longer time period for further insight on the relationship between engagement and persistence.

Some German universities offer separate women's engineering courses which include virtual STEM learning environments. Christophel and Schnotz explore the virtual learning environments and whether there are differences in the virtual learning of female and male learners in STEM courses. A field study was conducted with 56 students (female = 27, male = 29) completing a virtual STEM learning program. Results revealed that strategic competences were positively correlated with situational interest in the virtual learning environment regardless of gender. In contrast, the correlations between mental effort and competences differed between female and male participants. Female learners' mental effort decreased if they had more strategic competences while female learners' mental effort increased if they had more arithmetic-operative competences. The finding that female learners are more likely than their male colleagues to be influenced by strategic and arithmetic-operative competences regarding their mental effort indicates that separate women's courses may be an effective approach for increasing their representation in engineering.

The "Grad Cohort," a multi-day mentorship workshop for women graduate students developed by the Computing Research Association's Committee on the Status of Women in Computing Research (CRA-W), is an intervention strategy studied by Stout et al. The long-term impact of this program on the Ph.D. students' professional goals, computing identity, and entity beliefs was studied and compared to a sample of women and men Ph.D. students in computing programs who had never participated. Grad Cohort participants reported interest in becoming well-known in their field to a greater degree than women non-participants, and to an equivalent degree as men. Also, Grad Cohort participants reported stronger interest in giving back to the community than their peers. Further, whereas women non-participants identified with computing to a lesser degree than men and held stronger entity beliefs than men, Grad Cohort participants' computing identity and entity beliefs were equivalent to men. Importantly, stronger entity beliefs predicted a weaker computing identity among students, with the exception of Grad Cohort participants. This latter finding suggests Grad Cohort may shield students' computing identity from the damaging nature of entity beliefs. Together, these findings suggest Grad Cohort may fortify women's commitment to pursuing computing research careers and move the needle toward greater gender diversity in computing.

Photovoice, a Participatory Action Research method, was utilized by Amon to identify themes that underlie women's experiences in traditionally male-dominated fields. Photovoice enables participants to convey unique aspects of their experiences via photographs and their in-depth knowledge of a community through personal narrative. Forty-six STEM women graduate students and postdoctoral fellows from a large university in the USA participated in the Photovoice activity in small groups. They presented photographs that described their experiences pursuing leadership positions in STEM fields. Findings provide a basis for better understanding the complex ways that gender stereotypes surface in organizations, as well as the bottom-up strategies STEM women employ to cope with workplace challenges. Specifically, results provide a framework for understanding women's work preferences, challenges, and buffering strategies. This work generated insight into policies that can best support and enhance STEM women's career success including explicitly advocating for workplace collegiality, offering structured networking opportunities, instituting faculty mentorship programs along with mentorship training, and using incentives to increase departmental and interdepartmental collaboration.

Carrigan offers an ethnographic study of women's experiences in computing providing evidence of an existing systemic preference for the technical dimensions of computing over the social and a correlation between gender and social aspirations. The study suggests there is a gap between the current state of computing and the yearning of participants who desire to use computing to contribute to the collective well-being of society. Findings from the study suggest that gender equity in computing may be achieved by addressing the meaning of the social values, ideologies and practices of these institutions. A call for the development of measures and evaluations on how computing contributions to society is made along with a call for further studies in this area.

Fouad et al. utilized qualitative analysis on a national sample of 1,464 women engineers to identify the reasons women leave the profession. The findings show that women's decisions to leave their jobs and the engineering field was shaped by a lack of fit between their needs and values and the reinforcements present in their work environment. Further the results show that occupational values and needs related to comfort, safety, and achievement predominantly characterized women engineers' attrition decisions. Occupational reinforcers include status, altruism, and autonomy needs. Their detailed understanding helps promote organizational interventions aimed at engaging and retaining women in the profession. Specifically interventions should provide career development opportunities for women engineers. Work should include opportunities that allow a sense of accomplishment, security, good compensation, opportunities for advancement, and a workplace free from discrimination and harassment.

New theoretical directions are needed that provide a framework for continued understanding of the underrepresentation of women. Expanding current conceptual frameworks to better understand the underrepresentation of women in engineering and computing is important. Steinke does this while focusing on the role of popular media in the formation of adolescent girls' STEM identity. Steinke argues that the media plays a crucial role in the construction, representation, reproduction, and transmission of STEM stereotypes and that this may be particularly salient and relevant for girls during adolescence as they actively consider future personal and professional identities. Gender-stereotyped media images of STEM professionals are described and theories are examined to identify variables that explain the potential influence of these images on STEM identity formation. This article emphasizes the importance of focusing on STEM identity relevant variables and STEM identity status to explain individual differences in STEM identity formation.

A new framework for continued understanding of the underrepresentation of women in engineering and computing is provided by Buse et al. Arguing that an extensive body of research on gender equity already exists, this paper details a future research agenda that was developed from dialogue among 50 experts at a 2 day convening. The result is an innovative, collaborative approach to future research that focuses on identifying effective interventions. The new approach includes the creation of partnerships with stakeholders including businesses, government agencies, non-profits, and academic institutions to allow a broader voice in setting research priorities. Researchers recommend incorporating multiple disciplines and methodologies, while expanding the use of data analytics, merging and mining existing databases, and creating new datasets. Studies are recommended that focus on socio-cultural interventions particularly on career choice, within undergraduate and graduate programs, and for women in professional careers all leading to gender equity in the engineering and computing professions.

Critical reviews of the literature specifically those that identify gaps in understanding of women's experiences in engineering and computing including explanations of why these gaps exist and how to increase understanding are important to this topic. In a focused review, Boucher et al. discuss how stereotypic perceptions of computing and engineering influence who enters, stays, and excels in these fields. The focus here is on communal goal incongruity defined as the idea that some disciplines (like engineering and computing) are perceived as less aligned with people's communal goals of collaboration and helping others. Empirical literature is reviewed that demonstrates how perceptions of these disciplines are incongruent with communal goals and how this perception deters women and girls. This perspective is extended by reviewing accumulating evidence that perceived communal goal incongruity can deter any individual who values communal goals. The authors conclude that communal opportunities within computing and engineering have the potential to benefit first generation college students, underrepresented minority students, and communally-oriented men (as well as communally-oriented women). The implications is that those opting out of STEM perpetuate the stereotypic (mis)perceptions of computing and engineering. Recommendations are presented to highlight communal opportunities in computing and engineering to increase interest and motivation. By better integrating and publically acknowledging communal opportunities, the stereotypic perceptions of these fields could gradually change, making computing and engineering more inclusive and welcoming to all.

Case studies describing interventions that have improved the representation of women in engineering and/or computing, with an emphasis on the psychological and organizational factors that impacted women's ability to achieve within the organizations are important to this topic. A case study of a research-based approach to retaining and advancing women in the STEM professions is detailed by Van Oosten et al. The Leadership Lab for Women is an innovative professional development program that leverages recent research, 360° feedback, coaching, and practical strategies. The program provides women with knowledge, tools, and a supportive learning environment to help them navigate, achieve, flourish, and catalyze organizational change in male-dominated and technology-driven organizations. Early analysis of the program's outcomes show increases in participant's self-awareness, self-efficacy, and ability to persist, and excel in their chosen profession. These provide encouraging signs of the intervention's success in advancing and retaining women.

As one part of a multi-phase case study spanning over a decade Crenshaw et al. add to the understanding of the cultural and experiential issues impacting the retention of women and people in the computing disciplines. Their study compares data gathered at the Department of Computer Science at the University of Illinois at Urbana-Champaign in 2005 and more recently in a follow-up project completed in 2016. The data reveals improvements in the perceptions of undergraduate teaching quality and undergraduate peer mentoring networks. However, evidence was found of continuing feelings of isolation, incidents of bias, policy opacity, and uneven policy implementation particularly with respect to historically underrepresented groups. Preliminary findings, research and methodological reflections, and applied research suggestions are presented that aim to create positive cultural change in computing.

In closing we want to thank the many authors, reviewers, and editors who contributed to this special research topic addressing the underrepresentation of women in engineering and computing. You have worked collaboratively to inform the global community not only about advances in understanding the underrepresentation but have specified many intervention strategies that enable change. The grand challenge of gender equity in engineering and computing will be overcome as researchers, practitioners, and educators continue to work together to develop knowledge and apply intervention strategies to accelerate the rate of change.

AUTHOR CONTRIBUTIONS

The author confirms being the sole contributor of this work and approved it for publication.

REFERENCES

Catalyst (2012). *Women in the Labor Force in China*. Available online at: http://www.catalyst.org/knowledge/women-labor-force-china

Catalyst (2015). *Women in the Indian Labor Force*. Available online at: http://www.catalyst.org/knowledge/women-indian-labour-force

Engineers Australia (2017). *The Engineering Profession, A Statistical Overview, 13th Edn*. Available online at: https://www.engineersaustralia.org.au/Government-And-Policy/Statistics

Joshi, A., Neely, B., Emrich, C., Griffith, D., and George, G. (2015). Gender research in AMJ: an overview of five decades of empirical research and calls to action, thematic issue on gender in management research. *Acad. Manage. J.* 58, 1459–1475. doi: 10.5465/amj.2015.4011

Kanny, A. M., Sax, L. J., and Riggers-Piehl, T. A. (2014). Investigating forty years of STEM research: how explanations for the gener gap have evolved over time. *J. Women Minor. Sci. Eng.* 20, 127–148. doi: 10.1615/JWomenMinorScienEng.2014007246

The Association of German Engineers (2010). *European Engineering Report*. Available online at: https://www.vdi.de/uploads/media/2010-04_IW_European_Engineering_Report_02.pdf

US Bureau of Labor Statistics (2015). *Women in the Labor Force: A Databook*. Available online at: BLS Reports: http://www.bls.gov/opub/reports/cps/women-in-the-labor-force-a-databook-2015.pdf

Conflict of Interest Statement: The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The handling Editor declared a shared affiliation, though no other collaboration, with the author.

frontiers in Psychology

ORIGINAL RESEARCH
published: 15 March 2017
doi: 10.3389/fpsyg.2017.00329

Check for updates

Gendered Expectations: Examining How Peers Shape Female Students' Intent to Pursue STEM Fields

Catherine Riegle-Crumb * *and Karisma Morton*

Department of Curriculum and Instruction, STEM Education, and Department of Sociology, University of Texas, Austin, USA

Building on prior psychological and sociological research on the power of local environments to shape gendered outcomes in STEM fields, this study focuses on the critical stage of adolescence to explore the potential negative impact of exposure to exclusionary messages from peers within girls' science classrooms, as well as the positive potential impact of inclusionary messages. Specifically, utilizing longitudinal data from a diverse sample of adolescent youth, analyses examine how the presence of biased male peers, as well as confident female peers, shape girls' subsequent intentions to pursue different STEM fields, focusing specifically on intentions to pursue the male-dominated fields of computer science and engineering, as well as more gender equitable fields. Results reveal that exposure to a higher percentage of 8th grade male peers in the classroom who endorsed explicit gender/STEM stereotypes significantly and negatively predicted girls' later intentions to pursue a computer science/engineering (CS/E) major. Yet results also reveal that exposure to a higher percentage of confident female peers in the science classroom positively predicted such intentions. These results were specific to CS/E majors, suggesting that peers are an important source of messages regarding whether or not girls should pursue non-traditional STEM fields. This study calls attention to the importance of examining both positive and negative sources of influence within the local contexts where young people live and learn. Limitations and directions for future research are also discussed.

Keywords: gender, computer science, engineering, peers, stereotypes, college

OPEN ACCESS

Edited by:
Catherine Alison Hill, American Association of University Women, USA

Reviewed by:
Matthew Christopher Davis, University of Leeds, UK
Saliha Kozan, University of California, San Diego, USA
Catherine Alison Hill, American Association of University Women, USA

***Correspondence:**
Catherine Riegle-Crumb
riegle@austin.utexas.edu

Specialty section:
This article was submitted to Organizational Psychology, a section of the journal Frontiers in Psychology

Received: *31 October 2016*
Accepted: *21 February 2017*
Published: *15 March 2017*

Citation:
Riegle-Crumb C and Morton K (2017) Gendered Expectations: Examining How Peers Shape Female Students' Intent to Pursue STEM Fields. Front. Psychol. 8:329. doi: 10.3389/fpsyg.2017.00329

INTRODUCTION

While women in the U.S have made substantial progress in recent decades in many high-status areas, including comprising more than half of recent entering classes in both medical school and law school, and clearly surpassing their male peers in rates of college matriculation and attainment, nevertheless stark instances of inequality remain (DiPrete and Buchmann, 2013). Specifically, women remain substantially under-represented in some STEM fields, most markedly in computer science and engineering, two of the most in-demand and high-paying domains (National Academy of Sciences, 2007; England, 2010). Yet conditional on entry to college majors in these and other STEM fields, women persist to attain a degree at comparable rates to men (Xie and Shauman, 2003; Barton et al., 2008; Ohland et al., 2008). Thus, a principle barrier to equitable female representation among STEM degree earners, and subsequently, among STEM professionals, is the fact that females are much less likely than males to pursue these fields in college in the first place.

Additionally, it is important to recognize that the roots of gender inequality in the choice of college major reach further back. Research reveals that educational and occupational aspirations began to crystallize around early adolescence, coinciding with the increasing saliency of gender identity and gender roles in young people's lives (Bandura et al., 2001; Eccles, 2007; Eccles and Roeser, 2011). As they actively contemplate their possible futures, young people are subject to a multitude of messages from those around them regarding what is appropriate and expected for their gender. And at a developmental point when adolescents begin to move away from the parental sphere of influence, relationships with peers become increasingly salient, and thus signals and approval from them take on a newly powerful role (Wentzel et al., 2012) this may be even more pronounced for adolescent girls than boys, as they are socialized to be both more aware of and sensitive to others' opinions (Gilligan, 1982; Beutel and Marini, 1995).

Stepping back, it is clear that efforts to understand why young women are under-represented in certain STEM fields in college and beyond should focus on the formation of the gender gap in future educational and career plans that emerges during the adolescent years, and the critical role that peers play in this process (Eccles and Wigfield, 2002; Eccles, 2009). Indeed, scholars examining gender inequality in STEM fields have long acknowledged that peers and the classrooms and schools they populate likely play an important role in shaping young people's decisions (e.g., Eccles, 1994); yet nevertheless the bulk of prior literature on this topic has focused primarily on the impact of students' own attitudes and beliefs, such as self-efficacy and affect, as predictors of their subsequent STEM-related decisions (Eccles, 1994; Correll, 2001; Eccles and Wigfield, 2002).

Consequently, in this study, we focus needed attention on the role of peers in shaping adolescents' future intentions to pursue STEM fields, with the goal of understanding both positive and negative sources of influence on girls' decisions. Building on prior research in psychology and sociology, we examine the potential negative impact of exposure to exclusionary messages from peers within the local contexts of girls' science classrooms, as well as the positive potential impact of inclusionary messages. Specifically, informed by research on stereotype threat (Spencer et al., 1999; Inzlicht and Ben-Zeev, 2000), we examine whether being in a classroom where male students explicitly endorse gender/STEM stereotypes works to deter girls' intentions of pursuing STEM fields in the future. Additionally, building on the work of gender scholars who point to the power of counter-stereotypical evidence to disrupt gender norms (Dasgupta, 2011; Stout et al., 2011), we also examine whether being surrounded by female peers who are very confident in their science ability provides girls with messages of belonging and inclusion that subsequently promote their likelihood of pursuing STEM fields.

To investigate these issues, we utilize longitudinal data from middle and high school students collected in a large, urban, predominantly low-income and Hispanic school district in the U.S, a location that demographically mirrors the districts attended by millions of young people. Thus our study marks a departure from the majority of extant research on gender inequality in STEM that continues to focus on predominantly white populations despite both the changing demographics of the U.S. and the fact that minority students have relatively high levels of STEM interest (Hurtado et al., 2010; Riegle-Crumb et al., 2011; Xie et al., 2015). Our dataset is also relatively unique as it includes detailed information about peer attitudes and beliefs, which is made possible by surveying entire classrooms within schools. Additionally, we distinguish between future intentions to major in computer science and engineering, fields that are heavily male-dominated, compared to intentions to major in the biological and physical sciences, fields where women and men have similar rates of representation (Cheryan et al., 2017)[1]. In doing so we are better able to understand whether the exclusionary and inclusionary messages to which girls may be exposed to via their peers is particularly powerful in shaping their intentions to pursue fields that are non-normative for their gender.

BACKGROUND

Gender theorists and scholars argue that gender is a social construction, one that is created and reinforced across various levels, including the macro-level of institutions as well as the micro-level of the local environments that individuals inhabit (Ridgeway and Correll, 2004; Risman, 2004). Some scholars have argued that local environments are perhaps the most powerful location of the construction of gender, as the everyday interpersonal interactions that occur in homes, schools, and workplaces are where individuals first learn and are subsequently continually reminded of the normative expectations of others (Risman, 2004). Put simply, in the locations where girls and young women conduct their daily lives, they encounter a host of experiences and interactions with others who expect them to think and behave in ways that are consistent with prevailing societal gender norms and stereotypes. Yet at the same time, local environments offer the potential for the disruption of inequality and the creation of alternative constructions of gender (Deutsch, 2007; Risman, 2009). For example, if they are populated by individuals who do not endorse traditional norms and beliefs, local contexts can create opportunities for interactions and experiences that push back against larger social norms and paradigms.

Building on this logic, the schools that students attend and the classrooms within them are critical locations to investigate regarding the social construction of gender, and more specifically, the shaping of gendered expectations about STEM fields. A growing body of research in psychology and sociology has recognized and empirically examined how factors within local environments can recreate and reinforce traditionally gendered beliefs and roles, and to a considerably lesser extent, also considered how characteristics of local contexts can instead disrupt gender norms and stereotypes. Thus, below we briefly describe extant research on the power

[1]The category of physical science generally includes both chemistry and physics. Although the latter remains predominantly male, chemistry is indeed gender equitable (with 50% of undergraduate degrees in the field awarded to women) and is also the much larger category (National Science Foundation, 2014). Specifically, of those earning degrees in the category of physical science, over 2/3 of them were in chemistry (National Science Foundation, 2014).

of exclusionary messages in local contexts to deter females' interest and pursuit of STEM fields, as well as research on inclusionary messages that can offer support for non-normative choices. As we articulate in more detail below, while certainly informative, the current literature is nonetheless limited in its ability to shed light on our understanding of inequality due to both substantive and methodological issues.

Messages of Exclusion within STEM Local Environments

Recent research on the topic of stereotype threat has investigated how gender stereotypes and bias can function within local environments to deter the STEM interest and achievement of females. This literature is largely experimental, with cues manipulated by researchers to assess how exposure to statements about female inferiority in math and science subsequently impacts the behavior and attitudes of female study participants (Spencer et al., 1999; Shapiro and Williams, 2012). Within this literature, some studies call specific attention to the role of male peers in invoking stereotypes, suggesting that the gender composition of the environment can be sufficient to invoke threat. Specifically, in environments where STEM performance is being somehow evaluated, those that are very male-dominated can activate the notion that females do not belong or are out of place, thus impacting subsequent behavior or attitudes (Inzlicht and Ben-Zeev, 2000; Murphy et al., 2007; Dasgupta et al., 2015). While research in this area has called critical attention to how proximate exposure to bias and stereotypes can negatively impact females' STEM-related outcomes, nevertheless it is important to point out the results of such experiments may not necessarily translate outside these highly controlled settings.

Beyond the experimental literature on stereotype threat, some studies have attempted to measure the impact of bias and stereotypes on deterring females in STEM fields by asking young women to recount their exposure to such factors. For example, a recent study by Brown and Leaper (2010) found that female students' perceptions of academic sexism, measured as the frequency of overt comments they recall hearing others make regarding female inferiority in math, was negatively related to their interest in pursuing STEM fields. This study did not however, differentiate between comments made by peers, teachers, or family members, thus obscuring the source of negative messages. Other studies, mostly qualitative, ask female college students in STEM fields to report the extent to which they have experienced being a target of discriminatory acts in the classroom (Seymour and Hewitt, 1997; Ecklund et al., 2012). Importantly these studies highlight that exclusionary interactions typically occur with male individuals, which is consistent with other research that finds that males are much more likely to endorse gender/STEM stereotypes than females (Schmader et al., 2004). Thus, extant research generally falls short of directly assessing the stereotypic beliefs held by peers in real-world settings, instead relying on individuals' recall of particular discriminatory events. While certainly important, this focus likely underestimates the extent to which females interact daily with biased male peers in local STEM environments in ways that may work subtly but cumulatively to deter their STEM interest.

Stepping back, we suggest that prior research on the power of exclusionary messages within STEM environments is informative but nonetheless limited. In addition to the reasons outlined in the preceding paragraphs, we also note that research in this area typically focuses on college-age students, including those already enrolled in STEM fields, rather than examining the impact of exclusionary messages at the more formative stage of adolescence. Thus our longitudinal study will contribute new knowledge to the field by explicitly examining whether the actual presence of gender-biased male peers in science classrooms deters the future STEM intentions of adolescent females.

Messages of Inclusion within STEM Local Environments

Given the continued prevalence of stereotypes about females' presumed innate inferiority in math and science domains, it is logical to assume that most (if not all) females live and learn in local environments in which they interact with biased individuals. Yet at the same time, it is possible that some local contexts serve to disrupt these larger gender stereotypes. In this vein, some psychological research has recently moved to empirically examine the power of peers and role models to counter-act stereotypes and provide alternative depictions of females' strength and belonging in STEM fields (Dasgupta, 2011). Sometimes referred to as the stereotype-inoculation model, researchers have found that exposure to female peers and adult role models whose own behaviors and accomplishments in STEM fields contradicts larger stereotypes can therefore increase young women's own sense of identification with STEM fields, and in doing so promote their own subsequent choices (Dasgupta and Asgari, 2004; Lenton et al., 2009; Stout et al., 2011). This mostly experimental body of research thus provides empirical evidence suggesting that peers can be the source of messages of inclusion within STEM-focused local environments.

Consistent with this notion, other research in psychology and sociology has focused on the power of friends to act as a source of support and encouragement for girls' STEM-related decisions. Specifically, female friends who themselves work hard and succeed in STEM fields can help to create a local environment where girls feel included, increasing their desire to continue to pursue such fields. For example, Riegle-Crumb et al. (2006) found that girls' decisions to take advanced math classes in high school were influenced by the presence of such peers. Other studies provide similar evidence that having female peers who are STEM-focused provides legitimation to girls' own pursuits and promotes the sense of belonging to a community (Frank et al., 2008; Robnett and Leaper, 2013; Leaper, 2015).

While this relatively small body of research demonstrates the potential for peers to act as positive sources of influence in shaping girls' STEM expectations, we note that as with extant research on peers as a source of exclusionary messages, there are limitations. Few studies in this area utilize real-world settings, and those that do focus on peers' academic performance but not their actual STEM attitudes (Riegle-Crumb et al., 2006; Frank et al., 2008), or rely on individuals' perceptions of the attitudes of their peers rather than direct measurement (e.g., Robnett and Leaper, 2013). Further, while this research does sometimes focus on adolescents at formative stages in their STEM-related decision-making, it also typically focuses on close friends as a subset of peers. Yet foundational research on peer influence persuasively argues that the viewpoints and attitudes of friends may sometimes be less consequential than those of the larger group of peers in the local environment, as friends' support can often be taken for granted in a manner that the support of other peers cannot (Giordano, 2003). Therefore our study provides a new contribution to the literature by measuring how the science-related views of female peers in the classroom can potentially impact adolescent girls' subsequent STEM intentions.

CURRENT STUDY

Our study builds on the insights of several different areas of prior research to investigate how factors within the local environment of students' science classrooms can work to either deter or promote girls' future STEM intentions. Specifically, we will examine both the potential for male peers' biased beliefs to create messages of exclusion, as well as the potential for female peers' science confidence to provide supportive messages of inclusion and belonging in STEM fields. In doing so, we build upon prior research on stereotype threat, as well as social psychological research on stereotype inoculation and sociological research on the influence of peers. Our study attempts to bridge these relatively distinct areas of research to create new knowledge about the simultaneous influence of exclusionary and inclusionary factors at a critically important point when adolescents' intentions to pursue (or not to pursue) STEM majors are crystallizing, as these early decisions are highly predictive of subsequent patterns of gender inequality in STEM degree attainment and labor force participation (Xie and Shauman, 2003; Morgan et al., 2013).

Additionally, it is important to point out that the majority of prior literature that examines the potential impact of local contexts on girls' STEM outcomes does so utilizing samples of predominantly white students. Such a focus is very limited and does not capture the changing demographics of the U.S., particularly for the student-age population (Ayscue and Orfield, 2016). Regarding gender patterns in STEM, national studies have documented relatively similar gaps in interest and attainment that favor men across different racial/ethnic groups (Hanson, 2006; Riegle-Crumb and King, 2010; Xie et al., 2015); yet of course these patterns do not mean that the obstacles and experiences that shape Hispanic females' STEM choices, for example, are necessarily similar to those that are most relevant for white females. Our study therefore aims to contribute to the small body of extant research that examines gender disparities in STEM among a diverse population, with an eye towards understanding how experiences of social inclusion and exclusion might matter for girls from non-dominant backgrounds.

Finally, we note that the prior research discussed above is limited in its attention to different STEM domains, typically focusing only on one field, or instead considering STEM in the aggregate. Yet at the baccalaureate level and beyond, some fields are severely male-dominated while others are not. Therefore, in an effort to better understand the power of peer beliefs and attitudes to shape girls' future intentions, in this study we consider their potential influence both on intentions to pursue strongly male-dominated STEM fields (e.g., computer science and engineering), as well as more gender equitable fields (e.g., biological and physical sciences). Thus, our study will address the following research questions:

1a. Does exposure to *biased male peers* in their science classrooms negatively impact the intentions of female students to pursue college degrees in *computer science and engineering*?
1b. Does such exposure similarly impact female students' intentions to pursue degrees in the *biological and physical sciences*?
2a. Does exposure to *confident female peers* in their science classrooms positively impact the intentions of female students to pursue college degrees in *computer science and engineering*?
2b. Does such exposure similarly impact female students' intentions to pursue degrees in the *biological and physical sciences*?

DATA AND SAMPLE

For this study we utilize the Broadening Science in School Study (BSSS), a dataset collected from a very large urban school district (approximately 200,000 students) in the southwestern U.S. The district is predominantly Hispanic (more than 70%), and also serves a student population that is economically disadvantaged, with more than 75% of students in the district eligible for either free or reduced lunch. Additionally, 25% of students are classified by the district as Limited English Proficient (LEP).

The research team collected administrative data (including academic transcripts) as well as surveys from two cohorts of students in 18 middle schools in the district during the fall of their 8th grade year (2013 or 2014). Students were surveyed in their science classrooms with a response rate of almost 90% per school. Importantly for the purposes of our study, we were able to aggregate the responses of individuals in the same science classroom to create the measures of peer attitudes and beliefs (as well as other characteristics of the classroom) described below. Additionally, the team followed a sub-set of students and briefly surveyed them again after they transitioned into high school ($n = 11$ high schools; response rate of approximately 70% per school). This later survey is the source of our dependent variable (intentions to major in various STEM fields) described below.

Our final analytic sample is comprised of 1,273 high school students (647 females and 626 males) for whom 8th grade middle school administrative and survey data were available, who were not missing on the dependent variables capturing intended college majors, and who also indicated on the high school survey that there was at least a small chance that they would attend college in the future (we excluded 52 students who indicated that that is was extremely unlikely that they would attend college). Our analytic sample roughly mirrors characteristics of the district, as it is approximately 78% Hispanic, 12% Black, 7% white, and 3% other race/ethnicity (which includes Asian and Native American students). Additionally, approximately 87% of students in our sample qualified for either free or reduced lunch.

Dependent Variable

On the survey administered at the beginning of high school, students were asked to report how likely it is that they would choose to major in each of the following four STEM fields: biological sciences, physical sciences, computer science/technology and engineering. Response categories were on the following 5-point scale: 1 (not at all likely), 2 (somewhat unlikely), 3 (neutral), 4 (somewhat likely), to 5 (very likely). Exploratory analyses indicated that students' responses were correlated across certain STEM domains. Specifically, students who expressed a stronger likelihood or intention of majoring in computer science were also likely to express a strong intention of majoring in engineering ($r = 0.6$). A similar correlation was found between intentions to major in biological sciences and the physical sciences. Thus, we choose to ultimately collapse these four variables to create two dependent variables. Additionally, because responses were not normally distributed, we dichotomized them so that a score of 1 indicated that the student reported that they were either likely or very likely (a score of 4 or 5) to major in that field, vs. not likely (a score of 3 or below).

Thus, the first dependent variable for the analyses in this paper captures intentions to major in computer science or engineering (CS/E), distinguishing between those students who reported that were likely to major in either or both subjects (coded 1) vs. those who were not likely to major in either (coded 0). The second dependent variable captures intentions to major in either biological or physical sciences (B/PS), similarly distinguishing between those who were likely to major in either or both subjects (coded 1) vs not likely to major in either (coded 0). Across the entire sample, intentions to major in CS/E fields were quite high, with 46% of all students reporting that they were likely to major in such fields, and 54% reporting that they were not. In contrast, intending to major in B/PS fields was much less popular, with approximately 27% of all students reporting that they were likely to major in these fields, compared to 73% that were not[2].

Importantly, our data revealed substantial gender differences in these intentions. Of those students who were likely to pursue CS/E majors, approximately 67% of them were male, while only 33% were female. In contrast, among those expecting to major in B/PS majors, 48% were male and 52% were female. As seen in **Figures 1**, **2**, we note that this gender breakdown is quite similar to the gender breakdown from national statistics on degree attainment in STEM fields (National Science Foundation, 2014), providing further support to the notion that gendered STEM expectations are strong precursors to subsequent patterns of inequality.

[2]Consistent with our decision to treat these as separate fields, we note that there was little overlap between students intending to major in CS/E and B/PS fields. Specifically only 12% of female students and 18% of male students were coded as 1 on both variables.

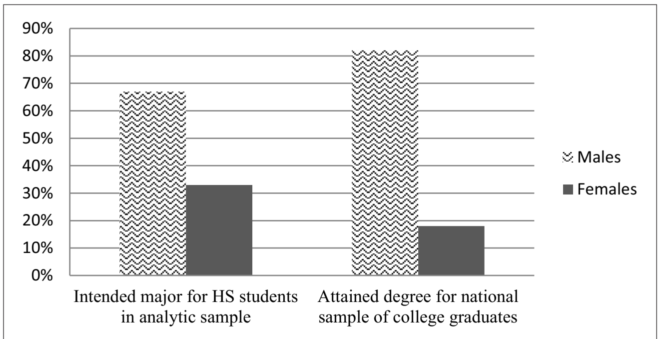

FIGURE 1 | Gender distribution of intended and attained degrees in computer science/engineering. Source: National Science Foundation (2014). *Science and Engineering Indicators 2014*, (NSB 14-01). Arlington, VA

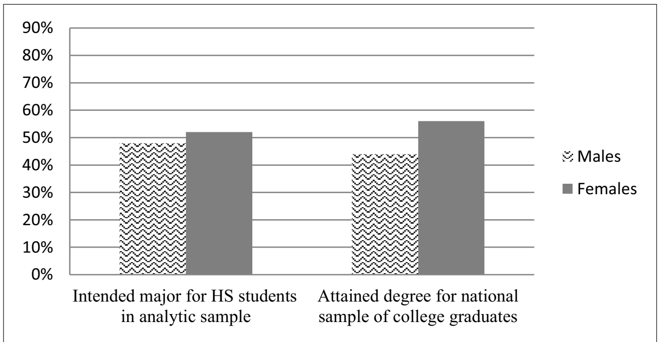

FIGURE 2 | Gender distribution of intended and attained degrees in biology/physical sciences. Source: National Science Foundation (2014). *Science and Engineering Indicators 2014*, (NSB 14-01). Arlington, VA

Independent Variables

Exclusionary and Inclusionary Peer Beliefs and Attitudes in the Classroom

Our two key independent variables capture the beliefs and attitudes of peers in students' science classrooms, measured in the fall of students' 8th grade year and thus preceding our dependent variable by approximately a year. The first variable originated from the Michigan Study of Adolescent and Adult Life Transitions (MSALT) and is meant to capture biased or exclusionary beliefs (Eccles et al., 1990; Eccles and Harold, 1991; Ambady et al., 2001; Bleeker and Jacobs, 2004; Eccles, 2015). Students were asked the following question: "Who is better at science and math, girls or boys?" Students choose from 4 responses including "girls are better than boys," "girls and boys are equally good," "boys are better than girls," or "I don't know." Responses were dichotomized such that 1 represented the response "boys are better than girls" and 0 represented all other responses. Exploratory analyses confirmed that male peers were the likely source of biased beliefs, as approximately 2% of girls reported that boys were better than girls at math and science. We note that this is consistent with other studies of explicit gender stereotypes, which tend to find that girls are very unlikely to endorse such stereotypes (Schmader et al., 2004). Thus our final measure captures the proportion of boys in the science classroom who endorsed the belief that boys are better at math and science. Individual student responses from boys in the same science classroom were aggregated to create this classroom measure. The mean for this variable is approximately 0.16 indicating that on average, students in our sample spent their 8th grade year in science classrooms where 16% of boys held this gender/STEM bias.

Our second key independent variable is meant to capture inclusionary peer attitudes for girls in STEM fields, and has previously been used in the Trends in International Mathematics and Science Study (TIMSS) (Wilkins, 2004; Riegle-Crumb et al., 2011; Kastberg et al., 2013). Specifically, students were asked to report their level of confidence in their science ability by reporting how much they agreed with the statement "I usually do well in science." Possible responses included "agree a lot," "agree a little," "disagree a little" and "disagree a lot." Responses were dichotomized so that 1 = agree a lot and 0 = all other responses. Consistent with the notion that female peers can act as role models and support against gender stereotypes, we created a classroom measure of the proportion of females in the science classroom who were very confident (agreed a lot) in their ability to do well in science by aggregating the responses of individual female students. The mean for this variable is approximately 0.29 indicating that on average, students in our sample spent their 8th grade year in science classrooms where almost 30 percent of girls were very confident in their science ability.

Additional Classroom Variables

We include additional variables as classroom control variables in our analyses. The first of these is the percent of male students in the classroom who are very confident in their science ability, constructed in a parallel measure to that described above for our measure of female peer confidence. By including this measure we are able to better assess the unique contribution of having highly confident female peers vs. a general classroom climate where students are confident in their abilities. Our second classroom control variable captures differences across classrooms in students' science performance, measured as the average science grade earned by students (available from their academic transcripts) in the same classroom in their 8th grade year[3].

To assess the association between different characteristics of classrooms, we calculated bivariate correlations. The association between male peer bias and female peer confidence was −0.11, indicating that although a higher percentage of biased male peers in the classroom was associated with a lower percentage of female peers with high science confidence, the magnitude of this relationship was very small in scope. The correlation between average classroom science grades and proportion of biased male peers was 0.05, while class grades and science-confident female peers were correlated at 0.20. Finally, the proportion of female peers with high science confidence also had a small positive correlation of 0.16 with the proportion of males with high science confidence. Thus in general the classroom characteristics we consider here appear to be quite independent of other.

Individual Control Variables

We also control on a number of characteristics to capture individual differences that may be relevant to intentions to major in STEM fields. First, we include measures for students' race/ethnicity, distinguishing between students who identified on the middle school survey as non-Hispanic white, Hispanic, Black, or other (which includes Asian and Native American students). A proxy for social class background was also included by utilizing a survey question asking students to estimate the number of books in their home. Responses on this variable range from 1 = few (0–10), to 4 = enough to fill several bookcases (more than 100). This survey item has been used in national studies of adolescents, as it is more reliable than asking students to report parent education level (Kastberg et al., 2013). An additional dichotomous variable captures whether or not the student has ever qualified for free or reduced lunch, as indicated on school administrative records. We also include a dichotomous measure from administrative records of whether the student was ever classified as Limited English Proficient (LEP).

Additionally, data from students' transcripts provided measures of students' academic background. This includes the final grade that the student earned in 8th grade science, as well as an indicator of the type of science class in which they were enrolled in 8th grade, where 1 = "Regular Science 8," 2 = "Honors Science 8," and 3 = "Other Science." The third category includes a collection of several different courses that had different titles than the first two categories but were designated as science courses on the students' transcripts. Students' college expectations are captured by a dichotomous indicator taken from the high school survey, coded 1 for those who reported that they were very sure they will go to college and 0 for those who were not. Finally, we include measures from the 8th grade survey of students' own science confidence, utilizing the same measure described above to create the classroom measures. In analyses for male students (described below) we also include a measure of their own belief about whether or not boys are better at math and science.

Table 1 displays means (or proportions) and standard deviations for each of the independent variables in our analyses by gender. We note that female students have significantly higher science grades than male students (providing further evidence that a belief that boys are better at math and science is reflective of a stereotype and not a fact), as well as higher college expectations.

ANALYSES AND RESULTS

To examine whether exposure to biased male peers and confident female peers impacts the future intentions to major in either CS/E or B/PS majors (both of which are measured dichotomously), we utilize logistic regression analyses. We note here that our primary interest is in examining how peers shape the intentions of

[3]In exploratory analyses, we also included classroom averages of students' social class background as measured by students' reports of books in the home (included as an individual level control), as well as the gender composition of the classroom (which had very little variation as most classes were comprised of equal numbers of male and females). These variables were not statistically significant and their inclusion did not alter any of our key findings. Therefore for the sake of parsimony they are not included in the final models.

TABLE 1 | Descriptive statistics by gender.

	Females		Males	
	Mean	*SD*	Mean	*SD*
INDIVIDUAL CHARACTERISTICS				
Race/ethnicity				
Black	0.13		0.11	
Hispanic	0.78		0.78	
Other race	0.02		0.04	
White	0.06		0.08	
Family background				
Books in the home	2.30	(1.09)	2.23	(1.06)
Free/reduced lunch	0.87		0.86	
Limited English proficient	0.29		0.30	
Academic background				
8th grade science confidence	0.30		0.34	
8th grade science grade	83.88	(6.45)	82.79	(7.34)
8th grade science course				
Science 8-regular	0.44		0.36	
Science 8-honors	0.43		0.42	
Other science	0.13		0.21	
College expectation	0.56		0.51	
CHARACTERISTICS OF 8TH GRADE SCIENCE CLASS				
Proportion of biased male peers	0.17	(0.24)	0.15	(0.19)
Proportion of confident female peers	0.29	(0.26)	0.29	(0.29)
Proportion of confident male peers	0.32	(0.31)	0.33	(0.26)
Average science grade	82.81	(4.47)	83.08	(4.84)
	$n = 647$		$n = 626$	

TABLE 2 | Logistic regression analyses predicting *female students'* likelihood of intending to major in different STEM fields.

	Model 1		Model 2	
	Computer science/ engineering		Biological/physical sciences	
	B	SE	*B*	SE
CLASSROOM VARIABLES				
Proportion of biased male peers	−0.877*	(0.440)	0.038	(0.437)
Proportion of confident female peers	0.703 ∼	(0.439)	−0.243	(0.459)
Proportion of confident male peers	−0.088	(0.325)	−0.241	(0.342)
Average classroom science grade	−0.011	(0.031)	−0.030	(0.032)
RACE/ETHNICITY (*Ref = White*)				
Hispanic	−0.412	(0.483)	0.316	(0.471)
Black	−0.621	(0.524)	0.174	(0.503)
Other race	0.334	(0.680)	−0.560	(0.737)
FAMILY BACKGROUND				
Books in the home	0.203*	(0.095)	0.314**	(0.101)
Free/reduced lunch	1.229**	(0.441)	0.378	(0.389)
Limited English proficient	0.058	(0.224)	−0.108	(0.241)
ACADEMIC BACKGROUND				
8th grade science confidence	−0.035	(0.250)	0.736**	(0.250)
8th Grade science grade	0.000	(0.019)	0.036 ∼	(0.020)
8TH GRADE SCIENCE COURSE (*Ref = Regular Science 8*)				
Honors science 8	0.030	(0.225)	0.210	(0.241)
Other science	−0.138	(0.410)	0.680 ∼	(0.402)
College expectations	−0.005	(0.193)	0.248	(0.204)

$n = 647$; Standard errors in parentheses.
*Two-tailed test: ***$p < 0.001$, **$p < 0.01$, * $p < 0.05$, $\sim p < 0.1$.*

female students, and based on the findings of previous literature discussed earlier, we do not anticipate that our measures of peer attitudes and beliefs would predict male students' STEM intentions. However, we do run parallel models for male students in our sample and briefly discuss their results as a basis of comparison. Our models also include fixed effects for both the middle schools and high schools that students attend to ensure that the standard errors in the models are properly estimated (as students are clustered within schools) and that differences between schools are taken into account. All results reported are from two-tailed tests of significance.

Beginning with **Table 2**, Model 1 displays the results predicting whether or not female students intend to declare a computer science or engineering major. We present logistic regression coefficients (rather than odds ratios), to ease interpretation. Similar to the logic of linear regression models, negative coefficients indicate that as the independent variable increases, the outcome is less likely to happen, while positive coefficients indicate that an increase in the independent variable is associated with an increase in the likelihood of the dependent variable occurring. To illustrate the magnitude of variables of interest we then report predicted probabilities.

As seen in Model 1, there is a negative and statistically significant effect of male peer STEM bias on the likelihood of intending to major in a CS/E field. Specifically, as the percentage of biased males in girls' increases, the likelihood that they intend to declare a CS/E major in their future significantly decreases. Furthermore, female peer STEM confidence is positively associated with declaring a CS/E major, although we note that variable is only significant at the $p < 0.10$ level.

Regarding control variables in the model, the only significant associations with intentions of declaring of a CS/E major are found for measures of individuals' social class background. Specifically, reporting more books in the home is positively associated, as is qualifying for free and reduced lunch. This perhaps indicates a somewhat curvilinear relationship such that students from both high and low levels of social class background are inclined to pursue this field. Neither students' race/ethnicity nor measures of their academic background significantly predict CS/E intentions.

Model 2 displays parallel results for a model where the dependent variable is females' intentions to major in the biological or physical sciences. None of our focal peer measures, neither male peer bias nor female peer confidence, significantly predicts the likelihood of expecting to pursue these fields. Yet interestingly we note that while having more female peers who are very confident in their science ability does not predict B/PS intentions, a girl's own individual level of science confidence does predict such intentions. Results for control variables reveal that as with CS/E majors, there is a significant positive effect of having more books in the home. Also as before, race/ethnicity does not predict B/PS intentions. Finally we note that girls' science grades have a positive effect ($p < 0.10$) on their intentions to major in B/PS fields.

Thus we see evidence that peer characteristics that could be considered exclusionary (male bias) and inclusionary (female confidence) predict girls' future intentions to major in the very male-dominated fields of computer science and engineering, while they do not significantly predict girls' intentions to major in the equitable fields of the biological and physical sciences. To get a better sense of the magnitude of potential peer influence on girls' CS/E intentions, we calculated predicted probabilities holding everything else in the model at the mean and varying the level of our peer variables of interest. Beginning with male peer bias (shown in **Figure 3**), we see that when girls are in a classroom where the average level of bias is low (one standard deviation below the mean), their probability of intending to declare a CS/E major is approximately 0.35. But as the percent of boys in their science classroom who endorse gender bias increases to one standard deviation above the mean (approximately 40% of boys endorse stereotypes), girls' probability of declaring a CS/E major falls to only 0.25.

We similarly calculated predicted probabilities to assess the impact of exposure to highly confident female peers (shown in **Figure 4**). When girls are in a classroom with levels of female peer confidence that are one standard deviation below the mean, their predicted probability of intending to declare a CS/E major is about 0.26. As the percent of female peers with high levels of confidence increases to one standard deviation above the mean (about 60%), their probability of intending to pursue such a major increases to 0.34.

We now turn briefly to the results of parallel models run for boys in our sample. As seen in **Table 3**, none of our measures of peer characteristics significantly predict either boys' intentions to pursue CS/E majors (Model 1) or B/PS majors (Model 2). While it would perhaps be logical to assume that the presence of more male peers endorsing gender stereotypes that favor males (or even the presence of more highly confident male peers) might embolden or encourage boys' choices to pursue STEM fields, this is not the case. Indeed, we find no evidence that any characteristics of peers are associated with boys' choices to pursue either type of STEM field. For Model 1, we do find that relative to white students, Black male youth are significantly less likely to intend to pursue CS/E fields, while those students who qualify for free or reduced lunch, as well as those who expect to go to college, are significantly more likely to intend to enter CS/E fields. Having high levels of confidence in their own science ability does significantly predict male students' intentions to declare a BP/S major, while net of other factors in the model,

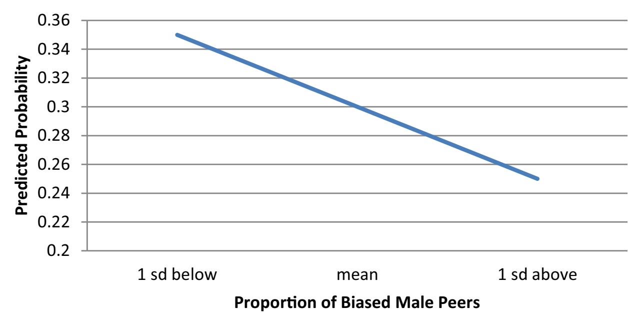

FIGURE 3 | Predicted probability of female students intending to declare a CS/E major by proportion of biased male peers.

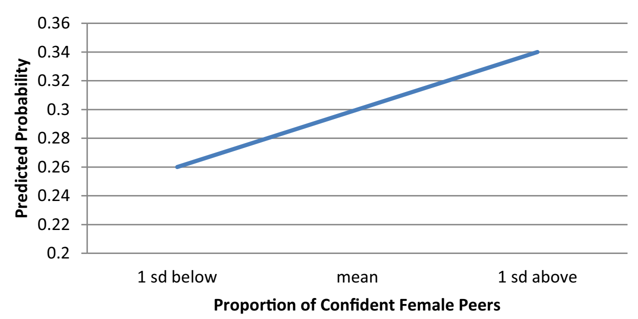

FIGURE 4 | Predicted probability of female students intending to declare a CS/E major by proportion of confident female peers.

TABLE 3 | Logistic regression analyses predicting *male students'* likelihood of intending to major in different STEM fields.

	Model 1		Model 2	
	Computer science/ engineering		Biological/physical sciences	
	B	SE	*B*	SE
CLASSROOM VARIABLES				
Proportion of biased male peers	−0.067	(0.547)	−0.805	(0.661)
Proportion of confident female peers	−0.081	(0.331)	−0.032	(0.368)
Proportion of confident male peers	−0.345	(0.418)	−0.106	(0.461)
Average classroom science grade	−0.023	(0.028)	0.027	(0.032)
RACE/ETHNICITY (*Ref = White*)				
Hispanic	−0.662	(0.406)	−0.106	(0.411)
Black	−1.165*	(0.471)	−0.057	(0.49)
Other race	0.219	(0.588)	0.402	(0.546)
FAMILY BACKGROUND				
Books in the home	−0.003	(0.089)	0.032	(0.100)
Free/reduced lunch	0.701*	(0.327)	−0.035	(0.341)
Limited English proficient	0.255	(0.211)	−0.102	(0.247)
ACADEMIC BACKGROUND				
8th grade science confidence	0.211	(0.225)	0.808***	(0.244)
8th grade gender bias	0.087	(0.277)	−0.041	(0.330)
8th grade science grade	−0.013	(0.016)	−0.043*	(0.018)
8TH GRADE SCIENCE COURSE (*Ref = Regular Science 8*)				
Honors science 8	0.360	(0.226)	−0.272	(0.258)
Other science	0.712*	(0.329)	0.091	(0.352)
College expectations	0.589**	(0.187)	0.241	(0.211)

n = 626; Standard errors in parentheses.
*Two–tailed test: ***p < 0.001, **p < 0.01, * p < 0.05, ~ p < 0.1.*

higher science grades negatively and significantly predict such intentions. No other control variables were significant predictors of future STEM plans.

DISCUSSION

Building on the insights of prior psychological and sociological research on the power of local environments to shape gendered outcomes in STEM fields, the goal of this study was to explore how peers could be the source of both exclusionary and inclusionary messages in the classroom. Specifically, we considered the potential influence of both biased male peers and confident female peers on shaping the future STEM intentions of adolescent females. In doing so, our study makes a new contribution to the field by directly measuring both positive and negative peer perspectives in the actual science classrooms that young people inhabit, as well as focusing on the critical stage of adolescence when future plans begin to firmly materialize (Morgan et al., 2013). Additionally our study advances prior research by distinguishing between intentions to pursue the male-dominated fields of computer science and engineering, compared to the more gender equitable fields of the biological and physical sciences (National Science Foundation, 2014).

Results of multivariate longitudinal analyses of our sample of diverse youth suggest that peers may indeed be important sources of both exclusionary and inclusionary messages that are relevant in shaping girls' STEM intentions. Specifically, we found that exposure to a higher percentage of 8th grade male peers in the classroom who endorsed explicit gender/STEM stereotypes significantly and negatively predicted girls' later intentions to pursue a computer science/engineering major. Yet conversely, exposure to a higher percentage of confident female peers in the science classroom positively predicted such intentions. These results were specific to CS/E majors, as we did not find similar effects for intentions to major in B/PS fields. This suggests that in contrast to fields that are quite normative for females to enter, peers are an important source of messages regarding whether or not girls should pursue non-traditional STEM fields.

Additionally, we note that the effects of male peer bias and female peer confidence are largely independent of one another, as we noted earlier the presence of a very small correlation (−0.11), and exploratory analyses also revealed there was not a significant interaction between the two. To the extent that these peer effects are additive and of similar magnitude, this suggests that the negative effect of a classroom where a high percentage of boys endorsed gender stereotypes could be counteracted by a similarly high percentage of very confident female peers. Yet if such highly confident female peers were absent, the negative effect of boys' bias could indeed substantially dampen girls' intentions to pursue CS/E fields. On the other hand, in the absence of bias from male peers, a classroom context characterized by a high percentage of confident female peers could lead to a noteworthy increase in girls' plans to pursue these male-dominated fields. Thus, our study calls attention to the importance of examining both positive and negative sources of influence within local contexts, as well as highlights the need for more research that focuses on male peers in particular. We argue that efforts to increase female representation in CS/E fields need to pay more attention to understanding the attitudes, beliefs, and choices of boys, including how they may directly or indirectly shape girls' attitudes, beliefs, and choices.

Further, our study is also somewhat unique regarding the predominantly Hispanic composition of our adolescent sample, a population that is increasing dramatically in the U.S. yet still often under-represented in research. Yet we also note that gendered patterns of interest in pursuing CS/E and B/PS fields among our mostly minority sample closely mirror national levels of gendered attainment in college degrees in these fields. This is consistent with research that finds very similar patterns of male advantage across racial/ethnic groups (Riegle-Crumb and King, 2010). Additionally, in exploratory analyses we tested for but did not find evidence of significant interactions between students' race/ethnicity and our peer variables of interest. We concur with feminist scholars who call for the need for more research that considers where and how the intersection of gender with race/ethnicity shapes individual trajectories, including those in STEM fields; this entails more research that seeks to compare the experiences of women from different backgrounds, as well as research that explicitly focuses on giving voice to the obstacles and experiences of minority women (Browne and Misra, 2003; Ong, 2005; Carlone and Johnson, 2007).

LIMITATIONS

Finally, we note that while our study addresses some of the limitations of prior research, it is nevertheless subject to its own limitations. Most notably our data contains no information regarding whether or not girls are aware of the views of their peers, either the negative stereotypes endorsed by their male peers or the positive and confident views of their female peers. Therefore while our study moves past the confines of some experimental research by measuring phenomenon that are indeed present in actual classrooms, we cannot test how this influences tangible experiences and interactions. Ideally, future research should combine explicit measurement of what peers think (as we have done) with measures of what individuals believe that their peers think, as well as measures of actual classroom experiences and interactions. Such a research design would provide researchers with a remarkably rich picture of the local context of STEM classrooms that can have strong implications for how young girls view their possible and desired futures.

IMPLICATIONS

Our study calls attention to the importance of examining both positive and negative sources of influence within local contexts, as well as highlights the need for more research that focuses on male peers during the formative stages of adolescence in particular. Recent studies have found that adult men in STEM fields in both the academy and industry are prone to endorse gender stereotypes regarding women's innate abilities, and that such views can be linked to subsequent discrimination (Bobbitt-Zeher, 2011; Ecklund et al., 2012). Yet the extant empirical research on gender inequality at earlier stages in STEM trajectories focuses almost exclusively on changing girls' attitudes and choices, with correspondingly little attention to examining the boys with whom they share classrooms and schools on a daily basis. We therefore argue that more research should examine boys' beliefs about gender and how such views are linked to exclusionary behavior and interactions, with an ultimate eye towards creating new programs and interventions that attend to boys' role in creating and sustaining inequality in certain STEM fields.

ETHICS STATEMENT

This study has been processed by the Office of Research Support at the University of Texas at Austin and was determined as "Exempt" from IRB review because it entails secondary data analyses.

AUTHOR CONTRIBUTIONS

CR developed the theoretical framework, designed the study, conducted most of the data analyses, and wrote the majority of the text. KM assisted with the theoretical framing, constructed variables, and assisted with data analyses.

ACKNOWLEDGMENTS

This research was supported by a grant from the National Science Foundation (HRD-1348819; Catherine Riegle-Crumb, PI). This research was also supported by NICHD grant 5 R24 HD042849, awarded to the Population Research Center at The University of Texas at Austin. Opinions reflect those of the authors and do not necessarily reflect those of the granting agencies.

REFERENCES

Ambady, N., Shih, M., Kim, A., and Pittinsky, T. L. (2001). Stereotype susceptibility in children:effects of identity activation on quantitative performance. *Psychol. Sci.* 12, 385–390. doi: 10.1111/1467-9280.00371

Ayscue, J. B., and Orfield, G. (2016). "Perpetuating separate and unequal worlds of educational opportunity through district lines: school segregation by race and poverty," in *Race, Equity, and Education: Sixty Years from Brown*, eds A. P. Noguera, C. J. Pierce, and R. Ahram (Cham: Springer International Publishing), 45–74.

Bandura, A., Barbaranelli, C., Caprara, G. V., and Pastorelli, C. (2001). Self-efficacy beliefs as shapers of children's aspirations and career trajectories. *Child Dev.* 72, 187–206. doi: 10.1111/1467-8624.00273

Barton, A. C., Tan, E., and Rivet, A. (2008). Creating hybrid spaces for engaging school science among urban middle school girls. *Am. Educ. Res. J.* 45, 68–103. doi: 10.3102/0002831207308641

Beutel, A. M., and Marini, M. M. (1995). Gender and values. *Am. Sociol. Rev.* 60, 436–448. doi: 10.2307/2096423

Bleeker, M. M., and Jacobs, J. E. (2004). Achievement in math and science: do mothers' beliefs matter 12 years later? *J. Educ. Psychol.* 96, 97–109. doi: 10.1037/0022-0663.96.1.97

Bobbitt-Zeher, D. (2011). Gender discrimination at work connecting gender stereotypes, institutional policies, and gender composition of workplace. *Gender Soc.* 25, 764–786. doi: 10.1177/0891243211424741

Brown, C. S., and Leaper, C. (2010). Latina and European American girls' experiences with academic sexism and their self-concepts in mathematics and science during adolescence. *Sex Roles* 63, 860–870. doi: 10.1007/s11199-010-9856-5

Browne, I., and Misra, J. (2003). The intersection of gender and race in the labor market. *Annu. Rev. Sociol.* 29, 487–513. doi: 10.1146/annurev.soc.29.010202.100016

Carlone, H. B., and Johnson, A. (2007). Understanding the science experiences of successful women of color: science identity as an analytic lens. *J. Res. Sci. Teach.* 44, 1187–1218. doi: 10.1002/tea.20237

Cheryan, S., Ziegler, S. A., Montoya, A.. K., and Jiang, L. (2017). Why are some STEM fields more gender balanced than others? *Psychol. Bull.* 143, 1–35. doi: 10.1037/bul0000052

Correll, S. J. (2001). Gender and the career choice process: the role of biased self-assessments. *Am. J. Sociol.* 106, 1691–1730. doi: 10.1086/321299

Dasgupta, N. (2011). Ingroup experts and peers as social vaccines who inoculate the self-concept: the stereotype inoculation model. *Psychol. Inq.* 22, 231–246. doi: 10.1080/1047840X.2011.607313

Dasgupta, N., and Asgari, S. (2004). Seeing is believing: exposure to counterstereotypic women leaders and its effect on the malleability of automatic gender stereotyping. *J. Exp. Soc. Psychol.* 40, 642–658. doi: 10.1016/j.jesp.2004.02.003

Dasgupta, N., Scircle, M. M., and Hunsinger, M. (2015). Female peers in small work groups enhance women's motivation, verbal participation, and career aspirations in engineering. *Proc. Natl. Acad. Sci. U.S.A.* 112, 4988–4993. doi: 10.1073/pnas.1422822112

Deutsch, F. M. (2007). Undoing gender. *Gender Soc.* 21, 106–127. doi: 10.1177/0891243206293577

DiPrete, T. A., and Buchmann, C. (2013). *The Rise of Women: The Female Advantage in Education and What it Means for American Schooling*. New York, NY: Russell Sage Foundation.

Eccles, J. (2009). Who am I and what am I going to do with my life? Personal and collective identities as motivators of action. *Educ. Psychol.* 44, 78–89. doi: 10.1080/00461520902832368

Eccles, J. S. (2015). Gendered socialization of STEM interests in the family. *Int. J. Gender Sci. Technol.* 7, 116–132.

Eccles, J. S. (1994). Understanding women's educational and occupational choices. *Psychol. Women Q.* 18, 585–609. doi: 10.1111/j.1471-6402.1994.tb01049.x

Eccles, J. S. (2007). "Where are all the women? Gender differences in participation in physical science and engineering," in *Why Aren't More Women in Science? Top Researchers Debate the Evidence,* eds S. J. Ceci and W. M. Williams (Washington, DC: American Psychological Association), 199–210.

Eccles, J. S., and Harold, R. D. (1991). Gender differences in sport involvement: applying the Eccles' expectancy-value model. *J. Appl. Sport Psychol.* 3, 7–35. doi: 10.1080/10413209108406432

Eccles, J. S., Jacobs, J. E., and Harold, R. D. (1990). Gender role stereotypes, expectancy effects, and parents' socialization of gender differences. *J. Soc. Issues* 46, 183–201. doi: 10.1111/j.1540-4560.1990.tb01929.x

Eccles, J. S., and Roeser, R. W. (2011). Schools as developmental contexts during adolescence. *J. Res. Adolesc.* 21, 225–241. doi: 10.1111/j.1532-7795.2010.00725.x

Eccles, J. S., and Wigfield, A. (2002). Motivational beliefs, values, and goals. *Annu. Rev. Psychol.* 53, 109–132. doi: 10.1146/annurev.psych.53.100901.135153

Ecklund, E. H., Lincoln, A. E., and Tansey, C. (2012). Gender segregation in elite academic science. *Gend. Soc.* 26, 693–717. doi: 10.1177/0891243212451904

England, P. (2010). The gender revolution uneven and stalled. *Gend. Soc.* 24, 149–166. doi: 10.1177/0891243210361475

Frank, K. A., Muller, C., Schiller, K. S., Riegle-Crumb, C., Mueller, A. S., Crosnoe, R., et al. (2008). The social dynamics of mathematics coursetaking in high school. *Am. J. Sociol.* 113:1645. doi: 10.1086/587153

Gilligan, C. (1982). New maps of development: new visions of maturity. *Am. J. Orthopsychiatry* 52, 199–212. doi: 10.1111/j.1939-0025.1982.tb02682.x

Giordano, P. C. (2003). Relationships in adolescence. *Annu. Rev. Sociol.* 257–281. doi: 10.1146/annurev.soc.29.010202.100047

Hanson, S. L. (2006). "African American women in science: experiences from high school through the post-secondary years and beyond," in *Removing Barriers: Women in Academic Science, Technology, Engineering, and Mathematics,* eds J. Bystydzienski and S. Bird (Bloomington, IN: Indiana University Press), 96–115.

Hurtado, S., Eagan, K., and Chang, M. (2010). *Degrees of Success: Bachelor's Degree Completion Rates Among Initial STEM Majors*. Los Angeles, CA: Higher Education Research Institute at UCLA, January.

Inzlicht, M., and Ben-Zeev, T. (2000). A threatening intellectual environment: why females are susceptible to experiencing problem-solving deficits in the presence of males. *Psychol. Sci.* 11, 365–371. doi: 10.1111/1467-9280.00272

Kastberg, D., Roey, S., Ferraro, D., Lemanski, N., and Erberber, E. (2013). *U.S. TIMSS and PIRLS 2011 Technical Report and User's Guide.* (NCES 2013-046). U.S. Department of Education. Washington, DC: National Center for Education Statistics.

Leaper, C. (2015). Do I belong?: Gender, peer groups, and STEM achievement. *Int. J. Gender Sci. Technol.* 7, 166–179.

Lenton, A. P., Bruder, M., and Sedikides, C. (2009). A meta-analysis on the malleability of automatic gender stereotypes. *Psychol. Women Q.* 33, 183–196. doi: 10.1111/j.1471-6402.2009.01488.x

Morgan, S. L., Gelbgiser, D., and Weeden, K. A. (2013). Feeding the pipeline: gender, occupational plans, and college major selection. *Soc. Sci. Res.* 42, 989–1005. doi: 10.1016/j.ssresearch.2013.03.008

Murphy, M. C., Steele, C. M., and Gross, J. J. (2007). Signaling threat how situational cues affect women in math, science, and engineering settings. *Psychol. Sci.* 18, 879–885. doi: 10.1111/j.1467-9280.2007.01995.x

National Academy of Sciences (2007). *Beyond Bias and Barriers: Fulfilling the Potential of Women in Academic Science and Engineering.* Washington, DC: The National Academies Press.

National Science Foundation (2014). *Science and Engineering Indicators 2013.* Arlington, VA (NSB 14-01). Available online at: https://www.nsf.gov/statistics/seind14/index.cfm/overview

Ohland, M. W., Sheppard, S. D., Lichtenstein, G., Eris, O., Chachra, D., and Layton, R. A. (2008). Persistence, engagement, and migration in engineering programs. *J. Eng. Educ.* 97, 259–278. doi: 10.1002/j.2168-9830.2008.tb00978.x

Ong, M. (2005). Body projects of young women of color in physics: intersections of gender, race, and science. *Social Problems* 52, 593–617. doi: 10.1525/sp.2005.52.4.593

Ridgeway, C. L., and Correll, S. J. (2004). Unpacking the gender system a theoretical perspective on gender beliefs and social relations. *Gender Soc.* 18, 510–531. doi: 10.1177/0891243204265269

Riegle-Crumb, C., Moore, C., and Ramos-Wada, A. (2011). Who wants to have a career in science or math? Exploring adolescents' future aspirations by gender and race/ethnicity. *Sci. Educ.* 95, 458–476. doi: 10.1002/sce.20431

Riegle-Crumb, C., Farkas, G., and Muller, C. (2006). The role of gender and friendship in advanced course taking. *Sociol. Educ.* 79, 206–228. doi: 10.1177/003804070607900302

Riegle-Crumb, C., and King, B. (2010). Questioning a white male advantage in STEM: examining disparities in college major. *Educ. Res.* 39, 656–664. doi: 10.3102/0013189X10391657

Risman, B. J. (2004). Gender as a social structure theory wrestling with activism. *Gender Soc.* 18, 429–450. doi: 10.1177/0891243204265349

Risman, B. J. (2009). From doing to undoing: gender as we know it. *Gender Soc.* 23, 81–84. doi: 10.1177/0891243208326874

Robnett, R. D., and Leaper, C. (2013). Friendship groups, personal motivation, and gender in relation to high school students' STEM career interest. *J. Res. Adolesc.* 23, 652–664. doi: 10.1111/jora.12013

Schmader, T., Johns, M., and Barquissau, M. (2004). The costs of accepting gender differences: the role of stereotype endorsement in women's experience in the math domain. *Sex Roles* 50, 835–850. doi: 10.1023/B:SERS.0000029101.74557.a0

Seymour, E., and Hewitt, N. (1997). *Talking about Leaving: Why Undergraduate Women Leave the Sciences*. Boulder, CO:Westview Press.

Shapiro, J. R., and Williams, A. M. (2012). The role of stereotype threats in undermining girls' and women's performance and interest in STEM fields. *Sex Roles* 66, 175–183. doi: 10.1007/s11199-011-0051-0

Spencer, S. J., Steele, C. M., and Quinn, D. M. (1999). Stereotype threat and women's math performance. *J. Exp. Soc. Psychol.* 35, 4–28. doi: 10.1006/jesp.1998.1373

Stout, J. G., Dasgupta, N., Hunsinger, M., and McManus, M. A. (2011). STEMing the tide: using ingroup experts to inoculate women's selfconcept in science, technology, engineering, and mathematics (STEM). *J. Pers. Soc. Psychol.* 100, 255–270. doi: 10.1037/a0021385

Wentzel, K. R., Baker, S. A., and Russell, S. L. (2012). Young adolescents' perceptions of teachers' and peers' goals as predictors of social and academic goal pursuit. *Appl. Psychol.* 61, 605–633. doi: 10.1111/j.1464-0597.2012.00508.x

Wilkins, J. L. (2004). Mathematics and science self-concept: an international investigation. *J. Exp. Educ.* 72, 331–346. doi: 10.3200/JEXE.72.4.331-346

Xie, Y., Fang, M., and Shauman, K. (2015). STEM education. *Annu. Rev. Soc.* 41, 331–357 doi: 10.1146/annurev-soc-071312-145659

Xie, Y., and Shauman, K. A. (2003). *Women in Science: Career Processes and Outcomes, Vol. 26, No. 73.4.* Cambridge, MA: Harvard University Press.

Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Psychology

ORIGINAL RESEARCH
published: 06 February 2017
doi: 10.3389/fpsyg.2017.00146

A Nuanced Look at Women in STEM Fields at Two-Year Colleges: Factors That Shape Female Students' Transfer Intent

Xueli Wang[1]*, *Hsun-yu Chan*[2], *Sara Jimenez Soffa*[3] *and Brett Ranon Nachman*[1]

[1] Educational Leadership and Policy Analysis, University of Wisconsin-Madison, Madison, WI, USA, [2] Department of Educational Psychology, Texas A&M University, Commerce, TX, USA, [3] Educational Leadership, Edgewood College, Madison, WI, USA

In this study, we explored the relationship between the intent to transfer upward and a set of motivational, contextual, and socio-demographic background factors among 696 female students beginning in science, technology, engineering, and mathematics (STEM) programs or courses at two-year colleges in a Midwestern state. Drawing upon survey data and administrative records, our multinomial logistic regression analysis revealed that students' math and science self-efficacy beliefs, as well as transfer-oriented interaction, were significant and positive predictors for their intent to transfer into STEM fields as opposed to having no intent to transfer. In addition, the association between transfer intent and these key motivational and contextual factors was moderated by students' racial/ethnic backgrounds, marital status, and childcare obligations. For example, despite the positive relationship between transfer-oriented interaction and the intention to transfer into STEM fields, Black women were less likely to have intent to transfer into STEM fields than White students until Black students reported a moderate level of transfer-oriented interaction. Conversely, Hispanic students were more likely to report intent to transfer into STEM fields than their White peers, even when Hispanic students reported a relatively low level of engagement in transfer-oriented interaction. These and other reported findings bear important and nuanced implications as policymakers, educators, and researchers continue to discover ways to better support women's educational pathways and success in STEM fields at and through two-year colleges.

Keywords: two-year college, community college, women in STEM, math self-efficacy, science self-efficacy, transfer-oriented interaction

OPEN ACCESS

Edited by:
Kathleen Buse, Advancing Women in STEM, USA

Reviewed by:
Amanda Diekman, Miami University, USA
Neslihan Burcin Tamer, Computing Research Association, USA

Correspondence:
Xueli Wang
xwang273@wisc.edu

Specialty section:
This article was submitted to Organizational Psychology, a section of the journal Frontiers in Psychology

Received: *24 October 2016*
Accepted: *20 January 2017*
Published: *06 February 2017*

Citation:
Wang X, Chan H-y, Soffa SJ and Nachman BR (2017) A Nuanced Look at Women in STEM Fields at Two-Year Colleges: Factors That Shape Female Students' Transfer Intent. Front. Psychol. 8:146. doi: 10.3389/fpsyg.2017.00146

BACKGROUND OF THE STUDY

An increasing national demand to employ baccalaureate graduates in science, technology, engineering, and mathematics (STEM) careers has called for robust research on students' decisions and pathways to pursue these postsecondary fields of study. Carnevale et al. (2010) indicated that, by 2018, ∼42% of STEM employment opportunities will require workers to possess a baccalaureate degree. A more pressing challenge within this endeavor is to resolve the severe gender gaps in the participation and completion rates of baccalaureate STEM programs (Ma, 2011). Historically, these programs are dominated by male students, with women seriously underrepresented (Riegle-Crumb and King, 2010). As such, supporting female students' pathways and success in STEM disciplines at the baccalaureate level is critical to ameliorating the human resource gap in these fields (Espinosa, 2011).

To close the noted gender gap, two-year colleges play an important role by serving as a potential pathway to four-year institutions for women pursuing baccalaureate STEM degrees (Christian, 2000; Boswell, 2004; Cohen et al., 2014). Historically, community and technical colleges are celebrated for their accessibility, affordability, and open admissions (Johnson et al., 2000; Cohen et al., 2014; Chavez, 2015). In recent years, emerging partnerships between four-year institutions and two-year colleges in supporting underrepresented students to pursue baccalaureate and/or graduate degrees in STEM fields provide realistic pathways for students who may not have otherwise considered transfer (Hirst et al., 2014). In particular, two-year colleges are increasingly recognized as entry points for women who plan to pursue degrees in STEM fields (Jackson et al., 2013). Compared to four-year colleges and universities, two-year colleges serve proportionately more women (Horn et al., 2006). Specifically, women make up 58% of students enrolled in two-year colleges (Phillippe and Patton, 2000; Bryant, 2001), with recent statistics showing over four million women enrolled at public two-year institutions (St. Rose and Hill, 2013). Female students' graduation rates also outshine their male counterparts, as women accounted for 62% of those who earned associate degrees during the 2009–2010 academic year (Cohen et al., 2014). Moreover, many women enrolled at two-year colleges also come from historically underserved populations, such as first-generation, racial/ethnic minority, low-income, and part-time students (Horn et al., 2006; Snyder and Dillow, 2012). As such, two-year colleges are uniquely positioned to expand both the number and diversity of women holding a STEM baccalaureate through the upward transfer function.

Despite this potential of two-year colleges for broadening women's participation in baccalaureate STEM programs, many baccalaureate-aspiring women starting in STEM fields at two-year colleges meet unexpected roadblocks to their pursuit of a four-year STEM degree, and consequently drop their intent to transfer (St. Rose and Hill, 2013). Empirical research is extremely limited to shed a holistic light on factors that influence these women's intent to transfer. In addition, research that examines the experiences of women in STEM fields is narrow in scope. Few studies have delved into how women's other identities, such as race/ethnicity, marital, and parental status, as well as first-generation status, shape their educational intent along the STEM pathways. These other characteristics and life responsibilities are particularly relevant to women at two-year colleges, considering the vast amount of diversity among this student population. Women outnumber men across all racial/ethnic backgrounds at two-year colleges, and 30% of women at two-year colleges identify as African American or Latina (Morganson et al., 2010; St. Rose and Hill, 2013). Adult women often select two-year colleges as their entry or reentry into college because these institutions are more conducive to balancing work, families, and school responsibilities (Johnson et al., 2000). Furthermore, low-income women and women with dependent children often choose two-year colleges (Costello, 2012). These background characteristics and factors may very well-intersect with other learning and motivational factors to collectively influence two-year college women's educational intent and outcomes in STEM. Yet, existing literature offers little insight into these nuances.

Aiming to address these important gaps in the literature, our study explores factors associated with the intent to transfer upward among female students beginning in STEM programs or courses at two-year colleges. In addition, our research examines how influential motivational and contextual factors intersect with other background characteristics of two-year college women to collectively shape their transfer intent. Our findings will inform the current knowledge base on the ways in which colleges and universities support and encourage upward mobility in STEM fields for two-year college women.

REVIEW OF THE LITERATURE AND CONCEPTUAL FRAMEWORK

In the following sections, we review relevant prior research that situates our study and informs the study's conceptual framework. Given the sparse literature directly addressing our research focus, we resort to the body of work dealing with choice of STEM fields as well as the small line of research on the general experiences of women in STEM fields at two-year colleges.

Potential Factors Associated with Two-Year College Women's STEM Pursuits

Several factors emerge that hold strong theoretical promise to guide our inquiry. To begin, the choice to pursue STEM fields of study is influenced by students' motivational beliefs in math and science (Wang, 2013b). In particular, confidence in math and science has been shown to have a profound influence on students' decisions to pursue STEM fields in the first place (Moakler and Kim, 2014), especially for women and minorities (Hackett and Betz, 1989). Specifically for women in STEM fields at community colleges, another factor that may strongly shape their success is the contextual supports they receive and barriers they encounter, especially through their interactions with and exposure to a variety of institutional agents such as faculty, advisors, and student peers, along with family and friends. For example, as Packard et al. (2011) found in their qualitative research, two-year college female students in STEM fields mostly persist throughout the first year in STEM fields, due in large part to having supportive faculty, peers, and family members, as well as flexible work schedules, among other factors. In the context of our study that addresses the intent to transfer in STEM, it stands to reason that such contextual exposure focused around transfer, that is, transfer-oriented interactions (Laanan et al., 2010; Starobin et al., 2014), may represent a prominent factor at play.

Transfer Intent of Women in STEM Fields at Two-Year Colleges

While previous research has demonstrated the importance of understanding factors that influence the educational intent among two-year college students (Wang, 2012, 2013a,b), we have limited knowledge that sheds light on the intent to transfer upward in STEM fields. This gap in the literature is remarkable, as two-year college students' educational goals and intent are diverse and fluid, and thus need to be understood and supported in a highly situated and purposeful way (Wang, 2015). Furthermore, considering the myriad challenges identified in prior research around women in STEM fields (e.g., Hoffman et al., 2010; Packard et al., 2011), it is pivotal to examine personal and contextual influences on intentions to transfer into STEM fields at four-year institutions among women enrolled in two-year colleges. These intentions are often disrupted by life experiences that shift the pathways and even alter the intentions of women in their academic and career pursuits (e.g., Wickersham and Wang, 2016). Unfortunately, to date, this is a sorely underdeveloped line of inquiry that warrants further exploration.

Multiple Roles and Background Characteristics of Women in STEM at Two-Year Colleges

Women beginning their STEM careers at two-year colleges tend to possess many forms of diversity, which may shape their transfer intent differently. For example, family obligations are common constraints that discourage women from enrolling in further education more often than men (Ferriman et al., 2009; Sax, 2012). In particular, two-year college students' marital status is negatively related to the likelihood of graduating or transferring, even when their postsecondary academic experience is accounted for (Chan and Wang, 2016). Also, childcare obligations have been identified as a critical factor for women's career plans in STEM fields (Sonnert, 1995). Though the flexible course schedule in two-year colleges would fit the needs of women who have children, they still struggle with securing childcare options because fewer than half of two-year colleges offer on-campus childcare (Costello, 2012; McKinney and Novak, 2013; Martin et al., 2014). In addition, many female students attending two-year colleges work long hours; as a result, women may feel like they have to compromise either their upward mobility or their ideal family lives in order to achieve some sort of life balance (Tajlili, 2014). Consequently, they may not be able to enroll full-time or contribute a reasonable amount of time and energy to academics due to these demands. The financial need would put female single parents in a particularly disadvantaged position, as they concurrently face multiple time and financial constraints. Finally, first-generation college women may not receive a reaffirming opinion from their parents about the benefits of a postsecondary credential, in that their parents are not able to be role models, or do not have the knowledge and experience of postsecondary education, to encourage their offspring to pursue a postsecondary degree in STEM (Shapiro and Sax, 2011).

Overall, our review of the literature indicates that the two-year college pathway to baccalaureate STEM studies for women has been understudied, and furthermore, research is scant that addresses how two-year college women's other characteristics may shape their transfer intent. To achieve a better and more accurate understanding of the educational intent and pathways of women in STEM fields, we must bring two-year colleges into the equation, as well as account for the many other backgrounds of women STEM students in two-year colleges. Given women's many roles and responsibilities, having a greater grasp of how their other characteristics may help or hinder their transfer intent will allow higher education policy makers and practitioners to better address women's needs accordingly. Informed by and contributing to the literature, our study will shed light on factors associated with the transfer intent among female two-year college students in STEM, as well as determine how their other backgrounds may intersect with learning and motivational factors that influence transfer intent. Our study thus adds to the literature by illuminating the potential barriers and supports facing two-year college women in STEM in their educational pursuits.

CONCEPTUAL FRAMEWORK

Figure 1 represents the conceptual framework that guides our study, which is informed by the social cognitive career theory (SCCT; Bandura, 1986; Lent et al., 1994, 2000) that postulates the central role of cognitive and personal factors in the process of individuals' career development, as well as pertinent prior literature in higher education research. Several constructs in SCCT are relevant for our study. Specifically, self-efficacy—individuals' belief in their own ability to accomplish a given task—is regarded as a pivotal factor underlying individuals' academic and career development. This assumption has been supported by previous studies on academic aspirations among two-year college students entering STEM fields (e.g., Hagedorn and DuBray, 2010; MacPhee et al., 2013; Wang, 2013a,b). Given the specific focus of our study, we highlight female students' *self-efficacy beliefs in math and science*, as women's self-beliefs in their proficiency in these two areas have been found to undergird their aspiration to enter STEM fields (Blickenstaff, 2005; Wang, 2013b). Another key element of our conceptual framework is *transfer-oriented interaction*, indicating students' engagement in interactions with institutional agents (e.g., instructors, academic advisors), or efforts to gather transfer information or to prepare essential materials needed for transfer. Transfer-oriented interaction may demonstrate the actual efforts students spend on preparing themselves to successfully transfer, and is a critically important construct to inform research on student transfer to four-year institutions (Laanan, 2007; Starobin et al., 2014).

To account for other relevant factors that may influence two-year college students' intent to transfer, our conceptual framework also includes students' academic background and experiences, such as the type of two-year institutions students attend, their engagement with active learning experiences (Prince, 2004; Hagedorn et al., 2008), their first term grade point average (GPA; e.g., Bean and Kuh, 1984), and their programs of study (Wang, 2016).

A number of socio-demographic background characteristics deemed critical for students' academic choices and pathways, as identified in prior literature, are also addressed in our framework, including the support for one's pursuit of postsecondary

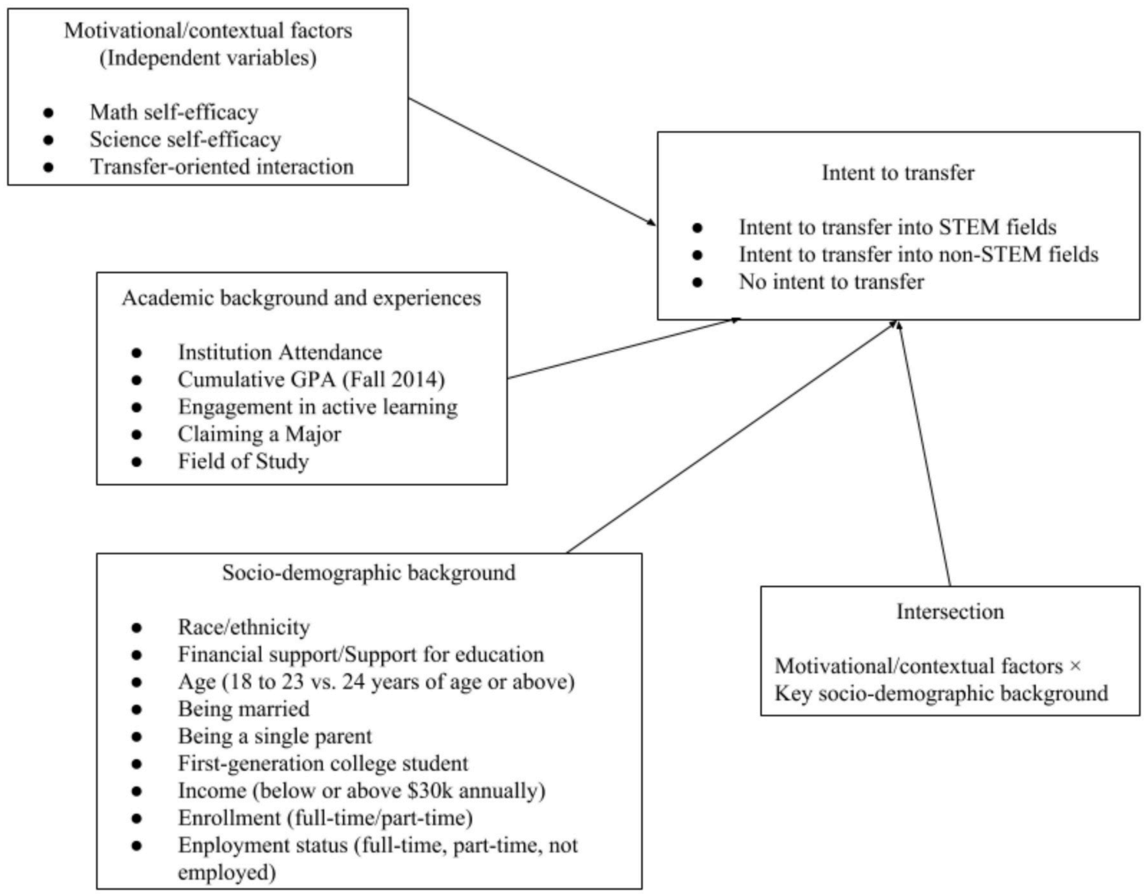

FIGURE 1 | Conceptual framework.

education, enrollment intensity, and students' employment status (Lent et al., 1994, 2000; Wang, 2009, 2013a). Furthermore, we focus on four background characteristics that are particularly pertinent to female students' pursuit of postsecondary education: race/ethnicity, marital status, single parent status, and first-generation status. We argue that these four background characteristics represent important aspects of women's identities and play a significant role when students develop their future academic goals and make career decisions. While some studies have started to empirically examine how women with these backgrounds fare differently in their academics compared with their peers (e.g., Oh and Lewis, 2011; Ruiz, 2013), how these identities interact with the noted motivational and contextual factors to inform women's academic and career pathway in STEM largely remains unclear (Cohen et al., 2014; see Ferriman et al., 2009; Costello, 2012, for recent examples). Without an examination of the intersections between these identities and the key motivational and contextual factors that are pertinent to students' transfer intent, researchers and practitioners may gain a false understanding that the relationship among these factors represents two-year college women as a homogenous group.

METHODS

Guided by the conceptual framework and prior literature, we examine the following two research questions. First, what are the factors associated with the intent to transfer to a four-year institution among female students beginning in STEM programs or courses at two-year colleges? We are particularly interested in exploring the relationship between transfer intent and three key independent variables: math self-efficacy, science self-efficacy, and transfer-oriented interaction; and hypothesize that these three factors are positively related to two-year college women's transfer intent. Second, how are the relationships between the three noted key independent variables and transfer intent moderated by background characteristics of two-year college women such as their race/ethnicity, first-generation status, marital status, and single parent status? We hypothesize that these background factors moderate the relationships, but given the lack of prior research, we do not assume specific directionality of the findings, as we approach the second question in a highly exploratory fashion.

Data and Sample

We analyzed data collected from the baseline survey of a statewide longitudinal study of students enrolled in two-year colleges with a transfer mission located in a Midwestern state. These colleges include two comprehensive two-year colleges and the two-year campuses within the state university system. First-time students who were enrolled in STEM courses in Fall 2014 were invited to participate in the study. Approximately 3000 students were targeted (i.e., 1000 students from each comprehensive two-year college and another 1000 students from all two-year campuses of the state university system). For institutions where enrollment is small within certain racial/ethnic groups or specific STEM fields, the sample was selected using a stratified sampling design with two strata: race/ethnicity and STEM fields. As a result, the sampling weight, which is the inverse of the probability of selecting a student from the target population, was calculated and applied across analyses. Data collected from the survey were also matched with students' administrative and transcript records.

The survey consisted of slightly over 100 items and was designed to measure two-year college students' learning experiences, motivational beliefs, and contextual factors that could influence their upward transfer. The survey's content validity was established based on extensive literature review and input from national experts specialized in STEM education issues, two-year colleges, and survey design. Furthermore, a pilot study was conducted in Summer 2014, involving a group of nearly 100 two-year college students in the state, including both survey data collection and cognitive interviews. These procedures helped establish initial evidence regarding the survey's content, face, and process validity.

Students in our target sample received the survey in Fall 2014 via a letter containing the survey URL. Students were offered a $5 cash pre-incentive, and another $10 incentive upon completing the survey. After the initial contact, we emailed non-respondents 1 week later, and repeated the process the following week with a postal mailing. Three weeks after initially contacting potential participants, we sent students another email. Survey packets were mailed 30 days following initial contact, and as a final contact, non-respondents received a last email with the survey URL 5 weeks after initial contact. In total, 56.6% of the target sample members, or 1668 students, completed the survey.

For the purpose of our study, the analytic sample includes a total of 696 females out of the 1668 students who completed the baseline survey (41.7%). In the unweighted sample, a majority of the students is White (69.1%), followed by Hispanic (14.7%), Asian (7.0%), Black (5.5%), and other racial/ethnic backgrounds (e.g., Native American, multi-racial; 3.7%). Over a quarter of the participants (27.9%) were above 24 years of age. About a third of the participants were first-generation students (32.0%), 11.4% of them were married, and 7.6% self-identified as single parent (see **Table 1** for a summary of the unweighted sample characteristics).

Measures

Transfer Intent

Students' intent to transfer to a four-year institution was measured using two multiple-choice survey items. The first item is a dichotomous item asking whether participants have the intention to transfer to a four-year university (1 = yes, 0 = no). If participants indicated intent to transfer, they were prompted to answer which of the five fields of study they would like to transfer into, where the first four alternatives are considered STEM-related fields (1 = biological, agricultural, or environmental life sciences, 2 = computer or mathematical sciences, 3 = engineering or engineering technologies, 4 = physical sciences including chemistry, physics, astronomy, etc., 5 = other major program of study). Based on responses to these two items, we derived a categorical outcome variable with three scenarios: intent to transfer into STEM fields, intent to transfer into non-STEM fields, and no intent to transfer.

Math and Science Self-efficacy

Participants responded to two five-item scales measuring their self-efficacy in math and science (e.g., how confident are you that you can do well on math exams), respectively, on a 5-point Likert scale (1 = not at all, 5 = extremely). The two scales share the same item stem but the subject matter varies between math and science. Both scales have high internal consistency (Cronbach α's = 0.96 for both scales). The scale scores were calculated by averaging the score of each item separately for math and science self-efficacy. Both scales were regarded as important motivational factors and as two of the three key independent variables in the study.

Transfer-Oriented Interaction

As one of the three key independent variables, transfer-oriented interaction is a seven-item scale that measures the frequency of utilizing campus resources or contacting institutional agents (e.g., instructors, academic advisors) through which the participants could gather information of transferring to a four-year institution (e.g., how often do you use the following service provided by your college or campus: advising for future transfer to a four-year college, either walk-in or online) on a 5-point Likert scale (1 = never, 5 = very often). The scale has high internal consistency (Cronbach $\alpha = 0.86$), and the mean score of the seven items was used as the scale score in the analyses.

Academic Background and Experiences

Five variables were controlled for as participants' academic background and experiences. These included participants' institution of attendance (attending a comprehensive two-year institution or the two-year campuses within the state university system; the latter was the reference group), cumulative GPA as of Fall 2014 on a 4.00 scale, the average score of the scale on students' engagement in active learning, whether the participants have claimed a major, and a set of dichotomous variables denoting their field of study (i.e., biological, agricultural, or environmental life sciences; computer or mathematical sciences; engineering or engineering technologies; physical sciences, including chemistry, physics, astronomy, etc.; students in the physical sciences were the reference group).

Socio-Demographic Backgrounds

Ten types of socio-demographic background, dummy-coded variables were controlled for, including race/ethnicity (separated

TABLE 1 | Summary of sample characteristics and descriptive statistics.

Variable	%	*M* (*SD*)	Skewness	Kurtosis
DEPENDENT VARIABLE: INTENT TO TRANSFER				
Intent to transfer into STEM fields	37.6			
Intent to transfer into non-STEM fields	37.8			
No intent to transfer	24.4			
INDEPENDENT VARIABLES				
Math self-efficacy		3.71 (0.91)	−0.60	0.29
Science self-efficacy		3.67 (0.88)	−0.47	0.05
Transfer-oriented interaction		2.34 (0.91)	0.29	−0.57
CONTROL VARIABLES: ACADEMIC BACKGROUND AND EXPERIENCES				
Institution attendance: comprehensive two-year institution	60.5			
Institution attendance: two-year campuses within the state university system	39.5			
Cumulative GPA (Fall 2014)		2.99 (0.99)	−1.35	1.53
Engagement in active learning		3.31 (0.69)	−0.14	0.19
Have claimed a major	54.4			
Have not claimed a major	45.6			
Field of study: biological, agricultural, or environmental life science	47.7			
Field of study: computer or mathematical sciences	23.0			
Field of study: engineering or engineering technologies	6.1			
Field of study: physical sciences	23.3			
CONTROL VARIABLES: SOCIO-DEMOGRAPHIC				
Black	5.5			
Hispanic	14.7			
Asian	7.0			
Other race/ethnicity	3.7			
White	69.1			
Financial support		2.78 (1.36)	0.11	−1.18
Support for education from family		4.03 (1.19)	−1.04	−0.01
Support for education from peers		3.79 (1.11)	−0.77	−0.03
Being 18– 23 years of age	72.1			
Being over 24 years of age	27.9			
Being married	11.4			
Not married	88.6			
Being a single parent	7.6			
Not a single parent	92.4			
First-generation college student	32.0			
Non-first-generation college student	68.0			
Low income (below $30 k annually)	37.2			
Not low income (above $30 k annually)	62.8			
Full-time student	64.7			
Part-time student	35.3			
Employed: full-time	20.7			
Employed: part-time	59.1			
Employed: not employed	20.2			

into Black, Hispanic, Asian, and other race/ethnicity, with White being the reference group), financial support for education, emotional support for education separately from family members and peers, being over 24 years of age when enrolled in Fall 2014, being married, being a single parent, being a first-generation student, having an annual household income lower than $30,000, being a part-time student (i.e., enrolled in <30 credits per year, according to the definition provided by the institutions included in our study), being employed full- or part-time (having no employment as the reference group).

Missing Data

Missing data were scarce in the current study. More than 96% of the study participants had complete data from their survey responses and administrative records, and merely a total of 0.2% of the data points were missing. Little's missing-completely-at-random test (Little, 1988), conducted in SPSS 22.0, indicated that the data were missing completely at random ($\chi^2 = 31.42$, $df = 21$, $p = 0.07$). While list-wise deletion would not seriously bias the data distribution, to retain all 696 female survey respondents we conducted multiple imputation using M*plus* 7.4. Ten imputed data sets were generated and the pooled results are reported in the present study.

Analysis

Confirmatory factor analysis (CFA) was first conducted in M*plus* 7.4 to verify the psychometric property of the math self-efficacy, science self-efficacy, transfer-oriented interaction, and engagement in active learning scales. The analysis was performed with weighted least squares means and variance adjusted estimation (WLSMV) to accommodate the nature of Likert scales and sampling weights. A four-factor solution was estimated, since the items were developed to measure four latent psychosocial and behavioral dispositions: self-efficacy (separately in math and science), transfer-oriented interaction, and engagement in active learning, where each scale corresponds to one latent construct. For a complete list of the survey items measuring each of the four latent factors, see Appendix A in Supplementary Material.

Second, a multinomial logistic regression model was analyzed with a categorical outcome variable indicating three scenarios (i.e., no intent to transfer, intent to transfer into non-STEM fields, and intent to transfer into STEM fields). Thus, in the multinomial logistic regression context, two discrete logistic regression models—respectively, no intent to transfer as opposed to intent to transfer into STEM, and intent to transfer into non-STEM as opposed to intent to transfer into STEM—were estimated simultaneously. The three key independent variables (i.e., transfer-oriented interaction, self-efficacy in math, and self-efficacy in science), other academic and background variables, along with a total of 21 interaction terms between each of the main independent variables and four key background variables (i.e., race/ethnicity, being married, single parent status, and first-generation student status). This multinomial logistic regression model was analyzed with robust maximum likelihood estimation (MLR) to accommodate the sampling weight, and the skewness and kurtosis of the continuous independent variables and covariates.

Odds ratio (OR) and projected changes in the probability of choosing a certain category in the outcome variable were calculated to further understand how the changes in a predictor were related to women's transfer intent. These statistics were reported for coefficients that achieved statistical significance at $p < 0.10$, $p < 0.05$, $p < 0.01$, and $p < 0.001$, specifically. Finally, for statistically significant interaction effects at the $p < 0.05$ level, we combined the two discrete logistic regression models, simultaneously estimated in our multinomial logistic regression analysis to plot the relative risk ratio and predicted probability (in **Figure 2**; and probability change in Appendix B in Supplementary Material) graphs of these interaction terms to describe the intersections between the key independent variables and the four background characteristics noted earlier. These estimates were derived based on Muthén and Muthén (1998–2015, pp. 495–499). To illustrate, the ORs of reporting *intent to transfer into non-STEM fields* and *no intent to transfer* at a given level of a key independent variable, when controlling for other variables, were calculated separately, both with *intent to transfer into STEM fields* as the reference category. Since there were three levels in the outcome variable, three ORs (two estimated and the reference category fixed at 1) were generated for a given level of the key independent variable. These ORs were then used to calculate the predicted probability of choosing a certain category of the outcome variable at a given level of the key independent variable, where each OR was the numerator and the summation of the three ORs the denominator, multiplied by 100%. Therefore, the summation of the three predicted probabilities is 100%. Given the involvement of all three ORs, conventionally, researchers plot all the predicted probabilities at a given level of the predictor regardless of its statistical significance. The process was repeated for different levels of the key independent variables and demographic background indicators.

Limitations

Given the nature of our research design and data sources, readers should interpret our findings with the following limitations in mind. First, some context-specific factors may influence students' transfer intent, such as articulation agreements between two- and four-year institutions, especially in STEM fields. However, given the focus and scope of our study, we are not able to explicitly account for articulation agreements in the study. Related, while within our sample of two-year colleges with a transfer mission, we further took into consideration institutional differences by introducing a covariate distinguishing between comprehensive institutions vs. two-year campuses within the state university system, our findings do not necessarily hold for institutions where transfer is not an explicit part of their mission. Especially, our study sample may engage in transfer-oriented interactions in more homogeneous ways than students enrolled at two-year institutions without an explicit transfer mission, as students enrolled in those institutions may lack the same degree of transfer intent toward STEM or other fields given that these institutions' educational offerings and opportunities may divert students away from transfer as a major educational goal. Another limitation of our study is that transfer intent regarding STEM fields is measured in an aggregated fashion. While this approach allows us to retain analytical viability, factors related transfer intent across specific STEM fields, such as from science to engineering, are not explored. Finally, like with all observational studies, the results presented in this study are correlational in nature. Though some predictors may form a temporal relationship with the outcome variable, our analytical framework precludes causal interpretation.

RESULTS

The Factor Structure of the Four Scales

The results from CFA revealed that the proposed four-factor solution fit the data well ($\chi^2 = 1732.17$, $df = 458$, $p < 0.05$;

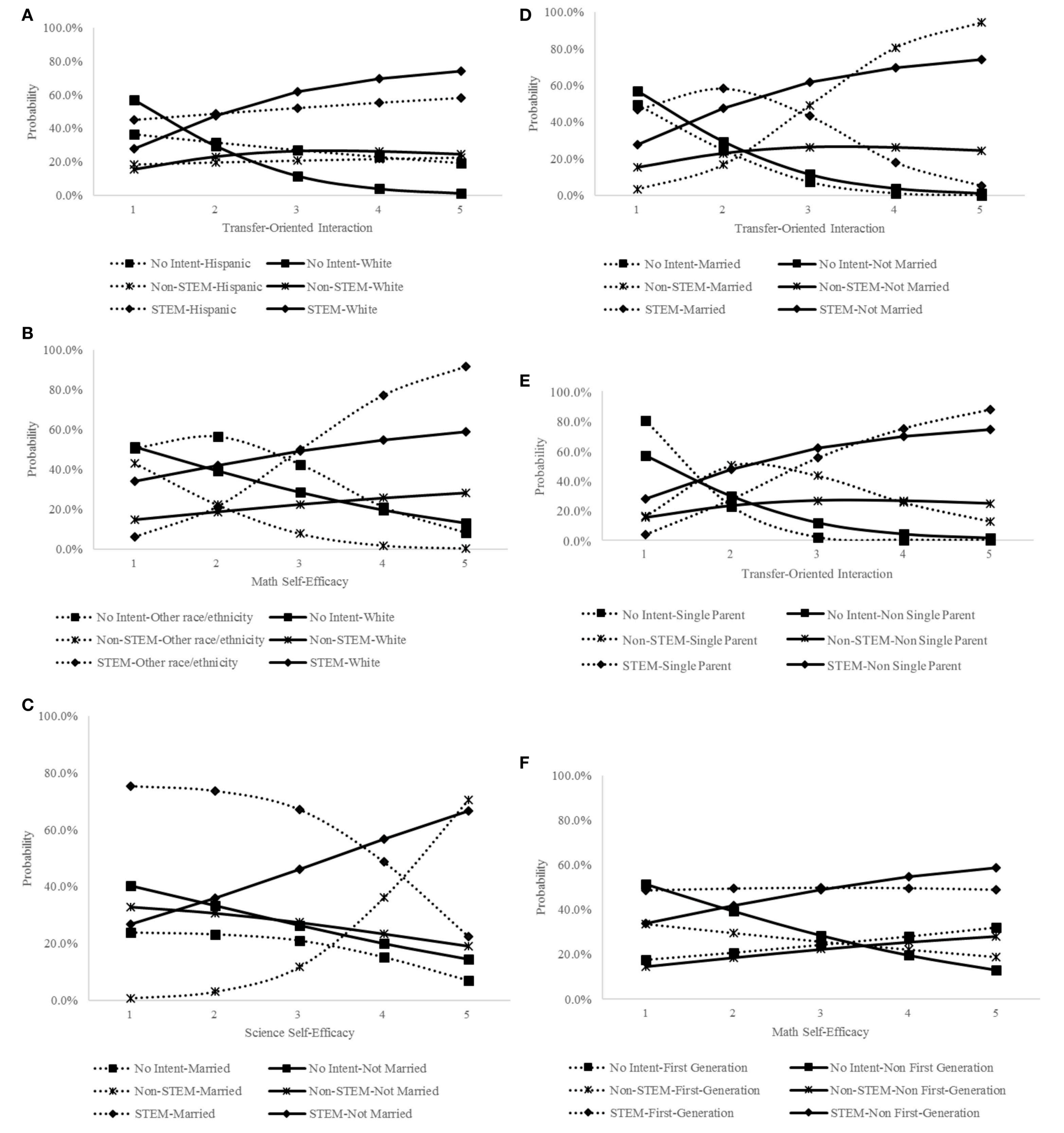

FIGURE 2 | Predicted probabilities of transfer intent based on the interaction effects between key independent variables and sociodemographic backgrounds. (A) Interaction between transfer-oriented interaction and race/ethnicity. **(B)** Interaction between math self-efficacy and race/ethnicity. **(C)** Interaction between science self-efficacy and marital status. **(D)** Interaction between transfer-oriented interaction and marital status. **(E)** Interaction between transfer-oriented interaction and being single parent. **(F)** Interaction between math self-efficacy and first-generation status.

90% CI of RMSEA = [0.06, 0.07], CFI = 0.98, TLI = 0.98), and the items were grouped together as designed. The standardized factor loadings ranged between 0.53 and 0.98, indicating that these items as a group are good measures of the latent construct. In short, these results demonstrated that the scales had acceptable divergent and construct validity.

Results from the Multinomial Logistic Regression

Largely aligned with our hypotheses, the results from the multinomial logistic regression demonstrated that the three motivational and contextual factors were significant and positive predictors for women's transfer intent (see **Table 2** for a summary of the multinomial logistic regression). Further, this relationship seemed to be moderated by students' background characteristics (see **Figure 2** and Appendix B in Supplementary Material for the graphs of the moderation effects). In essence, the relationship of transfer-oriented interaction and math self-efficacy to women's transfer intent differed between White and racial/ethnic minority students. For example, despite the positive relationship between transfer-oriented interaction and the intention to transfer into STEM fields, Black women were less likely to have intent to transfer into STEM fields than White students until Black students reported a moderate level of transfer-oriented interaction (at $p < 0.10$ level)[1]. Conversely, Hispanic students appeared to be more likely to report intent to transfer into STEM fields than their White peers, even when Hispanic students reported a relatively low level of engagement in transfer-oriented interaction (see **Figure 2A**). For students identified as other race/ethnicity (e.g., Pacific Islanders, Native Americans), they were more likely to report intent to transfer into STEM fields than their White peers at a medium to high level of math self-efficacy (see **Figure 2B**).

The relationship of science self-efficacy and transfer-oriented interaction to transfer intent also seems to vary based on marital status. Married women appeared to be less likely to report intent to transfer into STEM fields than those who are not married, despite the positive linkage of science self-efficacy and transfer-oriented interaction to transfer intent (see **Figures 2C,D**). Female students who were also single parents, compared with those who were not, seemed to be more likely to report intent to transfer into STEM fields if they report a relatively high level of transfer-oriented interaction (see **Figure 2E**). Finally, though first-generation female students would be more likely to report intent to transfer into STEM fields than non-STEM ones, this probability would lag behind that of non-first-generation students when they both scored relatively high in math self-efficacy (see **Figure 2F**).

DISCUSSION

In regard to our first research question on the relationship between the three key contextual and motivational factors and transfer intent, our findings align with prior research that transfer-oriented interaction aids in the process leading up to transfer (e.g., Kruse et al., 2015). Our results also show that math self-efficacy and science self-efficacy may enhance intent to transfer into STEM fields, which also resonates with existing empirical evidence pointing to the foundational role of self-beliefs in math and science performance in shaping students' STEM educational trajectories and outcomes (e.g., Peters, 2013; Wang, 2013a,b; Starobin et al., 2014; Larson et al., 2015; Lent et al., 2015). While these general patterns are what we would expect, it is important to note that, overall, these three factors seem to exert very similar positive influence on the intent to transfer into STEM as well as transfer into other fields. That is, transfer-oriented interaction and self-efficacy beliefs help distinguish between intent to transfer in general and having no intent to transfer, but not among major fields of study into which students intend to transfer. This is an intriguing finding, considering the fact that the women in our study were all exposed to STEM courses and/or programs. While the increased amount of transfer-oriented interaction or self-efficacy beliefs does seem to boost transfer intent in general, it does not necessarily push women further toward the STEM transfer path. This result suggests that other factors may matter more for transfer-aspiring two-year college women as they decide which area they want to pursue at the four-year level, such as academic interests and concerns about future careers, which have been identified as contributing factors to college major choice (Freeman and Hirsch, 2008; Martinez, 2012; Wang, 2013b). Considerations around these aspects may outweigh transfer-oriented interaction and self-efficacy beliefs as two-year college women map out their future academic plans.

With our second research question, we explored the potential ways in which two-year college women's other identity backgrounds (i.e., racial/ethnic background, marital status, single parent status, and first-generation status) may moderate the relationships between intent to transfer and the three contextual and motivational factors. As reported earlier, we uncovered some potential racial/ethnic differences regarding how transfer-oriented interaction and math self-efficacy may shape intent to transfer. An important takeaway is that, while transfer-oriented interaction is an important predictor of transfer intentions in general, it is a critically important type of interaction for Black women at two-year colleges. On one hand, the lack of such interaction is especially detrimental to the baccalaureate STEM aspirations among Black women who already feel isolated by being female and minority in White and male-dominated STEM programs (Jackson et al., 2013). On the other hand, based on our study, when students engage in transfer-oriented interaction to a great degree, it may serve as an amplifier that has a substantial boosting effect to STEM transfer intent of Black women. This complex dynamic also holds for how math self-efficacy is related to transfer intent among Black women relative to their White counterparts, and reinforces the promise and power of continued efforts to enhance academic confidence for women in order to increase the representation of women in STEM fields.

As for married women, an increasing level of transfer-oriented interaction appears to boost their intent to transfer into non-STEM fields, as opposed into STEM. In this sense, while transfer-oriented interaction still cultivates the intent to pursue a four-year, as women increasingly interact with institutional agents to talk about transfer, it serves to direct women into different transfer pathways depending on their

[1]We acknowledge that, based on the conventions of statistical reporting in psychology, the commonly adopted threshold for reaching statistical significance is 0.05. However, given the relatively small subsample sizes (such as that of Black women) and the exploratory nature of our study, we chose to also report parameter estimates with a p-value smaller than 0.10, in order to capture potentially meaningful relationships that can be further explored in future inquiry.

TABLE 2 | Summary of multinomial logistic regression.

Variables	STEM vs. no intent			STEM vs. non-stem		
	B **(*SE*)**	**OR**	**Prob. change (%)**	***B*** **(*SE*)**	**OR**	**Prob. change (%)**
MOTIVATIONAL/CONTEXTUAL FACTORS						
Math self-efficacy (Math SE)	0.48 (0.22)*	1.62	2.9	−0.03 (0.19)		
Science self-efficacy (Sci SE)	0.49 (0.25)$^{+}$	1.63	9.0	0.36 (0.22)$^{+}$	1.44	
Transfer-oriented interaction (TI)	1.19 (0.27)***	3.30	5.5	0.13 (0.18)		
ACADEMIC BACKGROUND AND EXPERIENCES						
Institution attendance: comprehensive two-year institution	−1.54 (0.37)***	0.22	−21.1	−0.04 (0.29)		
Cumulative GPA (Fall 2014)	0.13 (0.14)			−0.04 (0.14)		
Engagement in active learning	−0.01 (0.21)			0.41 (0.19)*	1.51	8.2
Have claimed a major	1.67 (0.29)***	5.34	39.6	2.76 (0.27)***	15.86	56.3
Field of study: biological, agricultural, or environmental life science	0.83 (0.34)*	2.30	14.0	0.59 (0.31)$^{+}$	1.81	11.3
Field of study: computer or mathematical science	−0.28 (0.43)			−0.70 (0.40)$^{+}$	0.50	−16.7
Field of study: engineering or engineering technologies	−0.79 (0.60)			1.14 (0.67)$^{+}$	3.12	18.8
SOCIO-DEMOGRAPHIC BACKGROUNDS						
Black	−14.75 (6.62)*	0.00	5.4	−9.02 (4.88)$^{+}$	0.00	−22.5
Hispanic	2.73 (2.20)			0.69 (1.99)		
Asian	−0.53 (3.17)			−3.58 (2.88)		
Other race/ethnicity	0.66 (3.66)			−3.14 (4.02)		
Financial support	−0.17 (0.10)$^{+}$	0.85	−3.6	−0.13 (0.09)		
Support for education from family	−0.24 (0.14)$^{+}$	0.79	−5.2	−0.13 (0.13)		
Support for education from peers	−0.16 (0.14)			−0.27 (0.14)$^{+}$	0.76	−6.2
Being over 24 years of age	−0.75 (0.38)$^{+}$	0.47	−17.3	0.57 (0.42)		
Being married	3.07 (1.90)			8.70 (3.32)**		0.1
Being a single parent	−1.85 (4.11)			−2.73 (4.20)		
First-generation college student	0.49 (1.68)			−2.43 (1.66)		
Low income (below $30 k annually)	0.22 (0.30)			0.92 (0.30)**	2.50	16.0
Part-time student	−0.22 (0.33)			−0.15 (0.32)		
Employed: full-time	−0.77 (0.41)$^{+}$	0.46	−17.9	−0.59 (0.39)		
Employed: part-time	−0.15 (0.34)			0.13 (0.29)		
INTERACTION TERMS						
TI × Black	1.95 (1.10)$^{+}$	7.03	–	1.04 (0.59)$^{+}$	2.82	–
TI × Hispanic	−0.97 (0.42)*	0.38	–	−0.11 (0.35)		
TI × Asian	−0.89 (0.71)			0.12 (0.49)		
TI × Other race/ethnicity	−1.00 (0.90)			−1.41 (0.91)		
Math SE × Black	2.29 (1.17)$^{+}$	9.90	–	1.41 (0.91)		
Math SE × Hispanic	−0.37 (0.39)			0.23 (0.37)		
Math SE × Asian	−0.03 (0.67)			0.35 (0.54)		
Math SE × Other race/ethnicity	0.65 (0.60)			1.93 (0.78)*	6.89	–
Sci SE × Black	0.77 (0.90)			0.12 (0.83)		
Sci SE × Hispanic	0.15 (0.49)			−0.31 (0.46)		
Sci SE × Asian	0.70 (0.83)			0.44 (0.74)		
Sci SE × Other race/ethnicity	−0.18 (0.61)			0.47 (1.15)		
TI × Married	−0.29 (0.45)			−1.49 (0.55)**	0.23	–
TI × Single parent	2.06 (0.80)*	7.82	–	0.72 (0.62)		
TI × First-generation	0.22 (0.37)			0.38 (0.31)		
Math SE × Married	−0.10 (0.53)			0.39 (0.66)		
Math SE × Single parent	−0.76 (0.48)			−0.22 (0.52)		
Math SE × First-generation	−0.63 (0.32)*	0.53	–	0.17 (0.30)		
Sci SE × Married	−0.48 (0.54)			−1.81 (0.82)*	0.16	–
Sci SE × Single parent	0.08 (0.94)			0.21 (0.98)		
Sci SE × First-generation	0.29 (0.41)			0.24 (0.42)		
(Intercept)	−3.77 (1.35)			−2.97 (1.15)		

OR, odds ratio. Probability change of statistically significant variables was calculated by comparing with the other group (for binary variables) or contrasting students scored at mean against who scored 1 point above the mean (for continuous variables). However, because of the interaction effects, some directions of the probability change of main effects are not equal to that of the corresponding coefficients. Probability change of the interaction terms was not calculated.

$^{+}p < 0.10$, $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

marital status. Also interesting to note is that an increased level of science self-efficacy operates in the same way as transfer-oriented interaction based on marital status. This counterintuitive finding may be explained by the widely-held perceptions of scientists and engineers working long hours (Terosky et al., 2014). It is possible that, as women learn about the expectations of the field, despite their growing confidence in career competence—as evidenced in their science self-efficacy—they may stay away from a STEM career for fear of not being able to balance life and work (Xie and Shauman, 2003).

Single parent status also emerged to be a noteworthy moderator of the relationship between transfer-oriented interaction and intent to transfer. The surge in probability of single parents reporting intent to transfer into STEM with greater levels of transfer-oriented interaction demonstrates the importance of contextual support in preparing female single parents for having a future in STEM careers, especially given that single parents have to juggle multiple obligations (Creamer and Laughlin, 2005; Hagedorn and Purnamasari, 2012).

Finally, with regard to first-generation status, our results indicate that math self-efficacy is more relevant to non-first-generation students' transfer intention, whereas its influence on first-generation women is rather minimal. This finding is interesting, considering that self-efficacy has been long established as a reliable and important precursor to students' academic aspirations and achievement (e.g., Hackett, 1985; Lent et al., 2015), especially in STEM fields (Heinze and Hu, 2009; Larson et al., 2015; Sax et al., 2016). It is plausible that first-generation two-year college women are more inclined to pursue STEM fields for reasons beyond their self-perceptions of their math abilities. Alternatively, given that our study focuses on transfer intent early in these women's two-year college careers, it is also likely that the relevance of math self-efficacy will gain more ground as these students spend more time navigating through the STEM curriculum.

Taken together, our findings suggest that, by and large, the three motivational and contextual factors of our key interest, transfer-oriented interaction, self-efficacy in math, and self-efficacy in science, are good predictors of two-year college women's intent to transfer into STEM fields. In addition, there are more nuanced findings that pertain to these three key factors when we take into consideration of women's other identities. In particular, while self-efficacy beliefs demonstrate solid predictive power for female students' intent to transfer in general, the role they play varies in magnitude across student subgroups. As a core component of the social cognitive theory, self-efficacy has been widely applied in research examining academic and career choices. Our study validates self-efficacy's established utility, but more importantly, it illuminates the imperative need to adopt a more nuanced approach to examining self-efficacy among diverse groups of community college women along the STEM transfer pathway. Further, factors other than self-efficacy, such as women's identity as a STEM learner and sense of belonging within STEM fields, need to be further explored in future inquiry.

IMPLICATIONS FOR POLICY AND PRACTICE

Engaging Students in Transfer-Oriented Interaction to Fuel Transfer Intent

In light of the substantial role transfer-oriented interaction plays in shaping women's transfer intent in our study, it is critical to identify ways to engage students in interaction with important institutional agents regarding transfer among women enrolled in STEM programs at two-year institutions. Accordingly, it is important that two-year colleges offer resources to help women increase their knowledge about transfer into four-year STEM programs, through intentional and proactive academic and transfer advising that helps illuminate viable transfer pathways (Packard et al., 2012; Packard and Jeffers, 2013). In her qualitative study, Jackson (2013) found that interpersonal exchange, such as consistent communication and information sharing within the community, as opposed to solitary activities (e.g., looking up information online), is the major venue through which Black two-year college women prepare for upward transfer and gain career knowledge in STEM fields. We would further recommend that in this endeavor, faculty, and transfer advisors work together to create a network of support, bridging the classroom with transfer advising to chart a seamless information network for students. Stronger collaboration between faculty and transfer advisors will allow students to receive holistic and consistent support and information, as two-year college women do not have extended time to spend on campus and navigate a multitude of functional areas.

For female STEM students initially with a low level of transfer-oriented interaction, a personalized transfer plan based on students' skills and interests may serve as a tangible way to build an understanding of upward transfer. Also, we advise two-year colleges to identify female role models in students who negotiated the transfer process and are completing baccalaureate STEM degrees. Given our findings, this practice may be especially valuable for women from backgrounds that are historically perceived as "disadvantaged" in STEM fields, such as being married. Engaging with peer role models sharing similar identity backgrounds who transferred into STEM fields may help dismiss notions that they are not capable or not able to attain support, should they pursue a baccalaureate STEM pathway.

Cultivating Math and Science Self-efficacy

For women in general, and women of color in particular, math and science self-efficacy beliefs play a significant and positive role in shaping intent to transfer into STEM fields. Therefore, more intensive efforts are called for to provide women pursuing STEM fields with ample opportunities to develop academic confidence. Arguably, faculty will serve as the key change agents in this process, given that the beliefs, practices, and attitudes of faculty have the power to diminish or strengthen self-efficacy for math and science among women of color (Bensimon, 2005). Moreover, STEM instructors' encouragement was deemed more valuable to students than that from their relatives and friends (Jenson et al., 2011).

Programs that immerse women in practical and applied experiences may also aid in this process. For example, undergraduate research experience may offer pivotal mastery experience that underscores self-efficacy (Bandura, 1986; Chemers et al., 2011). More intentional programming options that align female two-year college students with female instructors and scientists for research-related internships could provide women with mentors and role models they need to envision themselves successfully pursuing STEM fields. In a similar vein, if two-year colleges can pair female students with influential figures who share similar racial/ethnic, parental, or marital backgrounds, students may thus gain invaluable vicarious experiences (Bandura, 1986), which will increase their self-efficacy.

Vicarious learning experiences also stem from participating on teams and collaborating with peers (Jenson et al., 2011). In the present study, we also found that one's engagement in active learning is related to a higher probability of having intent to transfer into STEM fields as opposed to non-STEM fields. Peers provide support, learn from one another, and feel more confident in their abilities when they saw classmates succeed (Jenson et al., 2011). This suggests that, for women in STEM programs at two-year colleges, interactive curricular approaches adopted by STEM faculty may be beneficial in increasing both transfer intent and self-efficacy in math and science. However, faculty should be cautioned to allow students to designate their own teams, so women do not feel isolated or rejected if placed in groups of otherwise all male students.

IMPLICATIONS FOR FUTURE RESEARCH

Being one of the first empirical efforts disentangling two-year college women's transfer intent and how its associated factors intersect with women's other identity backgrounds, our study both sheds preliminary light on this understudied topic and illuminates two major future areas of inquiry that can build upon our findings.

First and foremost, more research is needed to further tease out how two-year college women's multiple roles and background characteristics shape their educational aspirations and eventual outcomes along the STEM pathway. Two-year college women are not a homogenous group, and as we continue to wrestle with the best approaches to closing the gender gap within STEM fields, researchers and policymakers alike must be cognizant of, and further examine, the diversity that exists within this subpopulation in order to tackle the unique challenges they might face based on their distinctive backgrounds. For example, our study shows that, while in general transfer-oriented interaction exerts a positive connection with intent to transfer, the extent to which it makes a difference varies based on women's other identity backgrounds. In light of our findings, more in-depth empirical effort should be devoted to studying the kinds of interventions that effectively help engage Black women and single parent women in transfer-oriented interaction; whereas the type of research that serves to better understand married women's transfer intent and pathways needs to extend beyond their transfer-oriented interaction and into women's perceptions of the demands and rewards of a STEM career, and how these factor into their pursuit of a STEM educational pathway. In sum, much remains to be researched in regard to the ways in which transfer intent among women in the STEM pipeline is shaped in connection with their other identities and roles.

In addition and related to the first point, more research needs to be conducted on the kinds of supports that are helpful for women in general and parents in particular to alleviate their hesitance in pursuing a STEM career. As our results show, single parent women indicate stronger transfer intent into STEM fields when their engagement in transfer-oriented interaction is frequent. On the other hand, married women have a low probability of reporting intent to transfer into STEM fields, despite a high level of engagement in transfer-oriented interaction. This finding may be attributed to a lack of recognition among the professional STEM community of the dual role of women balancing familial and work responsibilities (Xu, 2015), which may direct women to other fields of study as they become more informed about STEM career demands. Future studies may explore this dichotomy, as well as how two-year colleges can work with employers in STEM fields in creating empowering and welcoming environments, coupled with necessary educational and career resources that inform and encourage female students as they navigate their educational pathways into a STEM career.

CONCLUSION

Despite the two-year college promise in solving the gender gap in baccalaureate STEM attainment through the upward transfer function, empirical research is sorely lacking on what influences the transfer intent among women beginning in STEM at two-year colleges. Our study sets out to fill this void in the research literature and further unravel the role women's other backgrounds play in the development of their transfer aspirations. The findings from this study indicate that women who are highly engaged with transfer-oriented interaction were more likely to report intent to transfer into STEM fields, making it especially critical that institutions provide transparent pathways for students to access resources and information about the transfer process. The findings also indicate that the relationship between math self-efficacy and intent to transfer into STEM fields is positive and significant. Women's self-beliefs in their proficiency in math may indeed shape their intent to continue in fields that require math courses at a higher level. Given that self-efficacy in math is shaped over time and through academic experiences, it is imperative that two-year colleges provide opportunities for students to be successful in foundational math and science courses. In addition, more nuanced findings emerge from our study when we take into consideration of women's other identities. For example, the relationship of math self-efficacy and transfer-oriented interaction to intent to transfer into STEM fields varied based on racial/ethnic backgrounds.

These differences, as we discussed earlier, hold important implications for the ways in which researchers, policymakers, and practitioners study and inform students about pathways to STEM transfer.

As two-year colleges become more recognized as a pathway to four-year degrees in STEM fields, concentrated efforts are called for to support women who are traditionally underrepresented in STEM fields through the transfer pipeline. Future research is needed to dissect trends in the transfer decision process for women enrolled in two-year colleges, taking into account their many identities. More specifically, two-year colleges need to examine more deeply how women's identities interact with motivational and contextual factors that contribute to transfer ambitions, so as to better support women in their knowledge about upward transfer into STEM fields.

ETHICS STATEMENT

This study was carried out in accordance with the recommendations of UW-Madison's Institutional Review Board with written informed consent from all subjects. All subjects gave written informed consent in accordance with the Declaration of Helsinki. The protocol was approved by UW-Madison's Institutional Review Board.

AUTHOR CONTRIBUTIONS

XW was primarily responsible for conceiving the study as well as collecting and analyzing the data. HSC contributed to the study design and conducted data analysis. SJS and BRN contributed to interpretation of the data. All authors wrote and revised the manuscript.

FUNDING

This study is funded by the University of Wisconsin-Madison Graduate School Alumni Research Foundation and the National Science Foundation, grant No. DUE-1430642.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: http://journal.frontiersin.org/article/10.3389/fpsyg.2017.00146/full#supplementary-material

REFERENCES

Bandura, A. (1986). *Social Foundations of Thought and Action: A Social– Cognitive Theory*. Englewood Cliffs, NJ: Prentice Hall.

Bean, J. P., and Kuh, G. D. (1984). The reciprocity between student-faculty informal contact and academic performance of university undergraduate students. *Res. High. Educ.* 21, 461–477. doi: 10.1007/BF00992637

Bensimon, E. M. (2005). Closing the achievement gap in higher education: an organizational learning perspective. *New Dir. High. Educ.* 2005, 99–111. doi: 10.1002/he.190

Blickenstaff, J. C. (2005). Women and science careers: leaky pipeline or gender filter? *Gend. Educ.* 17, 369–386. doi: 10.1080/09540250500145072

Boswell, K. (2004). Bridges or barriers? Public policy and the community college transfer function. *Change* 36, 22. doi: 10.1080/00091380409604240

Bryant, A. N. (2001). ERIC review: community college students: recent findings and trends. *Community Coll. Rev.* 29, 77–93. doi: 10.1177/009155210102900305

Carnevale, A. P., Smith, N., and Strohl, J. (2010). *Help Wanted: Projections of Jobs and Education Requirements Through 2018.* Washington, DC: Georgetown University, Center on Education and the Workforce. Available online at: https://repository.library.georgetown.edu/bitstream/handle/10822/559303/FullReport.pdf?sequence=1

Chan, H.-Y., and Wang, X. (2016). Interact for what? The relationship between interpersonal interaction based on motivation and educational outcomes among students in manufacturing programs at two-year technical colleges. *Community Coll. Rev.* 44, 26–48. doi: 10.1177/0091552115612560

Chavez, M. A. (2015). Community college journeys of Hispanic ESL women. *Community Coll. J. Res. Pract.* 39, 207–221. doi: 10.1080/10668926.2013.795506

Chemers, M. M., Zurbriggen, E. L., Syed, M., Goza, B. K., and Bearman, S. (2011). The role of efficacy and identity in science career commitment among underrepresented minority students. *J. Soc. Issues* 67, 469–491. doi: 10.1111/j.1540-4560.2011.01710.x

Christian, M. E. (2000). *The Community College Transfer Function: A Study of Its Success in Higher Education.* Unpublished master's thesis. Northeastern State University, Tahlequah, OK.

Cohen, A. M., Brawer, F. B., and Kisker, C. B. (2014). *The American Community College, 6th Edn.* San Francisco, CA: Jossey-Bass.

Costello, C. B. (2012). *Increasing Opportunities for Low-Income Women and Student Parents in Science, Technology, Engineering, and Math at Community Colleges.* Washington, DC: Institute for Women's Policy Research. Available online at: http://files.eric.ed.gov/fulltext/ED556728.pdf

Creamer, E. G., and Laughlin, A. (2005). Self-authorship and women's career decision making. *J. Coll. Stud. Dev.* 46, 13–27. doi: 10.1353/csd.2005.0002

Espinosa, L. L. (2011). Pipelines and pathways: women of color in undergraduate STEM majors and the college experiences that contribute to persistence. *Harv. Educ. Rev.* 81, 209–240. doi: 10.17763/haer.81.2.92315ww157656k3u

Ferriman, K., Lubinski, D., and Benbow, C. P. (2009). Work preferences, life values, and personal views of top math/science graduate students and the profoundly gifted: developmental changes and gender differences during emerging adulthood and parenthood. *J. Pers. Soc. Psychol.* 97, 517–532. doi: 10.1037/a0016030

Freeman, J. A., and Hirsch, B. T. (2008). College majors and the knowledge content of jobs. *Econ. Educ. Rev.* 27, 517–535. doi: 10.1016/j.econedurev.2007.07.004

Hackett, G. (1985). Role of mathematics self-efficacy in the choice of math-related majors of college women and men: a path analysis. *J. Couns. Psychol.* 32, 47–56. doi: 10.1037/0022-0167.32.1.47

Hackett, G., and Betz, N. E. (1989). An exploration of the mathematics self-efficacy/mathematics performance correspondence. *J. Res. Math. Educ.* 20, 261–273. doi: 10.2307/749515

Hagedorn, L. S., Cypers, S., and Lester, J. (2008). Looking in the review mirror: factors affecting transfer for urban community college students. *Community Coll. J. Res. Pract.* 32, 643–664. doi: 10.1080/10668920802026113

Hagedorn, L. S., and DuBray, D. (2010). Math and science success and nonsuccess: journeys within the community college. *J. Women Minor. Sci. Eng.* 16, 31–50. doi: 10.1615/JWomenMinorScienEng.v16.i1.30

Hagedorn, L. S., and Purnamasari, A. V. (2012). A realistic look at STEM and the role of community colleges. *Community Coll. Rev.* 40, 145–164. doi: 10.1177/0091552112443701

Heinze, N., and Hu, Q. (2009). Why college undergraduates choose IT: a multi-theoretical perspective. *Eur. J. Inf. Syst.* 18, 462–475. doi: 10.1057/ejis.2009.30

Hirst, R. A., Bolduc, G., Liotta, L., and Packard, B. W. (2014). Cultivating the STEM transfer pathway and capacity for research: a partnership between a community college and a 4-year college. *J. Coll. Sci. Teach.* 43, 12–17. doi: 10.2505/4/jcst14_043_04_12

Hoffman, E., Starobin, S. S., Laanan, F. S., and Rivera, M. (2010). Role of community colleges in STEM education: thoughts on implications for policy, practice, and future research. *J. Women Minor. Sci. Eng.* 16, 85–96. doi: 10.1615/JWomenMinorScienEng.v16.i1.60

Horn, L., Nevill, S., and Griffith, J. (2006). *Profile of Undergraduates in US Postsecondary Education Institutions, 2003-04: With a Special Analysis of Community College Students (NCES 2006-184)*. Washington, DC: U.S. Department of Education, National Center for Education Statistics.

Jackson, D. L. (2013). A balancing act: impacting and initiating the success of African American female community college transfer students in STEM into the HBCU environment. *J. Negro Educ.* 82, 255–271. doi: 10.7709/jnegroeducation.82.3.0255

Jackson, D. L., Starobin, S. S., and Laanan, F. S. (2013). The shared experiences: facilitating successful transfer of women and underrepresented minorities in STEM fields. *New Dir. High. Educ.* 2013, 69–76. doi: 10.1002/he.20058

Jenson, R. J., Petri, A. N., Day, A. D., Truman, K. Z., and Duffy, K. (2011). Perceptions of self-efficacy among STEM students with disabilities. *J. Postsec. Educ. Disabil.* 24, 269–283.

Johnson, L. G., Schwartz, R. A., and Bower, B. L. (2000). Managing stress among adult women students in community colleges. *Community Coll. J. Res. Pract.* 24, 289–300. doi: 10.1080/106689200264079

Kruse, T., Starobin, S. S., Chen, Y., Baul, T., and Laanan, F. S. (2015). Impacts of intersection between social capital and finances on community college students' pursuit of STEM degrees. *Community Coll. J. Res. Pract.* 39, 324–343. doi: 10.1080/10668926.2014.981893

Laanan, F. S. (2007). Studying transfer students: part II: dimensions of transfer students' adjustment. *Community Coll. J. Res. Pract.* 31, 37–59. doi: 10.1080/10668920600859947

Laanan, F. S., Starobin, S. S., and Eggleston, L. E. (2010). Adjustment of community college students at a four-year university: role and relevance of transfer student capital for student retention. *J. Coll. Stud. Retent.* 12, 175–209. doi: 10.2190/CS.12.2.d

Larson, L. M., Pesch, K. M., Surapaneni, S., Bonitz, V. S., Wu, T. F., and Werbel, J. D. (2015). Predicting graduation: the role of mathematics/science self-efficacy. *J. Career Assess.* 23, 399–409. doi: 10.1177/1069072714547322

Lent, R. W., Brown, S. D., and Hackett, G. (1994). Toward a unifying social cognitive theory of career and academic interest, choice, and performance. *J. Vocat. Behav.* 45, 79–122. doi: 10.1006/jvbe.1994.1027

Lent, R. W., Brown, S. D., and Hackett, G. (2000). Contextual supports and barriers to career choice: a social cognitive analysis. *J. Couns. Psychol.* 47, 36–49. doi: 10.1037/0022-0167.47.1.36

Lent, R. W., Miller, M. J., Smith, P. E., Watford, B. A., Hui, K., and Lim, R. H. (2015). Social cognitive model of adjustment to engineering majors: longitudinal test across gender and race/ethnicity. *J. Vocat. Behav.* 86, 77–85. doi: 10.1016/j.jvb.2014.11.004

Little, R. J. A. (1988). A test of missing completely at random for multivariate data with missing values. *J. Am. Stat. Assoc.* 83, 1198–1202. doi: 10.1080/01621459.1988.10478722

Ma, Y. (2011). Gender differences in the paths leading to a STEM baccalaureate. *Soc. Sci. Q.* 92, 1169–1190. doi: 10.1111/j.1540-6237.2011.00813.x

MacPhee, D., Farro, S., and Canetto, S. S. (2013). Academic self-efficacy and performance of underrepresented STEM majors: gender, ethnic, and social class patterns. *Anal. Soc. Issues Pub. Pol.* 13, 347–369. doi: 10.1111/asap.12033

Martin, K., Galentino, R., and Townsend, L. (2014). Community college student success: the role of motivation and self-empowerment. *Community Coll. Rev.* 42, 221–241. doi: 10.1177/0091552114528972

Martinez, C. (2012). Stem, shoots, and leaves: increasing access of underrepresented groups to high-quality, career-readying science, technology, engineering and mathematics education. *Harv. J. Hisp. Policy* 25, 15–24.

McKinney, L., and Novak, H. (2013). The relationship between FAFSA filing and persistence among first-year community college students. *Community Coll. Rev.* 41, 63–85. doi: 10.1177/0091552112469251

Moakler, M. W., and Kim, M. M. (2014). College major choice in STEM: revisiting confidence and demographic factors. *Career Dev. Q.* 62, 128–142. doi: 10.1002/j.2161-0045.2014.00075.x

Morganson, V. J., Jones, M. P., and Major, D. A. (2010). Understanding women's underrepresentation in science, technology, engineering, and mathematics: the role of social coping. *Career Dev. Q.* 59, 169–179. doi: 10.1002/j.2161-0045.2010.tb00060.x

Muthén, L. K., and Muthén, B. O. (1998–2015). *Mplus User's Guide, 7th Edn.* Los Angeles, CA: Muthén & Muthén.

Oh, S. S., and Lewis, G. B. (2011). Stemming inequality? Employment and pay of female and minority scientists and engineers. *Soc. Sci. J.* 48, 397–403. doi: 10.1016/j.soscij.2010.11.008

Packard, B. W., Gagnon, J. L., and Senas, A. J. (2012). Navigating community college transfer in science, technical, engineering, and mathematics fields. *Community Coll. J. Res. Pract.* 36, 670–683. doi: 10.1080/10668926.2010.495570

Packard, B. W., and Jeffers, K. C. (2013). Advising and progress in the community college STEM transfer pathway. *NACADA J.* 33, 65–75. doi: 10.12930/NACADA-13-015

Packard, B. W.-L., Gagnon, J. L., LaBelle, O., Jeffers, K., and Lynn, E. (2011). Women's experiences in the STEM community college transfer pathway. *J. Women Minor. Sci. Eng.* 17, 129–147. doi: 10.1615/JWomenMinorScienEng.2011002470

Peters, M. L. (2013). Examining the relationships among classroom climate, self-efficacy, and achievement in undergraduate mathematics: a multi-level analysis. *Int. J. Sci. Math. Educ.* 11, 459–480. doi: 10.1007/s10763-012-9347-y

Phillippe, K. A., and Patton, M. (2000). *National Profile of Community Colleges: Trends and Statistics, 3rd Edn.* Washington, DC: American Association of Community College.

Prince, M. (2004). Does active learning work? A review of the research. *J. Eng. Educ.* 93, 223–231. doi: 10.1002/j.2168-9830.2004.tb00809.x

Riegle-Crumb, C., and King, B. (2010). Questioning a white male advantage in STEM: examining disparities in college major by gender and race/ethnicity. *Educ. Res.* 39, 656–664. doi: 10.3102/0013189X10391657

Ruiz, E. C. (2013). Motivating Latina doctoral students in STEM disciplines. *New Dir. High. Educ.* 2013, 35–42. doi: 10.1002/he.20063

Sax, L. J. (2012). *Examining the Underrepresentation of Women in STEM Fields: Early Findings from the Field of Computer Science.* Los Angeles, CA: Center for the Study of Women, University of California-Los Angeles. Available online at: http://escholarship.org/uc/item/84j9s1v1

Sax, L. J., Kanny, M. A., Jacobs, J. A., Whang, H., Weintraub, D. S., and Hroch, A. (2016). Understanding the changing dynamics of the gender gap in undergraduate engineering majors: 1971–2011. *Res. High. Educ.* 57, 570–600. doi: 10.1007/s11162-015-9396-5

Shapiro, C. A., and Sax, L. J. (2011). Major selection and persistence for women in STEM. *New Dir. Institut. Res.* 2011, 5–18. doi: 10.1002/ir.404

Snyder, T. D., and Dillow, S. A. (2012). *Digest of Education Statistics 2011.* Washington, DC: U.S. Department of Education, National Center for Education Statistics. Available online at: http://nces.ed.gov/pubs2012/2012001.pdf

Sonnert, G. (1995). *Who Succeeds in Science?* New Brunswick, NJ: Rutgers University Press.

Starobin, S. S., Chen, Y., Kollasch, A., Baul, T., and Laanan, F. (2014). The effects of a pre- engineering project-based learning curriculum on self-efficacy among community college students. *Community Coll. J. Res. Pract.* 38, 131–143. doi: 10.1080/10668926.2014.851954

St. Rose, A., and Hill, C. (2013). *Women in Community Colleges: Access to Success*. Washington, DC: American Association of University Women.

Tajlili, M. H. (2014). A framework for promoting women's career intentionality and work-life integration. *Career Dev. Q.* 62, 254–267. doi: 10.1002/j.2161-0045.2014.00083.x

Terosky, A. L., O'Meara, K., and Campbell, C. M. (2014). Enabling possibility: women associate professors' sense of agency in career advancement. *J. Divers. High. Educ.* 7, 58–76. doi: 10.1037/a0035775

Wang, X. (2009). Baccalaureate attainment and college persistence of community college transfer students at four-year institutions. *Res. High. Educ.* 50, 570–588. doi: 10.1007/s11162-009-9133-z

Wang, X. (2012). Factors contributing to the upward transfer of baccalaureate aspirants beginning at community colleges. *J. Higher Educ.* 83, 851–875. doi: 10.1353/jhe.2012.0043

Wang, X. (2013a). Modeling entrance into STEM fields of study among students beginning at community colleges and four-year institutions. *Res. High. Educ.* 54, 664–692. doi: 10.1007/s11162-013-9291-x

Wang, X. (2013b). Why students choose STEM majors: Motivation, high school learning, and postsecondary context of support. *Am. Educ. Res. J.* 50, 1081–1121. doi: 10.3102/0002831213488622

Wang, X. (2015). Pathway to a baccalaureate in STEM fields: Are community colleges a viable route and does early STEM momentum matter? *Educ. Eval. Policy Anal.* 37, 376–393. doi: 10.3102/0162373714552561

Wang, X. (2016). Course-taking patterns of community college students beginning in STEM: using data mining techniques to reveal viable STEM transfer pathways. *Res. High. Educ*. 57, 544–569. doi: 10.1007/s11162-015-9397-4

Wickersham, K., and Wang, X. (2016). What's life got to do with it? The role of life experiences in shaping female community college students' transfer intent in STEM fields of study. *Community Coll. J. Res. Pract.* 40, 1001–1012. doi: 10.1080/10668926.2016.1211039

Xie, Y., and Shauman, K. A. (2003). *Women in Science: Career Processes and Outcomes*. Cambridge, MA: Harvard University Press.

Xu, Y. (2015). Focusing on women in STEM: a longitudinal examination of gender-based earning gap of college graduates. *J. High. Educ.* 86, 489–523. doi: 10.1353/jhe.2015.0020

Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Psychology

ORIGINAL RESEARCH
published: 25 April 2017
doi: 10.3389/fpsyg.2017.00602

Engagement, Persistence, and Gender in Computer Science: Results of a Smartphone ESM Study

Carolina Milesi[1], Lara Perez-Felkner[2], Kevin Brown[3] and Barbara Schneider[4]*

[1] Education and Child Development, NORC at the University of Chicago, IL, USA, [2] Educational Leadership and Policy Studies and Sociology, Florida State University, Tallahassee, FL, USA, [3] Academic Research Centers, NORC at the University of Chicago, IL, USA, [4] College of Education and Department of Sociology, Michigan State University, East Lansing, MI, USA

While the underrepresentation of women in the fast-growing STEM field of computer science (CS) has been much studied, no consensus exists on the key factors influencing this widening gender gap. Possible suspects include gender differences in aptitude, interest, and academic environment. Our study contributes to this literature by applying student engagement research to study the experiences of college students studying CS, to assess the degree to which differences in men and women's engagement may help account for gender inequity in the field. Specifically, we use the Experience Sampling Method (ESM) to evaluate in real-time the engagement of college students during varied activities and environments. Over the course of a full week in fall semester and a full week in spring semester, 165 students majoring in CS at two Research I universities were "beeped" several times a day via a smartphone app prompting them to fill out a short questionnaire including open-ended and scaled items. These responses were paired with administrative and over 2 years of transcript data provided by their institutions. We used mean comparisons and logistic regression analysis to compare enrollment and persistence patterns among CS men and women. Results suggest that despite the obstacles associated with women's underrepresentation in computer science, women are more likely to continue taking computer science courses when they felt challenged and skilled in their initial computer science classes. We discuss implications for further research.

Keywords: computer science, experience sampling method, persistence, engagement, gender differences

OPEN ACCESS

Edited by:
Catherine Alison Hill, American Association of University Women, USA

Reviewed by:
M. Teresa Anguera, University of Barcelona, Spain
Miriam Lacey, Pepperdine University, USA

****Correspondence:***
Carolina Milesi
milesi-carolina@norc.org

Specialty section:
This article was submitted to Organizational Psychology, a section of the journal Frontiers in Psychology

Received: *01 January 2017*
Accepted: *31 March 2017*
Published: *25 April 2017*

Citation:
Milesi C, Perez-Felkner L, Brown K and Schneider B (2017) Engagement, Persistence, and Gender in Computer Science: Results of a Smartphone ESM Study. Front. Psychol. 8:602. doi: 10.3389/fpsyg.2017.00602

INTRODUCTION

Given the dramatic growth of the computer and technology industries over the past decades, it should come as no surprise that an estimated 1.24 million new computer occupations are expected to be available by the decade's end (Bureau of Labor Statistics, 2013). This is nearly double the rate of job growth projected across all occupational sectors. The need for computer scientists to fill these new jobs, and the requisite training and coding literacy, has become a matter of national importance. Indeed, a federal "Computer Science for All" initiated by President Obama has proposed $4 billion dollars in funding for enhancements in P-12 computer science education, including the training of students and teachers (U. S. Department of Education Office of Innovation and Improvement, 2016).

However, computer science (CS) has actually *declined* in popularity over the last three decades, from 4.3% of postsecondary majors in 1986 to 2.6% in 2012 (NCES, 2012). Women have experienced this decline far more severely than men (Ceci et al., 2014). Only 0.4% of college-bound high school girls express an interest in pursuing CS compared to 3.0% of males (American Association of University Women, 2010). Correspondingly, women represented only 17.6% of CS majors in 2011, down from a peak of 37.1% in 1984 (NCES, 2012). The employment of women in computer and technology industries has also declined, peaking around 35% in the 1980s. In fact, CS is the only STEM field in which women saw a decline in labor representation during this time period (Census, 2013). Even *Google*, which famously purports merit-based hiring practices, recently revealed that only 17% of its technology division is female (Google, 2014). To better understand this disturbing trend, our research uses the Experience Sampling Method (ESM) to (1) understand differences in men and women students' engagement in CS and (2) demonstrate how these differences affect persistence in the field.

Literature Review

The underrepresentation of women in computer science has been much studied but with little consensus as to its cause. Possible suspects are often the same factors attributed to women's lower rates of persistence in many science, technology, engineering, and mathematics (STEM) fields. These include gender differences in aptitude, retention, interest, classroom environment, and of particular interest to our study, student engagement.

Persistence in STEM

Based on a nationally representative sample of college students, Chen (2013) estimated that 48 percent of bachelor's degree students entering STEM fields between 2004 and 2009 had left these fields by spring 2009, either switching to a non-STEM field or exiting college before earning a degree or certificate. Problematically, more women than men leave STEM fields by switching to a non-STEM major (32 vs. 26%), whereas more men than women leave STEM fields by dropping out of college (24 vs. 14%). After college, men are retained in computing and related professions at a rate nearly double that of women (57–28%) in the first four first after undergraduate study (Corbett and Hill, 2015).

Broadly speaking, research has linked STEM attrition to a weak academic background (Astin and Astin, 1992; Lent et al., 2000). For example, enrollment in Advancement Placement (AP) classes and in math classes beyond Algebra 2 have been associated with an increased probability of choosing and persisting in STEM fields (Adelman, 2006). Griffith (2010) showed much of the gender difference in persistence to a STEM degree is eliminated once the analysis controls for academic preparation. Students' academic performance during college is also key to STEM persistence (Strenta et al., 1994; Ost, 2010; Rask, 2010). Recent reports on STEM attrition showed that taking lighter credit loads in STEM courses in the first year in college, taking less challenging math courses in the first year, and performing poorly in STEM classes relative to non-STEM classes increases students' chances of switching out of STEM majors (Chen, 2013, 2015). It is important to note that this study found that even after accounting for academic performance, women are still more likely than men to leave STEM (Chen, 2013).

Researchers have also found that persistence is associated with psychosocial factors related to STEM disposition. For example, self-efficacy in mathematics and science has been shown to be related to students' choice of college major (Porter and Umbach, 2006) and is a positive predictor of persistence within the STEM fields (Schunk and Pajares, 2002). National longitudinal data from the Cooperative Institutional Research Program (CIRP) indicates mathematics self-concept has been an important predictor of undergraduate students' STEM aspirations, although its influence among women is waning (Sax et al., 2015). Students' deep interest and engagement in mathematics is also related to STEM degree attainment (Engberg and Wolniak, 2013). These psychosocial factors have also been widely used to understand gender disparities in STEM. Gender differences in subjective orientations toward mathematics, for example, emerge early in life, and tend to increase throughout students' educational career (Eccles, 1994; Perez-Felkner, 2015), which in turn help to explain the different majors male and female college students choose (Perez-Felkner et al., 2012; Wang et al., 2013).

Persistence in Computer Science

The literature on gender differences in computer science reflects this broader trend. Nearly two decades ago, a meta-analysis of 82 studies found men had more positive attitudes toward computers than women, including greater positive affect and self-efficacy beliefs surrounding their use of computers (Whitley, 1997). Indeed, beliefs matter. According to a recent AAUW report finding women's persistence can be deterred by stereotype-related threats inhibiting women's sense of belonging and implicit biases held by most men majoring in computing, which associate science as a male domain (Corbett and Hill, 2015).

A now classic study at Carnegie Mellon found more women departed from CS majors than men, using 210 interviews with 97 male and female computer science majors (Margolis et al., 2000; Margolis and Fisher, 2002). The authors explain women tended to report experiencing less "intrinsic interest" and single-minded "passion" for programming, irrespective of their initial interest and ability (Margolis and Fisher, 2002). Before entering the major, women CS students at Carnegie Mellon seemed confident in their talent. In comparison to many of their aspiring "boy wonder" peers who seemed to "dream in code" however, women tended to leave in response to lower confidence in face of the stereotype of a particular type of successful CS student and the illusion that they must not have gotten into the major on their own merit (Margolis et al., 2000). Correspondingly, more recent studies using surveys and interviews have identified social isolation, a perceived lack of experience, and a sense of "not belonging" as key barriers preventing women from persisting in their CS studies (Biggers et al., 2008; Powell, 2008; Barker et al., 2009).

Notably, there is evidence these gendered beliefs are malleable. Cohoon (2001) argued that female CS students were retained at rates comparable to males when the CS department had female faculty, strong mentorship, and institutional support. Cheryan et al. (2009) found a less "chilly," more gender-inclusive environment in the CS classroom was sufficient to increase females' interest in CS to levels comparable to their male peers. Despite scant quantitative evidence on chilly STEM environments for women (e.g., Pascarella et al., 1997), qualitative data continues to indicate this phenomenon exists (Allan and Madden, 2006). Even in highly selective institutions, women who perceive a "chilly" instructional climate are more likely to leave mathematics and computer science (Strenta et al., 1994).

Building off the "chilly environment" concept, researchers have attributed gender differences in CS to cultural factors such as prevailing gender stereotypes/expectations and the lack of female mentorship. Cheryan et al. (2015) review this literature and provide evidence for how popular stereotypes and typical representations of computer scientists make the field seem inaccessible or inappropriate for females. Similarly, Leslie et al. (2015) examine the role of "brilliance" in various academic disciplines and show that fields where "innate talent" is perceived to be of utmost value—such as the STEM fields—also have the lowest representation of women, perhaps due to prevailing stereotypes assuming that females lack the required innate or natural math and science abilities. Given this lack of female representation, the work of Hoh (2009) and Drury et al. (2011) stress the importance of female role models in encouraging women to major in STEM fields such as engineering and computer science.

Student Engagement

In higher education, student engagement has long been used as a predictor of student success in college—notably, student retention and persistence (e.g., Harper and Quaye, 2008; Kuh et al., 2008). These studies are often associated with institutional-level studies of "student success" and tend to focus on behavioral measures of student engagement associated with the National Study of Student Engagement (NSSE), conducted annually on undergraduate first- and fourth-year students (see Kuh, 2009). In a major report on student-level outcomes commissioned by the National Center for Education Statistics, Kuh et al. (2006) conceptualize student engagement as being demonstrated by student behaviors—specifically, "in educationally effective practices"—and supported by institutional conditions for learning, each of which are influenced by additional external and background factors. Building on the work of other major scholars in higher education (e.g., Pascarella, 1980; Pace, 1982; Astin, 1984), these practices are defined as: (1) faculty-student interaction, (2) peer interaction fostering learning, (3) experiences with diversity, (4) cocurricular activities, and (5) student satisfaction with the institution (Kuh et al., 2006). Using the Multiple Institution Database for Investigating Engineering Longitudinal Development, Ohland et al. (2008) use these and related NSSE measures to capture engagement, finding it to be a critical "precursor" for persistence in engineering—in attracting and retaining students. While these studies reliably capture large-scale self-reports of students' behavior over the past year, there are limitations in the ability of these surveys to measure students' lived experience in college (Porter, 2011).

Few studies have looked beyond these behavioral measures of student engagement to assess its effects on longer-term decisions regarding their college majors, careers, and future goals (Harackiewicz et al., 2000; Shernoff and Hoogstra, 2001; Gasiewski et al., 2012). Even fewer have examined the classroom engagement of college students (Mills and Fullagar, 2008; Steele and Fullagar, 2009; Asakawa, 2010). Gasiewski et al. (2012) offered a multidimensional perspective in a rigorous mixed method study of students studying their academic engagement in STEM gateway courses. Nevertheless, the authors' main findings were behaviorally-oriented: authors found academic engagement was positively associated with (1) signals from STEM faculty "gatekeepers" that they were open to students' success (i.e., not being chilly) and (2) proactive student academic behavior (e.g., asking questions, seeking assistance). The studies noted thus far examine how student behaviors and institutional supports affect students' engagement and in some cases longer-term outcomes. They tend not however to assess how students experience engagement in academic and related activities, in particular in relation to their persistence in specific STEM gateway courses.

We build on this literature by providing a more precisely grounded definition of "engagement" with which to examine our longitudinal case study of computer science women at two institutions. Our study is the first to examine student engagement in CS as a function of their level of interest, challenge, and skill with college coursework by using the ESM to collect real-time data on student experiences. Specifically, our study approaches the operationalization of engagement in "flow" theory as a state in which high challenge is matched by high skill (Csikszentmihalyi, 1990). Shernoff et al. (2003) show that levels of engagement in high school vary substantially based on academic conditions, also noting the importance of engagement for keeping students' stimulated and eager to learn. Similar findings with regards to the positive effects of engagement on motivation and learning have been found at all stages of the K-12 education system (Marks, 2000; Rathunde and Csikszentmihalyi, 2005; Schweinle et al., 2006; Shernoff and Schmidt, 2008). Here, we apply this approach to college students taking computer science classes, with the intent of better understanding how differences in men and women's engagement in CS may help account for gender disparities in students' success in the field.

METHODOLOGY

Data

The data for this study were collected from a sample of students majoring (or interested in majoring) in computer science/engineering at two Research I institutions in the Midwest with highly rated computer science/engineering programs, one private (School A) and one public (School B). Data were collected through three primary instruments: (1) a real-time survey, based on the ESM, prompted and administered through smartphones on Fall 2013 and Spring 2014; (2) a pre-survey distributed to students in Fall 2013 prior to their receiving the smartphones aimed at obtaining students' background information and probing their prior academic and computer-science related experiences; and (3) students' administrative records on their declared majors, courses, grades, and credits accumulated in computer science from Fall 2013 through Fall 2014.

As compared to other methods of observational data, the ESM allows us to evaluate the engagement of students during varied activities and environments throughout the course of the day, all in real-time (Csikszentmihalyi and Larson, 1987; Hektner et al., 2007; Zirkel et al., 2015). ESM acquires information on where, when, and how a student is feeling at that moment. These responses can be aggregated within individuals over time. ESM is often referred to as an Ecological Momentary Assessment (EMA) as it is conducted in a natural setting that is outside of a laboratory condition. Over the course of a week during Fall 2013 and again during Spring 2014, participating students received smartphones programmed with an ESM app that beeped eight times a day, at which point they were prompted to fill out a short questionnaire including open-ended and scaled items (see Appendix in Supplementary Material for full ESQ). The purpose of the ESQ was to obtain information about students' momentary cognitions, affect, and behaviors both in and outside of academic contexts. Each questionnaire asked students to indicate where they were, who they were with, and what they were doing. Additional detail was requested regarding their location and main activity. Students were also asked whether their activity entailed the use of technology as well as a series of 15 questions probing how they felt about the activity on a Likert scale.

Each institution's registrar and admissions office provided information on student's characteristics and their coursetaking behavior from Fall 2013 through Fall 2014.[1] Administrative data provided information on students' academic year, college courses taken, grades received, cumulative college GPA, high school GPA, SAT, and/or ACT scores, home addresses, high school location, student race/ethnicity, athlete status, and whether the student is a US citizen, first generation college student, or transfer student.

Outcome Variables

This study relies on administrative data to measure students' persistence in computer science in two different ways. The first measures the percentage of credit hours coming from CS classes in Fall 2014, a year after students began participating in this study and one term after students were asked to participate in the ESM data collection. As an example, if a student took 6 credit hours in CS out of the 12 credit hours he completed in Fall 2014, he would be counted as having 0.50 credit hours in CS. The second measure compares the percentage of credit hours in computer science across two terms: Fall 2013 and Fall 2014. Students' persistence in CS was categorized as a decrease, increase, or no change in the percentage of credit hours in CS. Following the example mentioned above, if that same student had taken 3 of the 12 credit hours in CS a year earlier (Fall 2013), he would be counted as having increased his involvement in CS from 0.25 to 0.50 percentage of credit hours in CS. We used CS credit hours rather than CS courses in order to standardize coursetaking measures across schools.

[1]This study was conducted in compliance with institutional review board protocols for human subjects research.

Covariates and Other Measures

Responses to the ESM questionnaire were used to measure variations in students' levels of engagement across contexts. Based on the concept of "flow," we define engagement as the combination of challenge, interest, and skill. Specifically, we rely on student's responses to these three questions:

- Was this activity *challenging* to you?
- Was this activity *interesting* to you?
- How *skilled* are you in this activity?

Every time students were beeped, they reported whether the current activity ranged from "not at all" to "very" (scaled from 1 through 6) challenging, interesting, and skilled. We calculated the average levels of challenge, interest, and skill for each student. In this analysis, we combine students' ESM reports from Fall 2013 and Spring 2014. Because we are particularly interested in students' engagement across contexts, we calculated these averages separately for (i) beeps in which the student reported being involved in a CS academic activity, including CS classes or labs, studying or doing homework related to CS, and activities related to CS such as programming, coding, or learning a CS language; (ii) beeps in which the student reported being involved in a non-CS academic activity, such as classes, labs, homework, group projects, and studying subjects other than CS. We did not include beeps in which the student reported being in a non-academic activity such as socializing or at work.

Analytic Sample

In the Fall of 2013 we recruited a total of 167 students across the two postsecondary institutions involved in this study. We dropped from the analysis students who were no longer enrolled in Fall 2014 either because they had graduated, were suspended, or withdrew from the university ($n = 27$). We also dropped from the analysis students with no eligible beeps either because beeps were responded to outside of the study period or had no information that would allow us to code the main activity ($n = 2$). Finally, we dropped students with eligible beeps but with zero beep responses in either CS-academic activities or non-CS-academic activities ($n = 19$). Our analytic sample is composed of 123 students who had on average 6.7 beeps in CS-academic activities and 26.5 beeps in non-CS-academic activities ("other" academic activities).

Table 1 below shows key background characteristics of students in our analytic sample. About one-third of the sample at both universities was women, who were oversampled given the relative lack of female computer science majors. Over three-fourths of the students were either white or Asian, and just over 12% belonged to an underrepresented racial or ethnic minority group in STEM. Though freshmen account for a slightly larger percentage of students at School B than School A, the overall distribution of students among cohorts looks similar across universities, with about 70% of students being either freshmen or sophomores. Notably, the two schools differ in the proportion of students who have declared a CS-related major, primarily because School A does not require students to declare majors in their freshman and sophomore years. At both universities, just under one-quarter of declared majors chose a discipline that did not include computer science. However, the great majority of these were enrolled in a CS class in Fall 2013.

We compared our analytic sample to the national population of students majoring in CS using the Educational Longitudinal Study (National Center for Education Statistics, 2002), a nationally representative, longitudinal study of 10th graders in 2002, followed throughout secondary and postsecondary years. Both ELS and our dataset demonstrate the extent to which White and Asian students continue to pursue CS degrees, while minority students continue to be underrepresented. Because our study aimed to study gender disparities in the field, we oversampled female students and therefore, have a higher representation of women than ELS. Our sample is similar to ELS in students' career attainment values and subjective orientations toward mathematics. An important difference with ELS is the fact that students in our sample have about 15 percent higher SAT match and verbal scores than students majoring in CS as sophomores in most, highly, and very competitive institutions (results available upon request).

TABLE 1 | Demographic and academic characteristics of students in analytic sample, by institution.

	School A		School B		Schools A and B combined	
	n	%	*n*	%	*n*	%
GENDER						
Male	45	68.18	37	64.91	82	66.67
Female	21	31.82	20	35.09	41	33.33
RACE/ETHNICITY						
White	28	42.42	45	78.95	73	59.35
Asian	16	24.24	6	10.53	22	17.89
Underrepresented in STEM*	11	16.67	4	7.02	15	12.20
International	5	7.58	1	1.75	6	4.88
Unspecified	6	9.09	1	1.75	7	5.69
COHORT						
Freshmen	24	36.36	25	43.86	49	39.84
Sophomore	21	31.82	16	28.07	37	30.08
Junior	21	31.82	16	28.07	37	30.08
MAJOR IN FALL 2013						
Computer science**	16	24.24	46	80.70	62	50.41
Physical science, engineering	6	9.09	9	15.79	15	12.20
MATH						
Other STEM	6	9.09	0	0.00	6	4.88
Non-STEM	2	3.03	2	3.51	36	29.27
Common year/Undeclared	36	54.55	0	0.00	4	3.25
Total	66		57		123	

Source: School A and School B Registrar.
Includes Hispanic, Black or African American, Hawaiian or Pacific Islander, Native American, and Multiple Races.
*** In the case of a handful of students who reported multiple majors, the student was counted as a computer science major if one of the majors recorded was computer science related.*

Analytic Strategy

The study was designed as a pilot to determine the feasibility of analyzing the association between students' engagement and their persistence in CS. Since we did not find any meaningful differences in student characteristics across schools or any differences in their patterns of engagement, this analysis combines students across institutions. We carried out multivariate analysis for each of the dependent variables specified above. We estimated an OLS regression predicting the percentage of CS credits in Fall 2014, and a multinomial logistic regression predicting the change in CS credits from Fall 2013 to Fall 2014. In this second regression model, the dependent variable had three mutually exclusive categories: "increase in percentage of CS credit hours," "same percentage of CS credit hours," and "decrease in percentage of CS credit hours;" we used the latter as the reference category. Because we are particularly interested in how engagement affects female and male students differently, we estimated separate models by gender.

RESULTS

Table 2 shows mean and standard deviation of the three items that measure student engagement, separately for computer science academic activities and other academic activities. Both male and female students report higher levels of challenge and interest in academic activities related to CS than academic activities related to other subjects. The reverse is true for the third component of engagement: both male and female students report feeling less skilled in CS than in non-CS academic activities. It is important to note that there are no statistically significant differences between men and women in either the reports of challenge, interest, or skill.

Table 3 displays descriptive statistics for the two different measures of persistence in computer science described above. **Table 3A** shows that, on average, male and female students in our study took about a third of their credit hours in CS in Fall 2014. One in four students did not take any CS credit hours in Fall 2014 and also one in four students took more than half of their credit hours in CS. The distribution of this outcome differs slightly by gender: while half of women took 46 percent of their credit hours

TABLE 2 | Student engagement, by context and gender.

	Females		Males	
	Mean	Std. Dev.	Mean	Std. Dev.
COMPUTER SCIENCE ACADEMIC ACTIVITIES				
Was this activity challenging to you?	3.92	1.18	3.92	1.02
Was this activity interesting to you?	3.95	1.14	4.23	1.00
How skilled are you in this activity?	4.21	0.63	4.19	0.85
ACADEMIC ACTIVITIES IN NON-COMPUTER SCIENCE SUBJECTS				
Was this activity challenging to you?	3.31	0.58	3.16	0.69
Was this activity interesting to you?	3.72	0.71	3.67	0.68
How skilled are you in this activity?	4.39	0.54	4.50	0.50

ESM responses on 6-point scale, from "not at all" (1) to "very" (6).

TABLE 3 | Persistence in Computer Science, by gender.

A. Percentage of credit hours in Computer Science during Fall 2014.

	Females	Males	Total
n	41	82	123
Mean	0.361	0.343	0.349
Std. Dev.	0.283	0.292	0.288
25th percentile	0.000	0.000	0.000
Median	0.462	0.258	0.286
75th percentile	0.500	0.533	0.500

B. Change in percentage of credit hours in Computer Science from Fall 2013 to Fall 2014.

	Females		Males		Total	
	n	%	*n*	%	*n*	%
No change	31	38	16	39	47	38
Increase	32	39	14	34	46	37
Decrease	19	23	11	27	30	24
Total	82	100	41	100	123	100

TABLE 4 | OLS regression estimates predicting percentage of credit hours in computer science in Fall 2014, by gender.

	Females			Males		
	Coefficient	Std. Err.	$P > \|t\|$	Coefficient	Std. Err.	$P > \|t\|$
COMPUTER SCIENCE ACADEMIC ACTIVITIES						
Challenge	0.00	0.06	0.99	0.05	0.04	0.24
Interest	−0.01	0.05	0.85	0.03	0.04	0.42
Skill	0.14	0.08	0.08	−0.02	0.05	0.74
ACADEMIC ACTIVITIES IN NON-COMPUTER SCIENCE SUBJECTS						
Challenge	0.02	0.10	0.82	−0.04	0.05	0.47
Interest	0.02	0.06	0.80	−0.03	0.05	0.52
Skill	−0.03	0.09	0.75	0.03	0.06	0.60
Constant	−0.21	0.62	0.73	0.22	0.33	0.52

in CS, half of male students took 25 percent or more of their credit hours in CS. **Table 3B** shows that approximately 38 percent of students had the *same* percentage of CS credit hours in Fall 2014 as in Fall 2013; 37 percent of students *increased* the percentage of CS credit hours during this period; and about 24 percent of students *reduced* their CS credit hours 1 year later. Despite the underrepresentation of women in CS, women in our study were equally likely to persist in CS. In fact, throughout the course of the year, women tended to increase their CS coursetaking slightly more than men and to decrease their CS coursetaking slightly less than men.

Table 4 displays OLS regression estimates predicting the percentage of credit hours in Computer Science. Using the dependent variable described in **Table 3A**, these estimates stem from two separate models, one for women and one for men. Estimates for men do not show any statistically significant association between engagement and the percentage of credit hours in CS a term after the ESM data collection ended, but there is a positive association between male students' self-reports on how skilled and challenged they feel in CS and their subsequent persistence in CS. Results show that among women, feeling skilled in CS academic activities has a positive and statistically significant association with persistence in CS.

Table 5 displays estimates from a multinomial logistic regression predicting change in the percentage of credit hours in computer science from Fall 2013—when the ESM study began—to Fall 2014—a term after the ESM data collection ended. These models use the dependent variable described in **Table 3B** and are estimated separately for women and men. Estimates show that among men, students who report feeling more skilled in CS academic activities are also more likely to increase their percentage of credit hours in CS over the course of a year. Consistent with the OLS regression results, these estimates show that among men, while challenge in CS academic activities is positively associated with an increase in the percentage of credit hours in CS, challenge in other academic activities is negatively associated with an increase in the percentage of credit hours in CS. This pattern of association between engagement and persistence is not observable among women. However, it is important to note that female students who reported feeling more skilled in academic activities related to subjects other than CS are more likely to increase their CS credit hours.

CONCLUSION

This study uses the ESM to determine how male and female students at two different postsecondary institutions experience engagement in academic settings and how that engagement affects their persistence in pursuing a computer science degree. Results are robust across two alternative measures of persistence in computer science: Among women, reporting feeling more skilled in CS and non-CS academic activities is positively associated with persistence in CS. Among men, while challenge in CS academic activities is positively associated with persistence, challenge in non-CS academic activities is negatively associated with persistence in CS. These results are consistent with explanations of the leaky STEM pipeline in college attributed to (1) stereotypes of women as being less skilled than men in math and science and (2) cultural norms that portray computer science as being more "appropriate" for men than women. When faced with challenging CS coursework, male students redouble their efforts while female students who perceive their skills to be lacking tend to drop out. A third possibility is that women who begin college as a CS major tend to find computer science less intrinsically rewarding than men or perhaps fear that their gender will preclude a successful career in CS regardless of their passion for the field.

However, our study was originally conceived as a pilot to demonstrate "proof-of-concept" rather than yield definitive results. In that regard, we were successful at recruiting men and women computer science college students, implementing the ESM data collection, and conducting analysis that links ESM with administrative data on students' coursetaking behavior.

TABLE 5 | Multinomial logistic regression estimates change in percentage of credit hours in computer science Fall 2013-Fall 2014, by gender.

	Females				Males			
	Coeff.	Std. err.	Odds ratio	P > |z|	Coeff.	Std. err.	Odds ratio	P > |z|
INCREASE IN CS CREDIT HOURS VS. NO CHANGE								
Computer Science Academic Activities								
Challenge	−0.13	0.49	0.88	0.79	0.55	0.36	1.73	0.12
Interest	0.05	0.47	1.05	0.92	−0.21	0.32	0.81	0.51
Skill	0.66	0.71	1.93	0.35	0.69	0.42	1.99	0.10
Academic activities in non-Computer Science Subjects								
Challenge	1.76	0.94	5.81	0.06	−0.39	0.44	0.67	0.37
Interest	−0.73	0.57	0.48	0.20	−0.65	0.42	0.52	0.12
Skill	0.16	0.80	1.18	0.84	0.70	0.53	2.01	0.19
Constant	−7.81	5.75	0.00	0.17	−3.30	2.73	0.04	0.23
DECREASE IN CS CREDIT HOURS VS. NO CHANGE								
Computer Science Academic Activities								
Challenge	0.18	0.64	1.19	0.78	−0.04	0.38	0.96	0.91
Interest	0.83	0.63	2.29	0.19	0.00	0.36	1.00	0.99
Skill	−1.43	1.02	0.24	0.16	0.49	0.47	1.63	0.30
Academic activities in non-Computer Science Subjects								
Challenge	−0.02	1.01	0.98	0.99	0.91	0.57	2.49	0.11
Interest	−0.91	0.66	0.40	0.17	−0.51	0.49	0.60	0.29
Skill	0.73	1.02	2.08	0.47	0.18	0.62	1.19	0.77
Constant	1.55	5.78	4.69	0.79	−5.04	3.40	0.01	0.14

Our analysis is limited on three important counts. First, the small sample size does not allow us to conduct more complex analysis that takes into account additional student characteristics or coursetaking behaviors associated with persistence in CS, such as race/ethnicity, first generation status, or coursework and performance during the first year in college. Second, our study does not capture the wide range of postsecondary institutions that offer computer science programs. The institutions included in this study have relatively high selectivity, and the students who attend these institutions have stronger academic backgrounds than their national counterparts. Given that a solid academic background has been linked to CS persistence, it is not surprising that students in our sample exhibit higher rates of persistence in CS than national estimates would suggest. Third, although longitudinal by design, our 1-year data collection period does not allow us to track persistence to degree attainment for earlier cohorts of students or identify students who failed to persist for the juniors in our sample. Expanding this study across different types of institutions and over a longer time period would enable us to conduct further analyses on the relationship between engagement and persistence, ultimately providing insight into the factors that determine why more men than women obtain degrees in computer science.

ETHICS STATEMENT

This study was carried out in accordance with the recommendations of the Institutional Review Board (IRB) of NORC at the University of Chicago with written informed consent from all subjects. All subjects gave written informed consent in accordance with the Declaration of Helsinki. The protocol was approved by the IRB of NORC at the University of Chicago.

AUTHOR CONTRIBUTIONS

All authors contributed extensively to the work presented in this paper. CM conceptualized analysis, managed data collection, carried out analysis, interpreted results, and wrote initial draft. LP conceptualized analysis, reviewed various drafts, and co-wrote final paper. BS conceived and designed overall study, conceptualized theoretical framework, reviewed preliminary and final results, and co-wrote paper. KB conceptualize analysis, co-managed data collection, reviewed results, and co-wrote final paper.

FUNDING

This material is based upon work supported by the National Science Foundation under Grant Numbers HRD-1232139 and DRL-0815295. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: http://journal.frontiersin.org/article/10.3389/fpsyg.2017.00602/full#supplementary-material

REFERENCES

Adelman, C. (2006). *The Toolbox Revisited: Paths to Degree Completion from High School Through College*. Washington, DC: U.S. Department of Education.

Allan, E. J., and Madden, M. (2006). Chilly classrooms for female undergraduate students: a question of method? *J. High. Educ.* 77, 684–711. doi: 10.1353/jhe.2006.0028

American Association of University Women (2010). *Why So Few? Women in Science Technology Engineering and Mathematics.* Available online at: http://www.aauw.org/files/2013/02/Why-So-Few-Women-in-Science-Technology-Engineering-and-Mathematics.pdf

Asakawa, K. (2010). Flow experience, culture, and well-being: how do autotelic Japanese college students feel, behave, and think in their daily lives? *J. Happiness Stud.* 11, 205–223. doi: 10.1007/s10902-008-9132-3

Astin, A. W. (1984). Student involvement: a developmental theory for higher education. *J. Coll. Stud. Pers.* 25, 297–308.

Astin, A. W., and Astin, H. S. (1992). *Undergraduate Science Education: The Impact of Different College Environments on the Educational Pipeline in the Sciences*. Los Angeles, CA: The Higher Education Research Institute, University of California.

Barker, L. J., McDowell, C., and Kalahar, K. (2009). "Exploring factors that influence computer science introductory course students to persist in the major," in *ACM SIGCSE Bulletin*, Vol. 41 (Chattanooga, TN: ACM), 153–157.

Biggers, M., Brauer, A., and Yilmaz, T. (2008). "Student perceptions of computer science: a retention study comparing graduating seniors with cs leavers," in *ACM SIGCSE Bulletin,* Vol. 40 (Portland, OR: ACM), 402–406.

Bureau of Labor Statistics (2013). *Employment by Detailed Occupation*. Available online at: http://www.bls.gov/emp/ep_table_102.htm

Ceci, S. J., Ginther, D. K., Kahn, S., and Williams, W. M. (2014). Women in academic science: a changing landscape. *Psychol. Sci. Public Interest* 15, 75–141. doi: 10.1177/1529100614541236

Census (2013). *Disparities in STEM Employment by Sex, Race, and Hispanic, Origin*. United States Census Bureau. Available online at: http://www.census.gov/prod/2013pubs/acs-24.pdf

Chen, X. (2013). *STEM attrition: College students' paths into and out of STEM fields. (NCES 2014-001)*. Washington, DC: National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education. Available online at: http://nces.ed.gov/pubs2014/2014001rev.pdf

Chen, X. (2015). STEM attrition among high-performing college students: scope and potential causes. *J. Technol. Sci. Educ.* 5, 41–59. doi: 10.3926/jotse.136

Cheryan, S., Master, A., and Meltzoff, A. N. (2015). Cultural stereotypes as gatekeepers: increasing girls' interest in computer science and engineering by diversifying stereotypes. *Front. Psychol.* 6:49. doi: 10.3389/fpsyg.2015.00049

Cheryan, S., Plaut, V. C., Davies, P. G., and Steele, C. M. (2009). Ambient belonging: how stereotypical cues impact gender participation in computer science. *J. Pers. Soc. Psychol.* 97, 1045. doi: 10.1037/a0016239

Cohoon, J. M. (2001). Toward improving female retention in the computer science major. *Commun. ACM* 44, 108–114. doi: 10.1145/374308.374367

Corbett, C., and Hill, C. (2015). *Solving the Equation: The Variables for Women's Success in Engineering and Computing*. Washington, DC: American Association of University Women (AAUW). Available online at: http://www.aauw.org/files/2015/03/Solving-the-Equation-report-nsa.pdf

Csikszentmihalyi, M. (1990). *Flow: The Psychology of Optimal Experience*. New York, NY: Harper Perennial.

Csikszentmihalyi, M., and Larson, R. (1987). Validity and reliability of the experience sampling method. *J. Nerv. Ment. Dis.* 175, 525–536. doi: 10.1097/00005053-198709000-00004

Drury, B. J., Siy, J. O., and Cheryan, S. (2011). When do female role models benefit women? The importance of differentiating recruitment from retention in STEM. *Psychol. Inq.* 22, 265–269. doi: 10.1080/1047840X.2011.620935

Eccles, J. S. (1994). Understanding women's educational and occupational choices: applying the Eccles et al. Model of achievement-related choices. *Psychol. Women Q.* 18, 585–609. doi: 10.1111/j.1471-6402.1994.tb01049.x

Engberg, M., and Wolniak, G. (2013). College student pathways to the STEM disciplines. *Teach. Coll. Rec.* 15, 1–27.

Gasiewski, J. A., Eagan, M. K., Garcia, G. A., Hurtado, S., and Chang, M. J. (2012). From gatekeeping to engagement: a multicontextual, mixed method study of student academic engagement in introductory STEM courses. *Res. High. Educ.* 53, 229–261. doi: 10.1007/s11162-011-9247-y

Google (2014). *Diversity at Google.* Available online at: http://www.google.com/diversity/at-google.html

Griffith, A. (2010). Persistence of women and minorities in STEM field majors: is it the school that matters? *Econ. Educ. Rev.* 29, 911–922. doi: 10.1016/j.econedurev.2010.06.010

Harackiewicz, J. M., Barron, K. E., Tauer, J. M., Carter, S. M., and Elliot, A. J. (2000). Short-term and long-term consequences of achievement goals: predicting interest and performance over time. *J. Educ. Psychol.* 92:316. doi: 10.1037/0022-0663.92.2.316

Harper, S. R., and Quaye, S. J. (2008). *Student Engagement in Higher Education: Theoretical Perspectives and Practical Approaches for Diverse Populations*. New York, NY: Routledge.

Hektner, J. M., Schmidt, J. A., and Csikszentmihalyi, M. (2007). *Experience Sampling Method: Measuring The Quality Of Everyday Life*. Thousand Oaks, CA: SAGE Publications Inc.

Hoh, Y. K. (2009). Using notable women in environmental engineering to dispel misperceptions of engineers. *Int. J. Environ. Sci. Educ.* 4, 117–131.

Kuh, G. D. (2009). The national survey of student engagement: conceptual and empirical foundations. *New Dir. Inst. Res.* 2009, 5–20. doi: 10.1002/ir.283

Kuh, G. D., Cruce, T. M., Shoup, R., Kinzie, J., and Gonyea, R. M. (2008). Unmasking the effects of student engagement on first-year college grades and persistence. *J. High. Educ.* 79, 540–563. doi: 10.1353/jhe.0.0019

Kuh, G. D., Kinzie, J., Buckley, J. A., Bridges, B. K., and Hayek, J. C. (2006). *What Matters to Student Success: A Review of the Literature*. Washington, DC: National Postsecondary Education Cooperative, National Center for Education Statistics. Available online at: http://nces.ed.gov/npec/pdf/kuh_team_report.pdf

Lent, R. W., Brown, S. D., and Hackett, G. (2000). Contextual supports and barriers to career choice: a social cognitive analysis. *J. Couns. Psychol.* 47, 36–49. doi: 10.1037/0022-0167.47.1.36

Leslie, S. J., Cimpian, A., Meyer, M., and Freeland, E. (2015). Expectations of brilliance underlie gender distributions across academic disciplines. *Science* 347, 262–265. doi: 10.1126/science.1261375

Margolis, J., and Fisher, A. (2002). *Unlocking the Clubhouse: Women in Computing*. Cambridge, MA: MIT Press.

Margolis, J., Fisher, A., and Miller, F. (2000). The anatomy of interest: women in undergraduate computer science. *Women's Stud. Q.* 28, 104–127.

Marks, H. M. (2000). Student engagement in instructional activity: patterns in the elementary, middle, and high school years. *Am. Educ. Res. J.* 37, 153–184. doi: 10.3102/00028312037001153

Mills, M. J., and Fullagar, C. J. (2008). Motivation and flow: toward an understanding of the dynamics of the relation in architecture students. *J. Psychol.* 142, 533–556. doi: 10.3200/JRLP.142.5.533-556

National Center for Education Statistics. (2002). *Education Longitudinal Study of 2002*. Washington, DC: U.S Department of Education.

NCES (2012). *Bachelor's Degrees Conferred by Degree-Granting Institutions, by Field of Study: Selected Years, 1970-71 Through 2010-11.* National Center for Education Statistics. Available online at: http://nces.ed.gov/programs/digest/d12/tables/dt12_313.asp

Ohland, M. W., Sheppard, S. D., Lichtenstein, G., Eris, O., Chachra, D., and Layton, R. A. (2008). Persistence, engagement, and migration in engineering programs. *J. Eng. Educ.* 97, 259–278. doi: 10.1002/j.2168-9830.2008.tb00978.x

Ost, B. (2010). The role of peers and grades in determining major persistence in the sciences. *Econ. Educ. Rev.* 29, 923–934. doi: 10.1016/j.econedurev.2010.06.011

Pace, C. R. (1982). *Achievement and the Quality of Student Effort National Commission on Excellence in Education (ED).* Washington, DC. Available online at: http://eric.ed.gov/?id=ED227101

Pascarella, E. T. (1980). Student-faculty informal contact and college outcomes. *Rev. Educ. Res.* 50, 545–595. doi: 10.3102/00346543050004545

Pascarella, E. T., Hagedorn, L. S., Whitt, E. J., Yeager, P. M., Edison, M. I., Terenzini, P. T., et al. (1997). Women's perceptions of a 'chilly climate' and their cognitive outcomes during the first year of college. *J. Coll. Stud. Dev.* 38, 109–124.

Perez-Felkner, L. (2015). "Achievement differences and gender in science education," in *Encyclopedia of Science Education*, ed R. Gunstone (Dordrecht: Springer), 9–10.

Perez-Felkner, L., McDonald, S.-K., Schneider, B., and Grogan, E. (2012). Female and male adolescents' subjective orientations to mathematics and their influence on postsecondary majors. *Dev. Psychol.* 48, 1658–1673. doi: 10.1037/a0027020

Porter, S. R. (2011). Do college student surveys have any validity? *Rev. High. Educ.* 35, 45–76. doi: 10.1353/rhe.2011.0034

Porter, S. R., and Umbach, P. D. (2006). College major choice: an analysis of person–environment fit. *Res. High. Educ.* 47, 429–449. doi: 10.1007/s11162-005-9002-3

Powell, R. M. (2008). "Improving the persistence of first-year undergraduate women in computer science," in *ACM SIGCSE Bulletin,* vol. 40 (Portland, OR: ACM), 518–522.

Rask, K. (2010). Attrition in STEM fields at a liberal arts college: the importance of grades and pre-collegiate preferences. *Econ. Educ. Rev.* 29, 892–900. doi: 10.1016/j.econedurev.2010.06.013

Rathunde, K., and Csikszentmihalyi, M. (2005). Middle school students' motivation and quality of experience: a comparison of Montessori and traditional school environments. *Am. J. Educ.* 111, 341–371. doi: 10.1086/428885

Sax, L. J., Kanny, A. M., Riggers-Piehl, T. A., Whang, H., and Paulson, L. N. (2015). "But i'm not good at math": the changing salience of mathematical self-concept in shaping women's and men's STEM aspirations. *Res. High. Educ.* 56, 813–842. doi: 10.1007/s11162-015-9375-x

Schunk, D. H., and Pajares, F. (2002). "The development of academic self-efficacy," in *Development of Achievement Motivation*. A Volume in the Educational Psychology Series, eds A. Wigfield and J. S. Eccles (San Diego, CA: Academic Press), 15–31.

Schweinle, A., Meyer, D. K., and Turner, J. C. (2006). Striking the right balance: students' motivation and affect in elementary mathematics. *J. Educ. Res.* 99, 271–294. doi: 10.3200/JOER.99.5.271-294

Shernoff, D. J., Csikczentmihalyi, M., Schneider, B., and Shernoff, E. S. (2003). Student engagement in high school classrooms from the perspective of flow theory. *Sch. Psychol. Q.* 18, 158–176. doi: 10.1521/scpq.18.2.158.21860

Shernoff, D. J., and Hoogstra, L. (2001). Continuing motivation beyond the high school classroom. *New Dir. Child Adolesc. Dev.* 2001, 73–88. doi: 10.1002/cd.26

Shernoff, D. J., and Schmidt, J. A. (2008). Further evidence of an engagement–achievement paradox among US high school students. *J. Youth Adolesc.* 37, 564–580. doi: 10.1007/s10964-007-9241-z

Steele, J. P., and Fullagar, C. J. (2009). Facilitators and outcomes of student engagement in a college setting. *J. Psychol.* 143, 5–27. doi: 10.3200/JRLP.143.1.5-27

Strenta, A. C., Elliott, R., Adair, R., Matier, M., and Scott, J. (1994). Choosing and leaving science in highly selective institutions. *Res. High. Educ.* 35, 513–547. doi: 10.1007/BF02497086

U. S. Department of Education Office of Innovation and Improvement (2016). *Computer Science for All*. Available online at: https://obamawhitehouse.archives.gov/blog/2016/01/30/computer-science-all

Wang, M. T., Eccles, J. S., and Kenny, S. (2013). Not lack of ability but more choice: individual and gender differences in choice of careers in science, technology, engineering, and mathematics. *Psychol. Sci.* 24, 770–775. doi: 10.1177/0956797612458937

Whitley, B. E. Jr. (1997). Gender differences in computer-related attitudes and behavior: a meta-analysis. *Comput. Hum. Behav.* 13, 1–22. doi: 10.1016/S0747-5632(96)00026-X

Zirkel, S., Garcia, J. A., and Murphy, M. C. (2015). Experience-sampling research methods and their potential for education research. *Educ. Res.* 44, 7–16. doi: 10.3102/0013189X14566879

Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Psychology

EMPIRICAL STUDY
published: 24 October 2017
doi: 10.3389/fpsyg.2017.01681

Gender-Specific Covariations between Competencies, Interest and Effort during Science Learning in Virtual Environments

Eva Christophel and Wolfgang Schnotz*

Department of Psychology, University of Koblenz and Landau, Landau, Germany

Women are still underrepresented in engineering courses although some German universities offer separate women's engineering courses which include virtual STEM learning environments. To outline information about fundamental aspects relevant for virtual STEM learning, one has to reveal which similarities both genders in virtual learning show. Moreover, the question arises as to whether there are in fact differences in the virtual science learning of female and male learners. Working with virtual STEM learning environments requires strategic and arithmetic-operative competences. Even if we assume that female and male learners have similar competences levels, their correlational pattern of competences, motivational variables, and invested effort during virtual STEM learning might differ. If such gender differences in the correlations between cognitive and motivational variables and learning behavior were revealed, it would be possible to finetune study conditions for female students in a separate engineering course and shape virtual STEM learning in a more gender-appropriate manner. That might support an increase in the number of women in engineering courses. To reveal the differences and similarities between female and male learners, a field study was conducted with 56 students (female = 27, male = 29) as part of the *Open MINT Labs* project (the German term for Open STEM Labs, OML). The participants had to complete a virtual STEM learning environment during their regular science lessons. The data were collected with questionnaires. The results revealed that the strategic competences of both genders were positively correlated with situational interest in the virtual learning environment. This result shows the big impact strategic competences have for both genders regarding their situational interest. In contrast, the correlations between mental effort and competences differed between female and male participants. Especially female learners' mental effort decreased if they had more strategic competences. On the other hand, female learners' mental effort increased if they had more arithmetic-operative competences. All in all, female learners seem to be more sensitive to differences in their strategic and arithmetic-operative competences regarding their mental effort. These results imply that the implementation of separate women's engineering courses could be an interesting approach.

Keywords: virtual science learning environments, situational interest, mental effort, arithmetic-operative competences, strategic competences, facilitating function, enabling function, gender

OPEN ACCESS

Edited by:
Kathleen Buse, Advancing Women in STEM, United States

Reviewed by:
Sigrid Schmitz, Humboldt-Universität zu Berlin, Germany
Catherine Alison Hill, American Association of University Women, United States

***Correspondence:**
Eva Christophel
eva.christophel@ph-freiburg.de

Specialty section:
This article was submitted to Gender, Sex and Sexuality Studies, a section of the journal Frontiers in Psychology

Received: *24 October 2016*
Accepted: *12 September 2017*
Published: *24 October 2017*

Citation:
Christophel E and Schnotz W (2017) Gender-Specific Covariations between Competencies, Interest and Effort during Science Learning in Virtual Environments. Front. Psychol. 8:1681. doi: 10.3389/fpsyg.2017.01681

INTRODUCTION

Students differ in their preferences for specific subjects and these differences seem to be partly correlated with gender (Buse and Bilimoria, 2014). In Germany, for example, only 21 percent of female student beginners in 2014 were enrolled in STEM courses to obtain an engineering position (Statistisches Bundesamt, 2016). On the other hand, 44 percent of student beginners in chemistry and 48 percent of student beginners in mathematics were female (Kompetenzzentrum Technik-Diversity-Chancengleichheit e.V, 2015). Indeed, various studies have found that boys have somewhat higher spatial skills than girls, whereas girls have somewhat higher verbal skills and read slightly better than boys (Halpern, 2012). However, recent research revealed that such cognitive differences changing; moreover, the data depending on different tasks characteristics (Miller and Halpern, 2014). Additionally, recent research has indicated that such an essentialist view of social categories such as gender is highly problematic as it presupposes the existence of natural, clear-cut categories with relatively time-stable properties. There is little support for this essentialist view, especially from the side of neuroscience. It has proved difficult to replicate studies on gender differences in the functional organization of brain regions related to specific cognitive skills, which implies that research findings on this issue need to be reflected very carefully (Rippon et al., 2014). Contrary to the assumption of essential differences, Hyde recently concluded from a meta-analysis of gender-specific studies that "male and females are similar on most, but not all psychological variables" (Hyde, 2005, p. 581); this resulted in the formulation of a gender similarity hypothesis.

Despite these gender similarities, the question still arises as to which reasons might influence women's and men's different study choices. One possible explanation could be gender-specific socialization differences. From an antiquated point of view, gendered socialization means that women and men grow into society with fixed role labels, upon which they usually do not reflect (Gudjons, 2006). Indeed, recent perspectives of socialization describe both genders as socially structured with many inter-individual differences, but embedded in an asymmetric gender proportion (Bührmann et al., 2000). Although, as Bührmann et al. (2000) argued, the dual concept of gender-specific socialization is questionable, structural differences between genders are reflected by labor market segregation, indicating undercover mechanisms. Possible explanations might be allocative discrimination of women in engineering positions, when women with the same competencies and work-related characteristics as men are treated differently from their male counterparts (Brylla, 2005). For instance, some job advertisements can be posted only in male dominated networks. As Brylla (2005) mention, women start also frequently in lower positions and earn less money than their male colleagues. Further possible explanation could be found in different ways of learning, especially in corporate learning situations. Auszra (2001) suggested that women require specific learning formats in order to have the opportunity to learn need-orientated. On the one hand these formats should reflect women's biographical learning requirements, fostering the compatibility of job and family. On the other hand, one could speculate whether women prefer different forms of learning than men. Samel (2000), for example, considers men's behavior on the average as more competitive, whereas women are assumed to behave more implicitly, show more cooperative behavior and act more carefully than their male counterparts. These differences might be due to different socialization pattern of men and women. Moreover, of course, differences of that kind should not be interpreted as dichotomies but at the very most as slight tendencies because effect sizes are usually very small and the assumed gender differences are not as big as assumed (Hyde, 2005).

Regardless of the small differences and the impressive gender similarities, creating a customized learning situation for women can provide them with an opportunity to learn without the system of male dominance and gender-specific competitive situations (Auszra, 2001). For this reason, several universities have set up engineering courses that are only open to female students in Germany (Kuntz-Brunner, 2017). These courses incorporate virtual STEM learning environments that enable women to work in individualized situations on STEM contents without social competition and prevent the multifaceted mechanisms of gender discrimination from operating.

Despite the fact that female and male learners differ only marginally in competences (Hyde, 2005), there can be differences in the sensitivity of their competences in virtual science learning. For instance, the correlational pattern of cognitive competences, motivational variables, and invested effort when working with a virtual STEM learning environment might differ between female and male learners. If such gender differences were revealed with regard to correlations between cognitive and motivational variables and learning behavior, it would be possible to finetune study conditions for female students in a more gender-appropriate manner, creating a separate course for women and a virtual STEM learning environment adapted to female learners. Such motivational considerations cannot solve the problem of women's underrepresentation in engineering courses as a whole, of course, because they represent only a minor part of the picture regarding gender-specific barriers. However, they could be one small step within a series of others toward solving the problem.

With reference to this background, the following study will determine whether there are any correlations between cognitive competences, situational interest, and the individually invested mental effort of female and male learners when learning with virtual STEM learning environments. First, we will describe the common characteristics of learning with virtual STEM learning environments. Then, we will show how the competences needed for virtual science learning might affect the learners' situational interest and the mental effort they invest in their virtual STEM learning. After that, we will describe supposed similarities and differences between female and male students when learning with virtual STEM learning environments.

THEORY

Virtual STEM Environments

Any kind of science learning requires students to understand the logic of experimentation, which involves the evaluation of theory-based hypotheses under controlled conditions (Diekmann et al., 2010; Drexler and Baker-Schuster, 2012). Learners have to understand that relevant conditions have to be manipulated systematically in order to investigate how experimental results change when conditions vary. Besides conceptual understanding of the presented phenomena, mathematic competence (particularly arithmetic-operative skills) plays an important role when students are required to analyze quantitative data from experiments with regard to specific regularities or hypotheses.

Computer-based STEM learning environments offer learners the possibility to perform virtual experiments that enable them to test experimental conditions with regard to their outcome and to interact with the learning content on their own in an exploratory fashion. The virtual STEM environment encompasses all the knowledge necessary to understand and carry out the experiment, the simulated experiment itself, and its evaluation. Learners can independently investigate, manipulate, and change specific conditions that are expected to affect the results, and engage in the arithmetic-operative operations that are necessary to evaluate the experiments. In other words, these environments allow active science learning in the classroom due to their interactivity because learners can interact with and react to the subject matter and monitor and control the investigation process (Wirth and Leutner, 2006; Niegemann et al., 2008).

Effective learning in computer-based experimental learning environments is affected by strategic competences, which enable learners to plan experiments in a mindful and hypothesis-driven manner based on their conceptual understanding of the subject matter, and by mathematical skills, which are required for the quantitative analysis of results. Furthermore, it might be affected by motivational aspects such as interest and effort, which therefore constitute further requirements. According to Schraw et al. (2001), situational interest can be defined as the "temporary interest that arises spontaneously due to environmental factors such as task instructions or an engaging text" (p. 211). Thus, situational interest is environmentally activated and can possibly be fostered by virtual learning environments in which learners can control experimental conditions and actively investigate the research subject in their own way.

In the following, the relational pattern between strategic competences, mathematic competence, situational interest, and mental effort invested by the learner in virtual experimental STEM environments will be analyzed more closely with the aim of uncovering possible similarities and differences between female and male learners.

Strategic and Arithmetic-Operative Competences

Virtual STEM learning environments offer high potential for interactions. When learning with such learning environments, learners have to interact with the learning content to generate information (Wirth and Leutner, 2006). This means that learners have to plan and carry out actions; they have to record and analyze their observations, reflect on their results, and monitor their own learning process and adapt it, if necessary. As a consequence, learners need specific strategic competences to deal with the requirements of the virtual learning environment, for example, planning, analysis, monitoring, and reflection (Pokay and Blumenfeld, 1990; Heyn et al., 1994; Lin et al., 1999). Furthermore, a learner's arithmetic-operative competences allow her or him to solve the mathematic numerical operations associated with experimentation more easily. Thus, these competences are also highly important for students' mental effort when learning with virtual experimental STEM environments (Philipp, 2013). Hence, learners' strategic competences can be seen as an essential requirement for using virtual STEM learning environments, dealing with the learning content, and managing the demands of such an environment.

Situational Interest

Students' strategic competences allow them to interact more intensively with learning content (e.g., Ballstaedt, 2006). Therefore, these competences can also foster learners' spontaneous interest in the learning subject, as learners can explore the content more deeply when learning in a virtual learning environment. The implementation of learning strategies brings the learner closer to understanding the learning subject and its details. Indeed, the requirements of the learning situation during virtual experimentation encourage students to consistently use learning strategies, and higher usage of learning strategies (or higher strategic competence) can result in higher situational interest. As explained above, situational interest is defined as a spontaneous and environmentally activated type of interest that is based on the conditions of the learning situation and learning material (Schraw et al., 2001; Grüninger, 2013). Accordingly, virtual learning environments can be assumed to activate learners' spontaneous interest in the learning subject, provided that the learners have the necessary strategic competences to explore the environment. Thus, we assume that students with higher strategic competences are more likely to develop situational interest because their higher competences open up a broader range of possible experimental manipulations and investigations for them compared to students with lower strategic competences. The more competences they have, the higher situational interest can be expected to be and the more deeply the environment will be explored. Consequently, the usage of strategic competences has an inner relation with the content of the virtual learning environment. In contrast, arithmetic-operative competences are not related to content. Operations with numbers in general do not have a semantic relation with learning content (Krasa and Shunkwiler, 2009). Thus, there might be no inherent relation between the learners' arithmetic-operative competences and their situational interest. Next, we will consider the possible effects of arithmetic-operative and strategic competences on mental effort.

Mental Effort as a Function of Competences

The relationship between competences and effort seems to be inherently ambiguous. On the one hand, learning requires the usage of limited resources such as time and working memory. In addition, the learner has to activate motivational and energetic resources. The learners' cognitive resources invested in the learning process are the so-called 'mental effort' (Sweller, 2005; Sweller et al., 2011). The mental effort invested by students during learning is affected by their competences regarding the learning domain. This is because the amount of working memory capacity required for conscious control decreases with increasing expertise, due to a higher amount of automatic processing, which requires a lower amount of effort. With reference to cognitive load theory (Sweller et al., 2011), one could assume that learners with higher competences in the learning field need less mental effort than learners with lower competences. Therefore, competences have a *facilitating function* as they reduce the effective effort (Sweller et al., 1998; Sweller, 1999; Schnotz and Rasch, 2005). Learners with higher competences have higher abilities to deal with the learning demands; hence, they have to invest less mental effort in the respective learning field than learners with lower competences. Such a facilitating effect can be assumed, for example, for the learner's mathematical competences when learning with experimental environments because the required arithmetic operations can be performed more easily on the basis of higher competences.

Moreover, an increase of competences can also enable learners to do things they were not able to do previously with lower competences. In this case, the higher competences allow them to engage in deeper and more elaborate cognitive processing, and an increase of competences is then associated with an increase of invested cognitive effort. The learners' mental effort is related to their willingness to engage in the cognitive requirements of the learning process. Willingness to engage in the learning-relevant processes might generally be higher in students with higher competences than in students with lower competences (Paradies et al., 2009). Thus, adequate competences are a prerequisite for performing certain processes and can therefore have an *enabling function* (Sweller et al., 1998; Sweller, 1999; Schnotz and Rasch, 2005). Learners with higher competences deal better with the learning demands; hence, for them it might be easier to solve the learning tasks. As a consequence they might be willing to invest more mental effort in the respective learning field than learners with lower competences. Such an enabling effect can be assumed especially for learners' strategic competences because learning with virtual environments encompasses a broad range of possible interactions with the learning content, including deep consideration of complexity. Higher strategic competences can increase mental effort required to complete virtual STEM learning environments.

The general correlational pattern between conceptual competence, mathematical skills, situational interest, and mental effort expected based on these assumptions is depicted in **Figure 1**. The figure shows that we expect strategic competences to be correlated with higher situational interest, and we expect that higher arithmetic-operative competences could have a facilitating function and be correlated with lower mental effort, while strategic competences could have an enabling function and be correlated with higher mental effort (**Figure 1**).

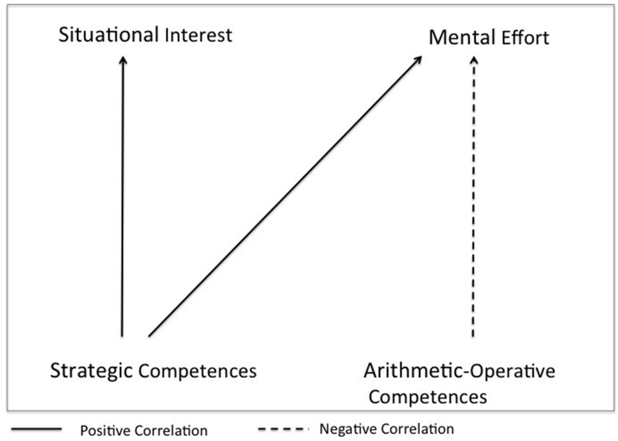

FIGURE 1 | Hypothetical correlations between arithmetic-operative competences, strategic competences, situational interest, and mental effort with a focus on the facilitating function and enabling function (Sweller et al., 1998; Sweller, 1999; Schnotz and Rasch, 2005).

Similarities and Differences between Female and Male Students

Learning with virtual STEM learning environments leverages the general habits of the so-called 'digital native' generation regarding usage of new media. Female and male learners might be rather similar in this respect because both are familiar with these media and usually enjoy working with them (Prensky, 2001). Accordingly the assumed positive correlation between strategic competences and situational interest might be the same for both genders. However, there might also be gender differences with regard to the above-mentioned competences. Several studies have revealed that, on the one hand, female learners use more strategic competences in learning situations on average than male learners (Dresel et al., 2004; Ziegler and Dresel, 2006). On the other hand, male learners frequently have more arithmetic-operative competences than female learners (Artelt et al., 2003; Halpern, 2012). Because, as Rippon et al. (2014) emphasized, it has proved difficult to replicate studies on gender differences in the functional organization of brain regions related to specific cognitive skills, research findings on this issue need to be reflected on very carefully. If we assume, however, that higher strategic competences lead to higher willingness to use such competences (Paradies et al., 2009), we can speculate that there might be differences in female and male learners' correlational patterns of situational interest, mental effort, and strategic and arithmetic-operative competences. Indeed, the sensitivity of women and men's strategic and arithmetic-operative competences might differ regarding their mental effort.

QUESTIONS AND HYPOTHESES

The purpose of our study was to determine whether there are differences and similarities in the sensitivity of female and male learners' arithmetic-operative and strategic competences in virtual science learning with regard to their situational interest and mental effort. If gender differences and similarities in the correlation patterns are revealed, it would be possible to finetune study conditions in a more gender-appropriate manner for female students, creating a separate course for female learners. That might support an increase in the number of women in engineering courses. With a focus on this purpose, we investigated the following research hypotheses:

Situational Interest

(H1a) Higher strategic competences are associated with higher situational interest in a virtual learning environment.

(H1b) The correlational patterns between situational interest and strategic competences are similarly pronounced in female and male learners.

Mental Effort

(H2a) Higher strategic competences have an enabling function regarding the conceptual planning of virtual experiments, resulting in more elaborated cognitive processing, which leads to higher invested mental effort.

(H2b) Higher arithmetic-operative competences have a facilitating function for the processing of quantitative data generated by virtual experiments. For specific computational tasks, higher arithmetic-operative competences are therefore associated with lower mental effort.

(H2c) The correlational patterns between mental effort and arithmetic-operative and strategic competences are differently pronounced in female and male learners.

METHODS

The following study is based on a project about the usage of virtual STEM labs conducted by the Universities of Applied Sciences Kaiserslautern, Koblenz, Trier, and Koblenz-Landau funded by the German Federal Ministry of Education and Research. The project aims at enabling college students of engineering to plan, conduct, and evaluate interactive virtual science experiments with a special emphasis on supporting female students in the domain of STEM (Fleuren et al., 2014).

Participants

A total of 56 high school students from 10th and 11th grades with a mean age of 15.89 ($SD = 2.31$) participated in this study. The precondition for their participation was that their legal guardians signed a consent form, which contained information about compliance with data protection guidelines as well as about the study's aims, procedure, and material. In the sample, 27 of the participants were female and 29 were male. The participants had a mean grade of 2.46 ($SD = 1.05$) in the relevant subject (chemistry or physics) in the previous school year.

Variables and Materials

We used gender (female vs. male), strategic competences, and arithmetic-operative competences as independent variables and mental effort and situational interest as dependent variables. The values for *Cronbach's Alpha* were assessed with 214 participants from all studies within the OML project (see values below).

To assess the strategic competences, we used three scales (planning, regulation, and monitoring) of the Kieler learning strategy inventory (KSI; Heyn et al., 1994) which has a four-step answer format (example item: "If I prepare myself/learn I make myself a list with the important things and learn it afterwards"). The value for *Cronbach's Alpha* was 0.88. The arithmetic-operative competences were assessed with two task packages from the Berlin intelligence structure test (BIS 4; Jäger et al., 1997) which challenge students to solve mathematical problems in a fixed time frame, moderated by an experimental assistant (example item: "A worker earns €15.20 per hour. How much does he earn if he works 5 h?"). The value for *Cronbach's Alpha* was 0.99. Mental effort was collected with an item of Paas et al. (1994) and an item of Wagner (2013). These items capture students' judgment of the amount of effort required and of the task difficulty (example item: "How much did you exert yourself while solving the learning environment?"). Both items included a nine-step answer format. The value for *Cronbach's Alpha* for mental effort was 0.56 and, therefore, low; this might be because the scale measures both estimated effort and perceived difficulty. The situational interest of students in the completion of the learning environment was explored with adapted items from the questionnaire in order to capture the actual motivation in learning and performance situations (FAM; Rheinberg et al., 2001). The value for *Cronbach's Alpha* was 0.81. The FAM questionnaire included a seven-step answer format (example item: "In this learning environment I like the role of the scientist who discovers relationships").

Procedure

The field study was carried out in the classroom during regular school lessons of physics or chemistry. First the students had to answer two task packages from the Berlin intelligence structure test (BIS; Jäger et al., 1997) in a fixed time frame, which was moderated by an experimental assistant. In the next step the students had to complete a virtual learning environment, which had been created in the OML project and includes five chapters: orientation, foundations, experiment, application, and reflection. The *orientation* chapter offers a motivational introduction to the learning environment. Additionally, it gives an overview of the content, goals, and relevant previous knowledge. The *foundations* chapter offers an overview of the theoretical background (e.g., the content, relevant diagrams, and formulas) and relevant questions or hypotheses. In the *experiment* chapter, the students investigate the questions or hypotheses by trying out different virtual experimental tools. **Figure 2** shows an example from the virtual learning environment, *air cushion tram*, which was used in physics lessons and developed at the University of Applied Sciences in Trier (Roth et al., 2014).

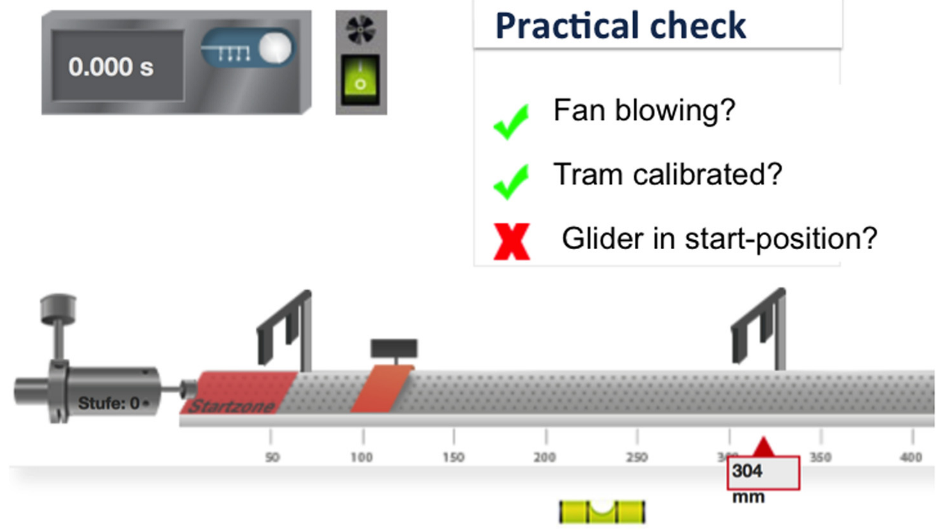

FIGURE 2 | *Experiment* chapter within the virtual learning environment: *air cushion tram* (Roth et al., 2014, p. 5).

The *application* chapter invites students to apply the knowledge and strategies they have learned in the previous chapters. The *reflection* chapter sums up the learned content and, with several questions, encourages learners to evaluate their own learning process. The virtual learning environment is interactive, enabling students to switch between different chapters. Thus, the learners can, for instance, reread the theoretical background if they have problems completing the virtual experiment or they can go back to the experiment during application of the learned content.

After completion of the learning environment, the participants received a questionnaire that assessed their mental effort, situational interest, and strategic competences (see variables and material above).

RESULTS

In a first step, we computed the correlations between the four variables *mental effort, situational interest, strategic competences, and arithmetic-operative competence*. **Table 1** shows that the learners' situational interest was significantly positively correlated with their strategic competences. The participants' arithmetic-operative competences were significantly negatively correlated with their strategic competences.

TABLE 1 | Pearson correlations, means, and standard deviations from the scales: Mental Effort, Situational Interest, Strategic Competences, and Arithmetic-Operative Competences ($N = 56$).

Indicant	1	2	3	4
Mental effort				
Situational interest	0.042			
Strategic competences	−0.073	**0.239***		
Arithmetic-operative competences	0.012	0.199	**−0.226***	
Mean	10.45	11.71	47.36	5.78
SD	3.75	5.37	12.34	1.90

**p < 0.05, **p < 0.01, one-tailed.*

In a next step, we examined the female and male learners' differences for the variables *mental effort, situational interest, strategic competences, and arithmetic-operative competences*. The results are displayed in **Table 2**.

To test our hypotheses, we conducted regression analyses with strategic competences, gender (female vs. male), and the interaction of these two factors as predictors and with mental effort and situational interest as the respective criteria.

Situational Interest

To verify Hypotheses1a and 1b, we ran regression analyses with the variables situational interest, strategic competence, and gender. The model with the predictors gender (female vs. male) and strategic competences significantly predicted situational interest, $R^2 = 0.11$, $adj\ R^2 = 0.08$, $F(2,53) = 3.34$, $p = 0.041$. The model revealed that situational interest was affected by students' strategic competences, $\beta = 0.32$, $t(55) = 2.34$, $p = 0.023$. This indicates that students with more strategic competences had more situational interest in the virtual learning environment (**Table 3**). Furthermore, gender had no impact on situational interest, $\beta = -0.25$, $t(55) = -1.84$, $p = 0.072$. Accordingly, there was no difference between the situational interest of female and male participants in the virtual learning environment. In the next step, we included interaction between gender and strategic competences in the model, $R^2 = 0.16$, $adj\ R^2 = 0.12$, $F(3,52) = 3.38$, $p = 0.025$. However, the interaction effect was not significant, $\beta = -0.22$, $t(55) = -1.75$, $p = 0.086$.

The model with the predictors gender and arithmetic-operative competences and the criterion situational interest was not significant, $R^2 = 0.05$, $adj\ R^2 = 0.01$, $F(2,53) = 1.37$,

TABLE 2 | Means, standard deviations and difference in means of both genders of the scales *Mental Effort, Situational Interest, Strategic Competences, and Arithmetic-Operative Competences* of Female and Male Participants.

	Female		Male		Total
N	**27**		**29**		**56**
Variable	**Mean**	***SD***	**Mean**	***SD***	**Difference in means of both genders**
Mental effort	10.70	4.11	10.21	3.44	0.49
Situational interest	10.89	4.75	12.48	5.86	1.59
Strategic competences	51.37	11.63	43.62	11.98	**7.75***
Arithmetic-operative competences	5.22	1.53	6.28	2.09	**1.06***

*Results of t-tests, *p < 0.05, **p < 0.01.*

TABLE 3 | Hierarchical regression predicting situational interest ($N = 56$).

Variable	*B*	*SE(B)*	β
Step 1			
Gender	−1.38	0.75	−0.25
Strategic competences	0.14	0.06	**0.32***
Step 2			
Gender x strategic competences	−0.11	0.06	−0.22

*Strategic competences were centered. Effect coding was used for gender. *$p < 0.05$, **$p < 0.01$, $R^2 = 0.16$, adj $R^2 = 0.12$, $F(3,52) = 3.38$, $p = 0.025$.*

$p = 0.263$. In the next step, we included interaction between gender and arithmetic-operative competences in the model, but neither the model, $R^2 = 0.05$, $adj\ R^2 = -0.01$, $F(3,52) = 0.90$, $p = 0.447$, nor the interaction effect, $\beta = 0.02$, $t(55) = 0.13$, $p = 0.897$, was significant.

To sum up, in accordance with our Hypothesis 1a, the results show that strategic competences are positively correlated with students' situational interest. In accordance with our Hypothesis 1b, this correlation did not differ between male and female participants. Additionally, there was no correlation between situational interest and arithmetic-operative competences.

Mental Effort

To test Hypotheses 2a and 2c, we ran regression analyses with the variables *mental effort*, *strategic competences,* and *gender*. The model with the predictors gender (female vs. male) and strategic competences and the criterion mental effort was not significant, $R^2 = 0.01$, $adj\ R^2 = -0.02$, $F(2,53) = 0.39$, $p = 0.681$. In the next step, we included interaction between gender and strategic competences in the model, which was then significant, $R^2 = 0.15$, adj $R^2 = 0.11$, $F(3,52) = 3.16$, $p = 0.032$. In addition, interaction was significant, $\beta = -0.37$, $t(55) = -2.93$, $p = 0.005$, while the regression coefficient for gender ($\beta = 0.11$, $t(55) = 0.84$, $p = 0.405$) and the regression coefficient for strategic competences ($\beta = -0.12$, $t(55) = -0.87$, $p = 0.387$) were not significant; strategic competences showed no enabling function for mental effort for both genders.

To verify Hypothesis 2c, we interpreted the interaction effect. Therefore, we used dummy coding for the dichotomous variable (0 = female/1 = male; 1 = female/0 = male) and included it in two complementary regression models. In the first model, in which the female group was coded 0 and the male group was coded 1, the regression coefficient for strategic competences was significant, $B = 0.24$, $t(55) = 2.93$, $p = 0.005$. Thus, strategic competences indeed affected mental effort in the group of female participants. By contrast, in the second model with the opposite coding pattern, the regression coefficient for strategic competences was not significant, $B = 0.08$, $t(55) = 1.43$, $p = 0.158$. Thus, higher strategic competences decreased the mental effort of female participants, whereas higher strategic competences had no effect on the mental effort of male participants. Consequently, strategic competences can be assumed to have a facilitating function, especially for females. To interpret the differences between individuals with higher (+ 1 standard deviation) and lower strategic competences (−1 standard deviation), two regression models were computed concerning mental effort (Richter, 2006). In the regression model that contained the variable indicating higher strategic competences, the coefficient for gender was not significant, $B = 2.13$, $t(55) = 1.52$, $p = 0.135$. By contrast, in the model with the variable that indicated lower strategic competences, the coefficient for gender was significant, $B = -3.81$, $t(55) = -3.81$, $p = 0.011$. Accordingly, the mental effort of female and male participants was significantly different if they had lower strategic competences. By contrast, female and male participants with higher strategic competences showed no significant difference in mental effort (**Figure 3**).

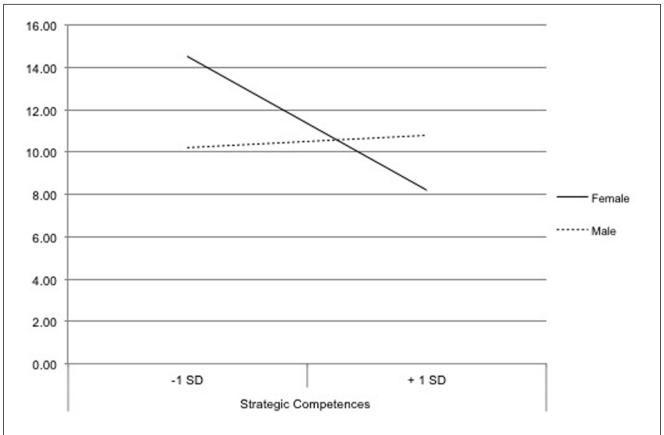

FIGURE 3 | Interaction effect between gender and strategic competences on participants' mental effort.

To test Hypotheses 2b and 2c, we ran a regression model with the predictors gender (female vs. male) and arithmetic-operative competences and the criterion mental effort; it was not significant, $R^2 = 0.01$, $adj\ R^2 = -0.03$, $F(2,53) = 0.15$, $p = 0.864$. In a next step, we included interaction between gender and arithmetic-operative competences in the model, which was then significant, $R^2 = 0.14$, $adj\ R^2 = 0.09$, $F(3,52) = 2.90$, $p = 0.043$. In addition, interaction was significant, $\beta = 0.39$, $t(55) = 2.89$, $p = 0.006$. Neither the regression coefficient of gender ($\beta = 0.12$, $t(55) = 0.88$, $p = 0.381$) nor the regression coefficient of arithmetic-operative competences ($\beta = 0.16$, $t(55) = 1.12$, $p = 0.270$) was significant. Consequently, gender and arithmetic-operative competences had no impact on the mental effort of participants. Hence, arithmetic-operative competences show no facilitating function with regard to mental effort generally.

To verify Hypothesis 2c, we interpreted the interaction effect. Therefore, we used dummy coding for the dichotomous variable (0 = female/1 = male; 1 = female/0 = male) and included it in two complementary regression models. In the first model, in which the female group was coded 0 and the male group was coded 1, the regression coefficient for arithmetic-operative competences was significant, $B = 0.58$, $t(55) = 2.51$, $p = 0.015$. By contrast, in the model in which the male group was coded with 0 and the female group was coded with 1, the regression coefficient for arithmetic-operative competences was not significant, $B = -0.24$, $t(55) = -1.46$, $p = 0.149$. Thus, especially the mental effort of female participants increased if they had higher arithmetic-operative competences. Consequently, especially in the group of female participants, the arithmetic-operative competences had an enabling function. To interpret the differences between individuals with high (+1 standard deviation) and low (−1 standard deviation) arithmetic-operative competences, two regression models were computed with regard to mental effort. In the regression model that contained the variable indicating higher arithmetic-operative competences, the coefficient for gender was significant, $B = -3.96$, $t(55) = -2.58$, $p = 0.013$. By contrast, in the model with the variable that indicated lower arithmetic-operative competences, the coefficient for gender was not significant, $B = 2.20$, $t(55) = 1.59$, $p = 0.117$. Thus, the mental effort of female and male participants was significantly different if they had higher arithmetic-operative competences. If female participants had higher arithmetic-operative competences than male participants, they invested significantly more effort in learning with the virtual environment than their male counterparts. By contrast, female and male participants with lower arithmetic-operative competences showed no significant difference in mental effort (**Figure 4**).

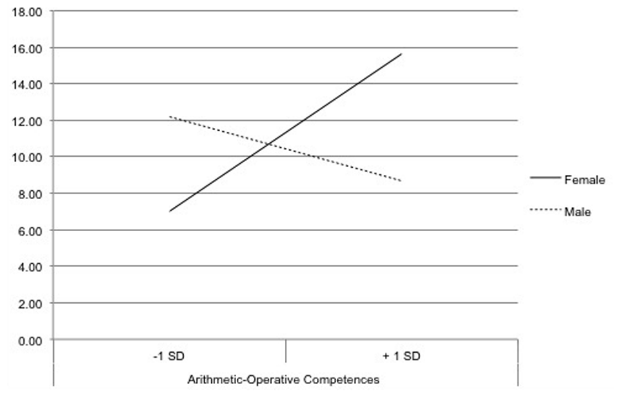

FIGURE 4 | Interaction effect between gender and arithmetic-operative competences on the participants' mental effort.

The results of both regression models with the effect of different competences (i.e., strategic and arithmetic-operative) on mental effort are shown in **Table 4**.

To summarize, strategic competences did not have an enabling function on metal effort in the entire sample, thus not supporting Hypothesis 2a. Additionally, arithmetic-operative competences did not have a facilitating function on the mental effort of all participants, contrary to Hypothesis 2b. In line with Hypothesis 2c, however, the correlation patterns of female and male learners show differences. The mental effort of female participants decreased if they had higher strategic competences. Thus, female learners' strategic competences seem to have a facilitating function on mental effort. Especially female participants increased their mental effort if they had higher arithmetic-operative competences. However, contrary to Hypothesis 2b, female learners' arithmetic-operative

TABLE 4 | Regression models predicting mental effort ($N = 56$).

	Models					
	Strategic competences			Arithmetic-operative competences		
Variable	***B***	***SE(B)***	**β**	***B***	***SE(B)***	**β**
Gender	0.44	0.52	0.11	0.49	0.52	0.12
Competences	−0.04	0.04	−0.12	0.31	0.28	0.16
Gender x competences	−0.012	0.04	**−0.37***	0.84	0.29	**0.39****
R^2		0.15			0.14	
F		**3.16***			**2.90***	

*Competences were centered; effect coding was used for gender, *p < 0.05, **p < 0.01.*

competences seem to have an enabling function on mental effort.

DISCUSSION

The mental effort and the situational interest of men and women were similar in learning with virtual science environments. The results of the present study indicate furthermore that both female and male students with higher strategic competences are more likely to show higher situational interest than students with lower strategic competences when learning from virtual STEM environments. One can therefore assume that both female and male students with higher strategic competences will engage in deeper exploration of the subject matter due to their higher spontaneous interest than students with lower strategic competences. For this reason, the use of virtual STEM learning environments can be beneficial for both genders regarding their situational interest. Because situational interest "often precedes and facilitates the development of personal interest" (Schraw et al., 2001, p. 211), both female and male students with higher strategic competences might also be more likely to develop personal interest in STEM topics than students with lower strategic competences. It follows that the use of virtual STEM learning environments in engineering courses should foster both women's and men's enrollment in such courses under the condition that their strategic competences are sufficiently high. Thus, in order to foster situational interest in virtual STEM learning the strategic competences of female and male students in learning with such learning environments should be enhanced.

Besides these similarities, there seem to be also differences between genders regarding the use of such learning environments. The results of the present study suggest that female students learning with virtual STEM learning environments are more sensitive to differences in strategic and arithmetic-operative competences than their male counterparts. Nevertheless, the empirical correlational patterns differed from our hypotheses. On the one hand, strategic competences seem to have a facilitating function for female students. Thus, higher strategic competences were correlated with lower mental effort (Sweller et al., 1998; Sweller, 1999). On the other hand, higher arithmetic-operative competences seem to have an enabling function for female students (Schnotz and Rasch, 2005). Accordingly, higher arithmetic-operative competences were correlated with higher mental effort. Thus, female students with higher arithmetic-operative competences were more likely to invest higher mental effort in learning with virtual STEM environments than female students with lower arithmetic-operative competences. Therefore, if female participants had more arithmetic-operative competences than male participants, they invested significantly more effort into learning with the virtual environment than their male counterparts, who's invested effort, in contrast, was not significantly affected by arithmetic-operative competences. It seems that male learners with higher arithmetic-operative competences are more likely at risk to invest too less effort into learning than females. Further research is needed on this issue.

The use of cognitive prompts that activate and support the application of strategic competences could therefore be especially useful for female students learning with virtual experimental STEM learning environments (Lin et al., 1999). In addition to activating their strategic competences, such prompts could also increase their situational interest in the environment and learning topic. In short, to promote female students' virtual STEM learning, they should be encouraged to use their strategic competences while working with such learning environments. More importantly, regarding female and male learners' situational interest such prompting while virtual science learning might be a benefit for both genders. Following the cognitive apprenticeship approach, such prompts could be given systematically by the learning environment at the beginning of learning with subsequent fading out as the learner becomes increasingly proficient in operating the environment (Collins et al., 1991). Another possibility would be to insert virtual coaching into the learning environment which could include hints for carrying out the virtual experiments.

The learning of female students from virtual experimental STEM environments could also be enhanced through support of their arithmetic-operative competences and especially through their meta-cognitive awareness of these competences (Hacker et al., 1998). The enabling function of these competences means that they are likely to increase female students' readiness to invest more mental effort in learning from experimental STEM environments.

Based on the differences found in the correlational patterns in this study, one could also tentatively consider whether it might be fruitful to create special engineering courses for women. Such courses would focus more on women's inter-individual competence differences and promote them depending on their learning needs. Within such courses, virtual STEM learning environments could offer individualized learning situations which take into account the higher sensitivity of female students' competences with regard to their invested mental effort and provide capabilities for appropriate support for them. With regard to the results of our study such support should especially trigger the female learners' strategic competences. That might have a facilitating function on the female learners' mental effort; in this case, single sex education can support the decrease of effective effort and facilitate the female learners' sciences learning process (Sweller et al., 1998, 2011; Sweller, 1999; Schnotz and Rasch, 2005). Furthermore, the integration of such learning environments can foster the compatibility of job and family, because virtual STEM environments can be solved in individual time slots.

Albeit, one has to keep in mind that there are not dichotomous groups of men and women, but rather several individuals with, sometimes different, sometimes similar, learning-needs. In addition, one needs to understand how biological factors interact with environmental factors to maximize the benefit of virtual STEM environments (Miller and Halpern, 2014). It should be noted, furthermore, that the present findings should be interpreted with care. First, only a relatively small number of students participated in this study. Second, background information about gender socialization and gender identity was not taken into account. Further research is needed to obtain a clearer picture of the sometimes subtle differences of female compared to male learners working in STEM environments.

Motivational considerations might be one facet of the complex picture of women's underrepresentation in engineering courses but, of course, they are far from solving the problem by themselves. For instance, they cannot solve the problem of allocative discrimination of women in engineering positions (Brylla, 2005), and they cannot remove, gender-specific socialization patterns in our society (Bührmann et al., 2000). Instead, they should be considered as a small step within a series of other research steps toward solving the problem of enhancing women's representation in the engineering labor market.

ETHICS STATEMENT

A full ethical review was not required for this type of study in Germany; however, the Aufsichts- und Dienstleistungsdirektion of Rheinland-Pfalz gave their permission for the study after consideration of the ethical aspects. Written informed consent was obtained from the legal guardians of all children included in the study.

AUTHOR CONTRIBUTIONS

EC: Substantial contributions to the conception and design of the work and the acquisition, analysis, and interpretation of data for the work; Drafting the work; Final approval of the version to be published. WS: Substantial contributions to the conception and design of work and revising it critically for important intellectual content; Final approval of the version to be published. EC and WS: Agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

FUNDING

This project was funded by the federal-state-program for better study conditions and more quality in teachings from funds from the Bundesministeriums für Bildung und Forschung, Germany with the grant 01PL12056.

ACKNOWLEDGMENTS

We are grateful to the Federal Ministry of Education and Research of Germany for funding the project *Open MINT Labs*. For the design and provision of the virtual STEM learning environments, we also want to thank in alphabetical order our colleagues from the Universities of Applied Science in Kaiserslautern, Koblenz and Trier: Daniela Fleuren, Marios Karapanos, Tobias Roth, Alexander Schwingel, and Manuel Stach.

REFERENCES

Artelt, C., Baumert, J., Julius-McElvany, N., and Peschar, J. (2003). *Learners for Life: Student Approaches to Learning. Results from PISA 2000*. Paris: OECD

Auszra, S. (2001). "Interaktionsstrukturen zwischen den geschlechtern in lernsituationen [Interaction-pattern between both genders in learning situations]," in *Handbuch der Frauenbildung,* ed. W. Gieseke (Wiesbaden: Springer), 321–329.

Ballstaedt, S. (2006). "Zusammenfassen von textinformationen [Summarizing text-information]," in *Handbuch der Lernstrategien,* eds H. Mandl and H. F. Friedrich (Göttingen: Hogrefe), 117–126.

Brylla, K. (2005). *Die Diskriminierung von Frauen auf dem Arbeitsmarkt [The Women's Discrimination on Labor Market]*. München: GRIN Verlag.

Bührmann, A., Diezinger, A., and Metz-Göckel, S. (2000). *Arbeit, Sozialisation, Sexualität [Work, Socialization, Sexuality]*. Wiesbaden: Springer.

Buse, K. R., and Bilimoria, D. (2014). Personal vision: enhancing work engagement and the retention of women in the engineering profession. *Front. Psychol.* 5:1400. doi: 10.3389/fpsyg.2014.01400

Collins, A., Brown, J. S., and Holum, A. (1991). Cognitive apprenticeship: making thinking visible. *Am. Educ. Winter* 6, 38–46.

Diekmann, F., Gleiche, O., Weiner, A. (2010). "Interesse wecken an ingenieurwissenschaftlicher tätigkeit. Unterstützung technologischer experimente durch internetgestützte medien [Create interest for engineering function. Support of technological experiments with internet-based media]," in *IngenieurBildung für Nachhaltige Entwicklung,* eds G. Kammasch, A. Schwenk, and B. Wieneke-Toutaoui (Berlin: Beuth Hochschule für Technik), 66–71.

Dresel, M., Stöger, H., and Ziegler, A. (2004). *Lernstrategiegebrauch in Abhängigkeit von Bildungsgängen und Jahrgangsstufen in der Sekundarstufe [Use of Learning-strategies in Dependency of Educational Careers and Year in Secondary Stage]*. Ulmer Forschungsberichte aus der Pädagogischen Psychologie Nr. 11. Ulm: Universität Abt Pädagogische Psychologie.

Drexler, A., and Baker-Schuster, L. (2012). "NaT-working: naturwissenschaft und technik – schüler, lehrer und wissenschaftler vernetzen sich – ein erfahrungsbericht aus sicht des förderers [NaT-working: science and technic – students, teachers and scientists network with each other – an promoter's experience report]," in *Wissenschafts- und Technikbildung auf dem Prüfstand,* eds U. Pfenning and O. Renn (Baden-Baden: NOMOS), 171–183.

Fleuren, D., Karapanos, M., Roth, T., and Berg, H. (2014). "Open MINT labs – ein virtuelles lehr-lern-konzept für grundlagenlabore in MINT-studiengängen [Open MNT labs – an virtual teaching-learning-concept for basic labs within STEM courses of study]," in *GML2 2014. Grundfragen Multimedialen Lehrens und Lernens. Der Qualitätspakt E-Learning im Hochschulpakt 2020,* eds N. Apostolopoulos, H. Hoffmann, U. Mußmann, W. Coy, and A. Schwill (Münster: Waxmann Verlag), 237–250.

Grüninger, R. (2013). Informationswidersprüche in Museen: Der Einfluss Personaler und Situativer Merkmale auf die Verarbeitung Konfligierender Information [Conflicting Information in Museums: The Impact of Personal and Situational Characteristics on the Processing of Conflicting Information]. Available at: https://kola.opus.hbz-nrw.de/files/783/Dissertation_RahelGrAninger_1.pdf

Gudjons, H. (2006). *Pädagogisches Grundwissen [Pedagogical Basic Knowledge],* 9th Edn. Bad Heilbrunn: Klinkhardt.

Hacker, D. J., Dunlosky, J., and Graesser, A. C. (eds). (1998). *Metacognition in Educational Theory and Practice*. Mahwah, NJ: Erlbaum.

Halpern, D. F. (2012). *Sex Differences in Cognitive Abilities,* 4th Edn. New York, NY: Psychology Press.

Heyn, S., Baumert, J., and Köller, O. (1994). *Kieler Lern-strategie-Inventar KSI. [Kieler Learning-strategy Inventory KSI]*. Kiel: Institute für Pädagogik der Naturwissenschaften.

Hyde, J. S. (2005). The gender similarities hypothesis. *Am. Psychol.* 60, 581–592. doi: 10.1037/0003-066X.60.6.581

Jäger, O. A., Süß, H.-M., and Beauducel, A, (1997). *BIS-Test. Berliner Intelligenzstruktur-Test [BIS-test. Berlin Intelligence-structure-test]*. Göttingen: Hogrefe

Kompetenzzentrum Technik-Diversity-Chancengleichheit e.V (2015). *Studienanfängerinnen und Studienanfänger der Fächergruppe Mathematik, Naturwissenschaften im Studienjahr 2014 [Female and Male Student Beginners in the Subjects Mathematics and Science in the Academic Year 2014]*. Available at: http://www.komm-mach-mint.de/Service/Daten-Fakten/2014/Studienanfaengerinnen-und-Studienanfaenger-der-Faechergruppe-Mathematik-Naturwissenschaften-im-Studienjahr-2014

Krasa, N., and Shunkwiler, S. (2009). *Number Sense and Number Nonsense. Understanding the Challenges of Learning Math*. Baltimore, MD: Paul H. Brookes Publishing.

Kuntz-Brunner, R. (2017). *Frauenstudiengang für Angehende Ingenieurinnen [Women Studying Courses for Engineers]*. Available at: http://www.ingenieur.de/Arbeit-Beruf/Ausbildung-Studium/Frauenstudiengang-fuer-angehende-Ingenieurinnen

Lin, X., Hmelo, C., Kinzer, C., and Secules T. J. (1999). Designing technology to support reflection. *Educ. Res. Dev.* 47, 43–62. doi: 10.1007/BF02299633

Miller, D. I., and Halpern, D. F. (2014). The new science of cognitive sex differences. *Trends Cogn. Sci.* 1, 37–45. doi: 10.1016/j.tics.2013.10.011

Niegemann, H. M., Domagk, S., Hessel, S., Hein, A., Hupfer, M., and Zobel, A. (2008). *Kompendium Multimediales Lernen [Compendium of Multimedia Learning]*. Berlin: Springer.

Paas, F., van Merriënboer, J. J. G., and Adam, J. J. (1994). Measurement of cognitive load in instructional research. *Percept. Mot. Skills* 79, 419–430. doi: 10.2466/pms.1994.79.1.419

Paradies, L., Linser, H.-J., and Greving, J. (2009). *Diagnostizieren, Fordern und Fördern [To Diagnose, to Exercise and to Promote]*. Berlin: Cornelsen Scriptor.

Philipp, K. (2013). *Experimentelles Denken. Theoretische und Empirische Konkretisierung einer Mathematischen Kompetenz [Experimental Thinking. Theoretical and Empirical Concretization of a Mathematic Competence]*. Wiesbaden: Springer.

Pokay, P., and Blumenfeld, P. C. (1990). Predicting achievement early and late in the semester: the role of motivation and use of learning strategies. *J. Educ. Psychol.* 82, 41–50. doi: 10.1037/0022-0663.82.1.41

Prensky, M. (2001). Digital natives, digital immigrants, part ii: do they really think differently? *Horizon* 9, 15–24.

Rheinberg, F., Vollmeyer, R., and Burns, B. D. (2001). FAM: ein fragebogen zur erfassung aktueller motivation in lern- und leistungssituationen [FAM: an questionnaire for acquisition oft he actual learn and performance motivation]. *Diagnostica* 47, 57–66. doi: 10.1026//0012-1924.47.2.57

Richter, T. (2006). *Interaktionen von Metrischen und Kategorialen Prädiktoren [Interactions of Metric and Categorial Predictors]*. Available at: https://www.uni-kassel.de/fb01/fileadmin/groups/w_270518/pub_richter/ZMP_Richter_Interaktionen.pdf

Rippon, G., Jordan-Young, R., Kaiser, A., and Fine, C. (2014). Recommendations for sex/gender neuroimaging research: key principles and implications for research design, analysis, and interpretation. *Front. Hum. Neurosci.* 8:650. doi: 10.3389/fnhum.2014.00650

Roth, T., Schwingel, A., Greß, C., Hein, U., Kirsch, R., and Appel, J. (2014). *Vorstellung eines Blended-Learning-Lab-Konzeptes für die Grundlagenlabore in MINT Fächern [Presentation of a Blended-Learning-Lab-Concept for Basic-Labs in STEM Courses]*. Frankfurt: Tagungsband der Früjahrstagung.

Samel, I. (2000). *Einführung in die Feministische Sprachwissenschaft [Implementation in Feministic Linguistics]*. Berlin: E. Schmidt.

Schnotz, W., and Rasch, T. (2005). Enabling, facilitating, and inhibiting effects of animations in multimedia learning: why reduction of cognitive load can have negative results on learning. *Educ. Technol. Res. Dev.* 53, 47–58. doi: 10.1007/BF02504797

Schraw, G., Flowerday, T., and Lehman, S. (2001). Increasing situational interest in the classroom. *Educ. Psychol. Rev.* 13, 211–244. doi: 10.1023/A:1016619705184

Statistisches Bundesamt (2016). *Frauenanteil bei Anfängern in Ingenieurwissenschaften 2014 bei nur 21 % [Percentage of Women in Engineering-Beginners in 2014 is only 21%]*. Available at: https://www.destatis.de/DE/PresseService/Presse/Pressemitteilungen/2016/09/PD16_328_217pdf.pdf?__blob=publicationFile

Sweller, J. (1999). *Instructional Design in Technical Areas*. Camberwell, VIC: ACER Press.

Sweller, J. (2005). "Implications of cognitive load theory for multimedia learning," in *The Cambridge Handbook of Multimedia Learning* ed. R. E. Mayer (New York, NY: Cambridge University Press), 19–30.

Sweller, J., Ayres, P., and Kalyuga, S. (2011). *Cognitive Load Theory*. New York, NY: Springer. doi: 10.1007/978-1-4419-8126-4

Sweller, J., van Merriënboer, J. J. G., and Paas, F. (1998). Cognitive architecture and instructional design. *Educ. Psychol. Rev.* 10, 251–296. doi: 10.1023/A:1022193728205

Wagner, I. (2013). *Lernen mit Animationen: Effekte Dynamischer und Statischer Visualisierungen auf die Bildung Perzeptueller und Kognitiver Repräsentationen beim Erwerb von Wissen über Dynamische Sachverhalte [Learning with Animation: Effects of Dynamic and Static Visualizations on the Creation of Knowledge about Dynamic Issues]*. Available at: http://kola.opus.hbz-nrw.de/volltexte/2013/858/pdf/Dissertation_IngaWagner.pdf

Wirth, J., and Leutner, D. (2006). "Selbstregulation beim lernen mit interaktiven lernumgebungen [Self-regulation during learning with interactive learning environments]," in *Handbuch Lernstrategien,* eds H. Mandl and H. F. Friedrich (München: Hogrefe), 162–184.

Ziegler, A., and Dresel, M. (2006). "Lernstrategien: die genderproblematik [Learning-strategies: the gender-difficulty]," in *Handbuch Lernstrategien,* eds H. Mandl and H. F. Friedrich (München: Hogrefe), 378–389.

Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Psychology

ORIGINAL RESEARCH
published: 10 January 2017
doi: 10.3389/fpsyg.2016.02071

The Grad Cohort Workshop: Evaluating an Intervention to Retain Women Graduate Students in Computing

Jane G. Stout [1]*, *Burçin Tamer* [1], *Heather M. Wright* [1], *Lori A. Clarke* [2], *Sandhya Dwarkadas* [3] and *Ayanna M. Howard* [4]

[1] Computing Research Association, Washington, DC, USA, [2] College of Information and Computer Sciences, University of Massachusetts Amherst, Amherst, MA, USA, [3] Department of Computer Science, University of Rochester, Rochester, NY, USA, [4] School of Electrical and Computer Engineering, Georgia Institute of Technology, Atlanta, GA, USA

Women engaged in computing career tracks are vastly outnumbered by men and often must contend with negative stereotypes about their innate technical aptitude. Research suggests women's marginalized presence in computing may result in women psychologically disengaging, and ultimately dropping out, perpetuating women's underrepresentation in computing. To combat this vicious cycle, the Computing Research Association's Committee on the Status of Women in Computing Research (CRA-W) runs a multi-day mentorship workshop for women graduate students called Grad Cohort, which consists of a speaker series and networking opportunities. We studied the long-term impact of Grad Cohort on women Ph.D. students' (a) dedication to becoming well-known in one's field, and giving back to the community (*professional goals*), (b) the degree to which one feels computing is an important element of "who they are" (*computing identity)*, and (c) beliefs that computing skills are innate (*entity beliefs*). Of note, entity beliefs are known to be demoralizing and can lead to disengagement from academic endeavors. We compared a propensity score matched sample of women and men Ph.D. students in computing programs who had never participated in Grad Cohort to a sample of past Grad Cohort participants. Grad Cohort participants reported interest in becoming well-known in their field to a greater degree than women non-participants, and to an equivalent degree as men. Also, Grad Cohort participants reported stronger interest in giving back to the community than their peers. Further, whereas women non-participants identified with computing to a lesser degree than men and held stronger entity beliefs than men, Grad Cohort participants' computing identity and entity beliefs were equivalent to men. Importantly, stronger entity beliefs predicted a weaker computing identity among students, with the exception of Grad Cohort participants. This latter finding suggests Grad Cohort may shield students' computing identity from the damaging nature of entity beliefs. Together, these findings suggest Grad Cohort may fortify women's commitment to pursuing computing research careers and move the needle toward greater gender diversity in computing.

Keywords: gender, computing, graduate students, role models, intervention

OPEN ACCESS

Edited by:
Kathleen Buse,
Advancing Women in STEM, USA

Reviewed by:
Mary Jean Amon,
University of Cincinnati, USA
Jeria Quesenberry,
Carnegie Mellon University, USA

***Correspondence:**
Jane G. Stout
jane@cra.org

Specialty section:
This article was submitted to Organizational Psychology, a section of the journal Frontiers in Psychology

Received: *14 October 2016*
Accepted: *22 December 2016*
Published: *10 January 2017*

Citation:
Stout JG, Tamer B, Wright HM, Clarke LA, Dwarkadas S and Howard AM (2017) The Grad Cohort Workshop: Evaluating an Intervention to Retain Women Graduate Students in Computing. Front. Psychol. 7:2071. doi: 10.3389/fpsyg.2016.02071

> "I actually feel like I'm part of the computer science field now [that I have attended Grad Cohort]. I don't feel so isolated or insignificant as a female in the field..." – *Grad Cohort Participant, 2014*

> "[One of my favorite things about Grad Cohort was] meeting so many other women who liked similar things as me! For the first time, I didn't feel like it was weird to be a woman in computer science." – *Grad Cohort Participant, 2016*

The quotes by the graduate students above illustrate the field of computing can be alienating for women. Indeed, social science research indicates women who have opted into a computing career path must regularly contend with negative stereotypes about their technical abilities (e.g., Miller et al., 2015), as well as the belief that women do not "fit" in computing to the degree that men do (Cheryan et al., 2013). The cultural stereotypes that computer science is for men is reinforced by the fact that most students, post-docs, college professors, and other professionals in the field are men (National Science Foundation, 2015a,b, 2016a,b,c,d), as are portrayals of these professionals in the media (Smith et al., 2014).

That women are vastly underrepresented at all levels of the computing education and career pipeline is problematic for a number of reasons. First, diversity in the workplace is known to foster innovation; a diversity of experiences and perspectives yields greater opportunity for creativity (Leung et al., 2008; Woolley et al., 2010; Hoever et al., 2012). Second, a homogenous set of prerogatives at the decision table leaves unrepresented voices unheard, so that the needs of many are ignored. For example, early voice activated systems developed by computer scientists only worked for men because women's voices were literally unheard during development (Margolis and Fisher, 2002; Camp, 2012). Finally, computing professions tend to be financially lucrative and culturally valued (Forbes, 2016; U.S. News World Report, 2016). Thus, low representation of women in computing may perpetuate social inequality among women and men (Cejka and Eagly, 1999; Sheffield, 2004). In sum, a dearth of women in computing careers poses a host of problems for our culture.

The Computing Research Association's Committee on the Status of Women in Computing Research (CRA-W) designs and runs programs to boost the number of women in computing research careers. The CRA-W especially encourages women to pursue Ph.D.s in computing in order to increase the proportion of women eligible for senior leadership roles. As of 2014, approximately 21% of doctoral awardees in computer science are women (National Science Foundation, 2016c). Because so few women engage in computing research career paths to begin with, it is critical to retain the small number of women in these fields. The CRA-W focuses on encouraging women who have chosen to pursue a computing career to stay the course, reach their full potential, and help increase the number of successful women role models in computing research.

Unfortunately, encouraging women to persist in computing can be an uphill battle. Prior research indicates belonging to an underrepresented or negatively stereotyped group in achievement settings, as is the case for women in computing, can lead individuals to psychologically distance themselves from that domain in order to protect the integrity of the self (Crocker and Major, 1989; Major and O'Brien, 2005; Aronson and Rogers, 2008). For instance, women graduate students in computer science may witness but not be included in camaraderie among their male peers and men faculty members. As a result, women graduate students may feel socially isolated in their program and seek camaraderie in other areas of their life (e.g., social circles in non-computing activities). As a result, women may come to place less value on the computing aspect of their lives, compared to other activities where they feel valued, thereby protecting their self-worth (Crocker and Major, 1989; Steele, 1997). Although this strategy may be self-protective, disengaging from one's computing identity may hamper women's potential for professional success. This is because when domain identification is high, positive outcomes in that domain are self-relevant and rewarding, thereby motivating persistence (Finn, 1989; Steele, 1997). Thus, women who distance their identity from computing may miss out on opportunities to feel good about their achievements in computing. This may, in turn, cause women to leave computing in pursuit of other fields that allow women to more fully develop their identity and sense of self-worth. In sum, to promote women's persistence in computing, it is important that computing is deeply integrated into their identity.

One barrier to women integrating computing into their identity is the cultural belief that computing intelligence is inborn and immutable. People who hold this belief system are called "entity theorists" (Dweck, 2006); these people are particularly likely to respond to negative feedback by becoming disheartened, losing interest in, and avoiding that particular domain (Grant and Dweck, 2003; Blackwell et al., 2007; Stout and Dasgupta, 2013). Thus, because academic settings present ample opportunity for negative feedback (e.g., critique from professors; low exam scores), students who endorse an entity theory of intelligence are particularly "at risk" of psychologically disengaging (i.e., dis-identifying) from academics (Hong et al., 1999). Because women are scarce in computing, it is important to mollify women's existing entity beliefs about computing. Importantly, research indicates entity beliefs can indeed shift so that intelligence is viewed as a muscle that can grow with time and effort (Dweck, 2006). Thus, interventions aimed at retaining women in computing should provide women with evidence that, with time and effort, success in computing is achievable for women and men alike, and women belong in computing just as much as men do. In the section that follows, we outline one intervention that aims to do just that.

THE GRAD COHORT INTERVENTION

Grad Cohort is an intervention that has been orchestrated and run by the CRA-W annually since 2004. The number of women who have attended Grad Cohort has grown steadily over the years, ranging from 102 in 2004 to 511 in 2016.

Attendees are primarily women enrolled in Ph.D. programs, with a small percentage of women enrolled in Terminal M.S. programs (e.g., 4% of participants in the 2016 cohort). At the 2-day long workshop, participants listen to presentations from and interact with 20 to 25 computing-related researchers and professionals who are women. These women role models are solicited using an internal list maintained by the CRA-W. The list includes full professors and senior level researchers who are well known for their research accomplishments; many have served as Grad Cohort speakers before and/or are CRA-W committee members. Although the content of the workshop is modified slightly from year to year, the general themes at Grad Cohort have remained consistent over the years. Specifically, through a series of presentations and panels, senior women share information on graduate school survival skills (e.g., developing a productive working relationship with one's advisor; building self-confidence), as well as more personal information and insights about professional development (e.g., strategies for navigating gender politics; balancing personal and professional goals). In addition to presentations, the workshop offers ample opportunity for questions, informal discussions, social events, and one-to-one mentoring. Through the workshop, students are able to build mentoring relationships and develop peer networks that can form the basis for ongoing interactions during their graduate careers. The workshop explicitly focuses on building community by exposing women graduate students to successful senior women in their field and enabling an opportunity to enhance their own peer networks. To the authors' knowledge, no other mentorship program of this nature exists for women graduate students in computing programs.

Although the workshop content does not explicitly focus on the factors observed in the current research, it makes sense at a theoretical level that the workshop might have an impact on all of our factors of interest. For one, the workshop intentionally exposes participants to many successful women role models in order to motivate participants to become the next generation of senior researchers. Thus, we would expect women to aspire to be successful in their own careers, and *become well known in their field*. Participants are also exposed to role models who are "giving back" to the community of women in computing. All speakers at Grad Cohort are volunteers who are dedicated to mentoring women computing students. Thus, participants may also aspire to be like those role models by wishing to *give back to their community*. Further, Grad Cohort exposes participants to an abundance of peers and role models who are women in computing, providing concrete evidence that women can be successful in computing careers. Participants likely get the sense that computing aptitude need not be biologically predetermined—women and men alike can be competent in computing. Thus, participants may be particularly *unlikely to hold entity beliefs* about the nature of computing aptitude. Together, the Grad Cohort experience is designed to give women the tools they need to overcome challenges and be successful in a computing career so that computing is a strong part of women's sense of "who they are," or their *identity*.

PRELIMINARY RESULTS FOR GRAD COHORT

The Computing Research Association's social science research and evaluation center, the Center for Evaluating the Research Pipeline (CERP), has assessed the immediate impact of Grad Cohort on women's commitment to computing since 2014. Prior work by CERP has found that immediately after Grad Cohort, participants report (a) greater confidence in their ability to become leaders in their field (Cundiff et al., 2014; Stout and Wright, 2015); (b) a stronger computing identity (Wright and Stout, 2016); and (c) stronger beliefs that negative feedback and setbacks are opportunities for growth (i.e., growth mindset; Cundiff et al., 2014; Stout and Wright, 2015). In addition, open ended feedback from participants, collected by the Computing Research Association, indicates women may come away from Grad Cohort feeling prepared to face hurdles head on:

> "[At Grad Cohort], the session about being a woman in computing changed my life. I thought I was the only one dealing with this pressure and it is so helpful. Now I understand that differences will always be there and that my job is learning how to succeed in that environment. The session about self-confidence is another session that I will never forget; understanding that a successful career can be accompanied with failures motivates me to stand up even when I feel that I can't." – *Grad Cohort Participant, 2012*

Grad Cohort may also encourage women to "pay it forward" by mentoring younger women:

> "I am more confident to talk to other younger students and give advice about these kind of issues and make them aware that they are not alone and that we are here to support each other!" – *Grad Cohort Participant, 2015*

Thus, there is existing evidence that Grad Cohort has an immediate, positive impact on the degree to which women believe they can be successful leaders in the field, increases interest in giving back to the community, alleviates entity beliefs (i.e., promote a growth mindset), and boosts women's computing identity. But what is the shelf life of these benefits? Is there lasting impact of the workshop on women's professional goals and self-concept? And, how do women's professional goals and self-conceptions compare to those of men? If gender disparities exist, does Grad Cohort narrow these gaps? The current work was designed to address these questions.

OVERVIEW OF THE CURRENT WORK

In the current work, our research question is *What is the long-term impact of Grad Cohort on women compared to women who have not participated in the workshop, and men?* To answer this question, we used CERP's unique infrastructure, which works with a network of computing departments across the U.S. who distribute CERP's survey instrument to graduate students. This methodology allows CERP to collect data from a large sample of graduate students, some of whom are past Grad Cohort participants, but most of whom are non-participants. To assess long-term impact of the workshop for participants vs. non-participants, we measured dedication to (a) becoming well-known in their field, and (b) using one's work to give back to the community. We also measured students' identification with computing, which refers to one's self-definition, or the degree to which one feels their computing career pursuit is an important element of "who they are." Finally, we measured students' beliefs about the nature of computing intelligence, namely, the degree to which women viewed computing aptitude as an innate, unchangeable characteristic (i.e., *entity beliefs*). We also observed whether the typical relationship between students' entity beliefs and identification with computing existed in our sample, where stronger entity beliefs predict weaker identification with computing. We then assessed whether the Grad Cohort intervention would interrupt this relationship. That is, we thought it possible that Grad Cohort participants would show strong identification with computing, even if they held strong entity beliefs. In this way, women, who are typically a vulnerable population in computing, would be protected against the (typically pernicious) notion that computing ability is inborn.

METHOD

Grad Cohort Participant Selection

Recruitment methods for Grad Cohort participants simulate random assignment as much as is possible outside of the laboratory. Announcements advertising Grad Cohort are disseminated to institutions affiliated with the Computing Research Association (CRA)[1], which includes more than 200 academic institutions across the United States and Canada. Dissemination within each department is ad hoc (e.g., department chairs distribute emails to students; information is conveyed via word of mouth). Email announcements are also distributed among women's groups within the computing research field. Thus, announcements are distributed to a broad array of academic departments and special interest groups.

Women then apply to participate in Grad Cohort. The workshop is primarily funded through annual donations from academic, industry, and other computing organization sponsors; the total amount donated per year determines how many students can be accepted. Women are eligible to participate if they are a 1st, 2nd, or 3rd year graduate student, with preference given to students who have not attended before. The applicant's GPA is not considered during the application process, so priority is not given to students based on academic merit. The result is a broad sample, maximizing the numbers of women graduate students who can attend at least once during their early graduate school years, and the number of institutions that are represented regardless of size or rank.

Research Participants

During the fall of 2015, CERP distributed a survey to 74 computing departments that awarded graduate degrees. One-thousand-three-hundred-ninety-five students enrolled in a Ph.D. program in a computing field[2] completed the survey. Of those students, 134 were women who had participated in Grad Cohort in the past[3] and 1199 were non-participants ($n = 293$ women, $n = 874$ men, $n = 9$ non-binary gender identity, and $n = 23$ with no gender data)[4]. Because students' binary gender identity (i.e., women vs. men) was central to our research questions, we excluded individuals who identified as either non-binary or had missing gender data from our analysis.

Among participants, we opted to exclude women from this study who had only participated in the 2015 workshop ($n = 41$). For these women, it had only been approximately 6 months between their only experience with the workshop and the time we distributed the survey discussed here. Excluding this group of women from analyses allowed for the most stringent test of long-term effects of Grad Cohort on women available in our dataset. Excluding these women, as well as women who had missing data for our main variables of interest ($n = 9$), resulted in $n = 84$ past participants for analysis. Within our final sample of Grad Cohort participants, the amount of time that had elapsed since their first Grad Cohort experience ranged from 18 to 78 months [mean (M) = 31.57, standard deviation (SD) = 14.28], with 63% having participated one time, 32% having participated two times, and 5% having participated three times.

We used a propensity score matching procedure to generate two separate comparison groups for our analyses: women non-participants and men. Groups were matched on the following variables:

- Institution type: respondents reported their academic institution (all doctoral granting); we coded research activity for each institution ranging from moderate to very high using the Carnegie classification system[5].
- Expected graduation date: respondents reported the year they expected to complete their Ph.D. program.
- Race/ethnicity: respondents selected race/ethnic categories that applied to them, resulting in the following nine categories: Arab, Middle Eastern, Persian; Asian or Asian American; Black or African American; Hispanic or Latina; Native American; Native Hawaiian or other Pacific Islander; White or Caucasian; Mixed race/ethnicity; and other.

[1]The Computing Research Association is a non-profit organization whose goal is to advance computing research. The CRA-W is a subcommittee of the CRA.

[2]We define *computing field* as computer science, computer engineering or electrical and computer engineering, computing information systems or information systems, or other computing related field as reported by the respondent. Seventy-eight percent of the sample was computer science students ($n = 196$), and 22% was students from some other computing field ($n = 56$). While it would have been ideal to control for the type of subfield students were enrolled in when we analyzed the data, small sample sizes of students from other subfields of computing precluded our ability to do so.

[3]Past Grad Cohort participants in the survey were identified by asking the respondents whether they had attended CRA-W's Grad Cohort workshop in the past, and, if they had, what year(s) they attended the workshop.

[4]Ideally, the comparison group would consist of individuals who applied to Grad Cohort, but did not participate. However, applicant contact information was not available at the time of data collection for this project. Further, such a comparison group does not exist for men, given that men are not eligible to participate in Grad Cohort.

[5]See http://webtest.iu.edu/∼carclass/demo2/methodology/basic.php for further information on how the institutions were coded using the Carnegie classification system.

- U.S. citizenship status: respondents indicated whether they were a U.S. citizen, permanent resident, temporary visa holder, or "other" (e.g., dual citizenship).
- Age: respondents reported their age in years.
- Terminal M.S. degree holder: respondents indicated whether or not they had completed a terminal M.S. degree prior to enrolling in their Ph.D. program.

The treatment group (i.e., Grad Cohort participants) was matched to each comparison group using 1:1 nearest neighbor matching (Rosenbaum, 2002; Austin, 2011). After matching was completed, the matched groups were compared on their similarity in terms of the matching variables using chi-squared tests and *t*-tests as applicable. These tests showed the matched samples did not significantly differ on the matching variables.

Within our full matched sample ($N = 252$; $n = 84$ participants, $n = 84$ women non-participants, $n = 84$ men non-participants), 88% was enrolled at a doctoral research university with very high research activity, 8% was enrolled at a doctoral research university with high research activity, and 4% was enrolled at a doctoral research university with moderate research activity, according to the Carnegie classification system. Eight percent of our sample expected to graduate in 2015, 33% expected to graduate in 2016, 29% expected to graduate in 2017, 18% expected to graduate in 2018, and 12% expected to graduate in 2019 or later. The racial/ethnic distribution of our sample was as follows: 5% Arab, Middle Eastern, Persian; 24% Asian or Asian American; 3% Black or African American; 5% Hispanic or Latino(a); 57% White or Caucasian; 5% Mixed race/ethnicity; and 1% other. Fifty-nine percent of the sample was U.S. citizens, 5% was non-U.S. citizens with permanent residency, 34% was non-U.S. citizens with a temporary visa, and 2% was other (e.g., dual citizen, etc.). The median age of our sample was 28. Forty-three percent of our sample had completed a Terminal M.S. before entering their current Ph.D. program, and 57% of our sample entered their current Ph.D. program without already having completed a Terminal M.S. degree.

Procedure

Grad Cohort participants and non-participants were invited to complete an online survey via (a) an email invitation sent by their department chair or an administrative staff person in their department or (b) a direct invitation from CERP. Incentive for completing the survey was entry in a raffle to win a $100 gift card. Questions relating to students' professional goals, computing identity, and entity belief orientation were embedded within the survey. This study was reviewed and approved by an independent IRB, Solutions IRB. The IRB waived the requirement for written informed consent.

Measures

Professional Goals: Becoming Well Known, and Giving Back to the Community

Students were asked "How important to you is it that your future career allows you to do each of the following?," using a scale of (1) *strongly disagree* to (5) *strongly agree*, and presented with a series of goals. A single item of interest was "become well-known in my field." Also of interest was a set of goals pertaining to students' interest in giving back to their community included the following: "give back to my community"; "have social impact"; and "be a role model for people in my community." The latter three items reliably measured a single construct (Cronbach's alpha = 0.81), so were averaged to create a composite measure.

Computing Identity

Students were asked to rate the degree to which they agreed with the following statement, using a scale of (1) *strongly disagree* to (5) *strongly agree*: "Computing is a big part of who I am"; "I see myself as a 'computing person'"; "Computing is not very important to me" (reverse scored); "I am interested in learning more about what I can do with computing"; and "Using computers to solve problems is interesting." Items had good internal reliability (Cronbach's alpha = 0.80), and were aggregated to create a composite measure of computing identity.

Entity Orientation

To measure entity orientation, we measured students' agreement with the following statements using a scale ranging from (1) *strongly disagree* to (5) *strongly agree*: "People have a certain amount of computing ability that really can't be changed"; "People can't really change how good they are in computing"; and "People can learn new things, but they can't change their basic ability to do computing." These items formed a reliable index of entity orientation (Cronbach's alpha = 0.86), so we aggregated them to create a composite index.

RESULTS

Professional Goals

Becoming Well Known in One's Field

As a group, students valued becoming well known in their field at a level just above the midpoint of our scale (3.00), $M = 3.40$, $SD = 1.27$. To assess whether students differed in their desire to become well known, we ran a one-way Analysis of Variance (ANOVA) on this measure, treating a three level student variable (Grad Cohort participants, women non-participants, men non-participants) as a between subjects factor. The degree to which students valued becoming well known in their field differed across the three groups, $F_{(1, 249)} = 3.34$, $p < 0.05$, $\eta^2 = 0.03$. Post-hoc Dunnett tests revealed Grad Cohort participants placed more value on becoming well known in their field than women non-participants (Grad Cohort participants: $M = 3.63$, $SD = 1.15$; women non-participants: $M = 3.13$, $SD = 1.40$), $p < 0.05$, $d = 0.39$, but Grad Cohort participants and men did not differ in this value (Grad Cohort participants: $M = 3.63$, $SD = 1.15$; men non-participants: $M = 3.43$, $SD = 1.23$), $p = 0.48$, $d = 0.17$. See **Figure 1** for a graph of this effect. Because men vastly outnumber women in leadership roles in computing (and outside of computing), this finding is particularly promising.

Giving Back to the Community

Among all students in the sample, interest in giving back to the community was above the midpoint (3.00), $M = 3.67$, $SD = 0.89$. However, the degree to which students valued this goal differed across groups, $F_{(1, 249)} = 5.89$, $p < 0.01$, $\eta^2 = 0.05$. Specifically, post-hoc Dunnett tests indicated Grad Cohort participants placed more value on giving back to the community ($M = 3.93$, $SD = 0.84$) than women non-participants ($M = 3.58$, $SD = 0.90$), $p < 0.05$, $d = 0.40$, and men non-participants ($M = 3.50$, $SD = 0.88$), $p < 0.01$, $d = 0.50$. See **Figure 2** for a graph of this effect. As will be discussed in detail below, this finding suggests Grad Cohort may be fostering a desire to "pay it forward," so that women take an active role in mentoring the next generation of computing researchers.

Computing Identity

As a group, students identified quite strongly with computing; this was evident by the fact that students' mean identification score was well above the midpoint of the scale (3.00), $M = 4.21$, $SD = 0.69$. This is not surprising, given that students in our sample were Ph.D. students and had invested a significant amount of time and energy into studying computing during the past several years. However, computing identity differed among the three groups of students, $F_{(1, 249)} = 5.71$, $p < 0.01$, $\eta^2 = 0.04$. Post-hoc Dunnett tests revealed whereas non-participant women identified with computing less strongly than men (women non-participants: $M = 4.02$, $SD = 0.77$; men non-participants: $M = 4.36$, $SD = 0.72$), $p < 0.01$, $d = 0.46$, Grad Cohort participants identified with computing to a statistically equivalent degree as men (Grad Cohort participants: $M = 4.23$, $SD = 0.63$; men non-participants: $M = 4.36$, $SD = 0.72$), $p = 0.33$, $d = 0.19$. These results suggest Grad Cohort may be alleviating a gender gap in students' computing identity. See **Figure 3** for a graph of this effect.

Entity Orientation

Next, we assessed students' entity belief system, and found, as a group, students held entity beliefs well below the midpoint of our measure (3.00), $M = 1.79$, $SD = 0.78$. However, the degree to which students held entity beliefs about the nature of computing did differ by student group, $F_{(1, 249)} = 3.36$, $p < 0.05$, $\eta^2 = 0.03$. Specifically, post-hoc Dunnett tests indicated non-participant women held stronger entity beliefs than men (women non-participants: $M = 1.96$, $SD = 0.82$; men non-participants: $M = 1.67$, $SD = 0.81$), $p < 0.05$, $d = 0.36$, but Grad Cohort participants and men did not differ in their endorsement of entity beliefs (Grad Cohort participants: $M = 1.73$ $SD = 0.67$; men: $M = 1.67$, $SD = 0.81$), $p = 0.87$, $d = 0.07$. See **Figure 4** for a graph of this effect.

The Relationship between Entity Orientation and Computing Identity

We next observed the relationship between entity orientation and computing identity for students, and whether this relationship differed across the three student groups. We expected to find stronger entity beliefs would predict weaker identification with computing for students in general. Indeed, entity orientation was negatively correlated with computing identity for the full sample, $r = -0.21$, $p < 0.01$. Importantly we thought it possible

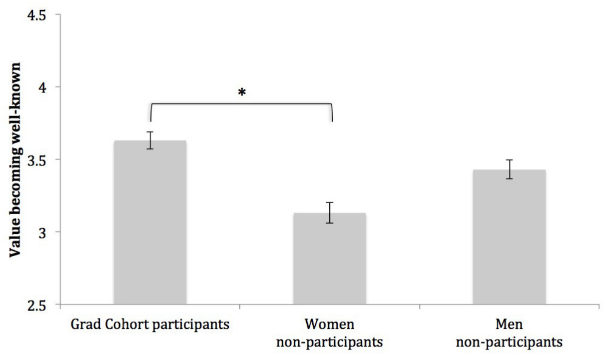

FIGURE 1 | Group differences in the degree to which students value becoming well known in their field. Note. Bars represent group means; intervals at the top of bars represent standard errors of the mean. Scale values range from *(1) Low* to *(5) High.* *Indicates group means are significantly different, $p < 0.05$.

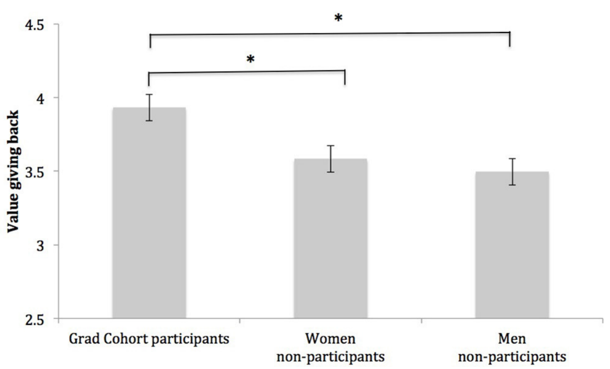

FIGURE 2 | Group differences in the degree to which students value giving back to their community. Note. Bars represent group means; intervals at the top of bars represent standard errors of the mean. Scale values range from *(1) Low* to *(5) High.* *Indicates group means are significantly different, $p < 0.05$.

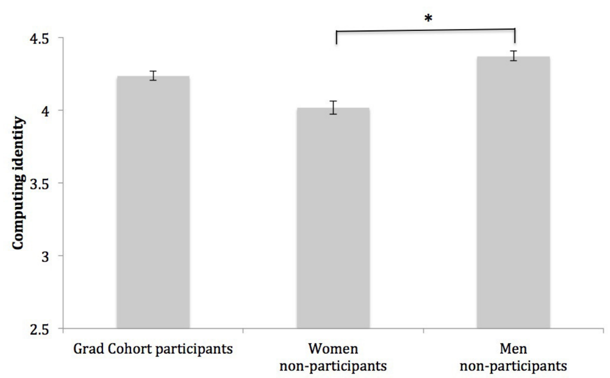

FIGURE 3 | Group differences in computing identity. Note. Bars represent group means; intervals at the top of bars represent standard errors of the mean. Scale values range from *(1) Low* to *(5) High.* *Indicates group means are significantly different, $p < 0.05$.

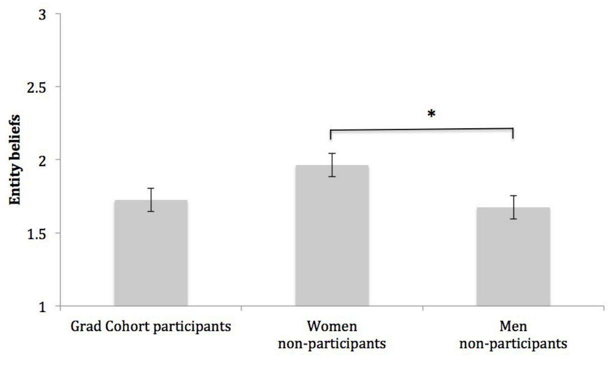

FIGURE 4 | Group differences in entity beliefs. Note. Bars represent group means; intervals at the top of bars represent standard errors of the mean. Scale values range from *(1) Low* to *(5) High.* *Indicates group means are significantly different, $p < 0.05$.

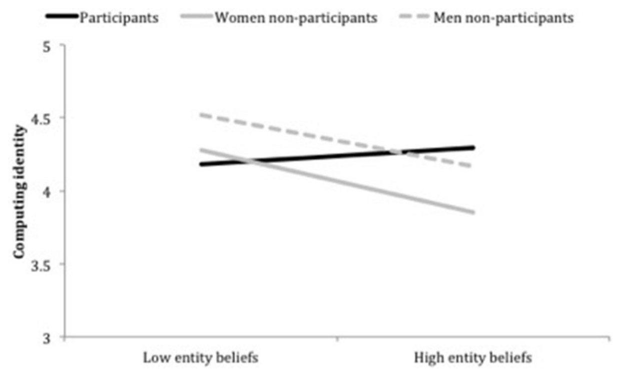

FIGURE 5 | Computing identity as a function of entity orientation and student group. Note. Low and High entity orientation represent 1 SD below and 1 SD above the mean for entity orientation, respectively.

that Grad Cohort participants would not show a relationship between these two variables, suggesting Grad Cohort may protect students' identity from entity beliefs. To test this, we regressed computing identity (the dependent variable) on entity beliefs (mean centered), student group (two dummy-coded variables computed separately for the women non-participants and men non-participants, treating Grad Cohort participants as the reference group), and their interaction terms. The overall model was statistically significant, $R^2 = 0.10$, $F_{(5,\ 243)} = 5.65$, $p < 0.001$. We found two significant Entity Belief × Student Group interactions: one comparing Grad Cohort participants to women non-participants, β = −0.24, $B = -0.35$, $SE = 0.14$, $p < 0.05$, and a second comparing Grad Cohort participants to men, β = −0.20, $B = -0.30$, $SE = 0.14$, $p < 0.05$[6]. See **Figure 5** for a graph of these interaction effects.

To interpret this interaction effect, we examined whether the effect of entity orientation on computing identity differed for the three student groups using conventional dummy coding protocol where our reference group was zero and the non-reference group was 1 (Aiken and West, 1991). In doing so, we found stronger entity beliefs significantly predicted a weaker computing identity among women non-participants, β = −0.31, $B = -0.27$, $SE = 0.09$, $p < 0.01$, and men non-participants, β = −0.25, $B = -0.23$, $SE = 0.09$, $p < 0.05$. However, entity beliefs did not predict Grad Cohort participants' computing identity, β = 0.08, $B = 0.07$, $SE = 0.11$, $p = 0.51$.

We also examined the two-way interactions by observing group differences in computing identity at high and low levels of entity beliefs by re-running our original regression model using two new iterations: (1) centering entity orientation at 1 standard deviation below mean entity orientation and (2) centering entity orientation 1 standard deviation above mean entity orientation (Aiken and West, 1991). Using this strategy, we first compared Grad Cohort participants to women non-participants (solid black and solid gray lines in **Figure 5**), and found when entity beliefs were low (negative portion of the x axis in **Figure 5**), women identified with computing to a statistically equivalent degree, β = 0.07, $B = 0.10$, $SE = 0.15$, $p = 0.54$. However, when entity beliefs were high (positive portion of the x axis in **Figure 5**), non-participants identified with computing significantly less than Grad Cohort participants, β = −0.30, $B = -0.44$, $SE = 0.15$, $p < 0.01$. This finding suggests Grad Cohort may be protecting women's computing identity from entity beliefs; we discuss implications for this finding in the Discussion section.

Next, we compared Grad Cohort participants to men non-participants (solid black and dashed gray lines in **Figure 5**), and found when entity beliefs were low (negative portion of x axis in **Figure 5**), men identified with computing to a significantly greater degree than Grad Cohort participants, β = 0.23, $B = 0.33$, $SE = 0.14$, $p < 0.05$. But, when entity beliefs were high (positive portion of x axis in **Figure 5**), men and Grad Cohort participants identified with computing to a statistically equivalent degree, β = −0.09, $B = -0.13$, $SE = 0.16$, $p = 0.43$. Thus, although Grad Cohort participants identified with computing to a similar degree as men when students held strong entity beliefs, men identified with computing to a greater degree than Grad Cohort participants when students held weak entity beliefs.

DISCUSSION

Our research assessed the long-term outlook for women in computing who have participated in the CRA-W's Grad Cohort mentorship workshop, compared to women and men who have never participated in the workshop. First, we found past Grad Cohort participants were more interested in becoming well-known in their field than women who had not participated in Grad Cohort, and were more interested in "giving back" to their communities than their peers (both women and men). To the degree that women's "community" consists of other women—particularly young women—this finding is important as computing seeks to engage dramatically more girls and young women in the field. That is, when well-known women computing experts reach out and mentor younger women, those younger

[6] A second model treating women non-participants as the reference group indicated there was no significant interaction when comparing women non-participants to men non-participants, $p = 0.71$.

women are exposed to computing experts who "look like them." As will be expanded upon below, seeing competent women role models can help inoculate women's self-concept from the cultural stereotype that computing is for boys. Thus, women who have participated in Grad Cohort may be particularly motivated to build a public persona, and "pay it forward" in order to help build diversity into the next generation of computing professionals.

We also found non-participant women reported computing was a less important element of "who they are" (i.e., their identity) compared to men. Of note, Grad Cohort participants' computing identity was at parity with men. This finding is consistent with existing research documenting that women identify with fields less than men when women are underrepresented and/or marginalized in those fields, but women identify with fields to an equal degree as men when both genders are represented and valued (Stout and Dasgupta, 2011; Stout et al., 2011; Dasgupta and Stout, 2014). Ph.D. students have achieved a great deal in order to gain acceptance into a Ph.D. program, and are on track to achieve a great deal more (completing a dissertation; publications; contributing to innovations in computing research). As such, it is important that students connect these achievements with their sense of self-worth in order to remain engaged in their career track. This is particularly important for women, who are strikingly underrepresented in computing careers. That is, a strong link between women's sense of self and computing can help make their achievements personally meaningful, motivating, and potentially keep women on track to become the next generation of leaders in computing research.

We also examined the degree to which students held entity beliefs about the nature of computing intelligence. This belief system is known to be maladaptive, particularly when individuals are faced with negative feedback, which is common during graduate training (Dweck, 2006). For individuals with entity beliefs, negative feedback can lead to discouragement and disengagement (Hong et al., 1999); thus, a rejected manuscript submission or criticism from one's advisor might send the message that one is intrinsically incapable of success. This chain of events is particularly undesirable when those individuals are women in computing, because women are so scarce in the field. Our findings suggest Grad Cohort may be alleviating the negative impact of entity beliefs on women's self-concept. Specifically, whereas holding strong entity beliefs about computing intelligence was related to a weak computing identity among women and men non-participants, there was no such relationship between entity beliefs and computing identity for Grad Cohort participants. We believe this finding is particularly important for retaining women in computing; moreover, this finding is reminiscent of research on other interventions for women that help inoculate women's self-concept (identity; belonging) from negative stereotypes about women's technical aptitude (see Dasgupta, 2011). That is, although negative stereotypes about women's innate technical ability continue to exist worldwide (Miller et al., 2015), and those stereotypes can lead women to underperform and psychologically disengage from those fields (Spencer et al., 1999; Stout et al., 2011; Stout and Tamer, 2016), learning environments can be modified to protect women's achievement and engagement when confronted with gender stereotypes. For instance, the presence of women teachers in calculus classes can foster a sense of enjoyment and belonging in math, even when women know negative stereotypes about women's math abilities exist (Stout et al., 2011). Other research indicates women feel strong self-efficacy and belonging in computing classrooms that foster collaboration, even when those women students are aware of stereotypes that computing is "for men" (Stout and Tamer, 2016). Because Grad Cohort shares characteristics with the studies outlined here (i.e., showcasing competent, successful women role models in computing; a sense of togetherness and support among participants), it makes sense that Grad Cohort participants' computing identity appears to be protected against beliefs that computing ability is biologically predetermined.

In summary, our results highlight the importance of same-group role models for underrepresented individuals (see Dasgupta, 2011; Stout et al., 2011). These role models can make the path to professional success for underrepresented groups more clear by (a) providing mentoring that speaks to those groups' unique experiences and (b) serving as an example of someone from that group who has succeeded (i.e., "If they can do it, I can do it too"). These role models serve as counterevidence for cultural stereotypes about natural aptitude. That is, cultural stereotypes suggest technical aptitude is innate; a related stereotype is that women are "naturally" less technically apt than men (see Miller et al., 2015). This stereotype can be debunked by showing concrete opposing evidence, such as successful, hard-working women in technical fields. Like the Grad Cohort intervention, other interventions aiming to promote success among underrepresented groups in technical fields should showcase same-group role models who symbolize the fact that hard work as opposed to inborn aptitude is the key to success in the field.

Limitations and Future Directions

One limitation of the current work is its strictly quantitative focus. Taking a mixed-methods approach involving qualitative and quantitative data would strengthen the work. Future directions for Grad Cohort evaluation at CERP include directly following up with Grad Cohort participants to ask for a retrospective account of particularly impactful elements of the workshop. This inquiry will be qualitative so that we can develop hypotheses about the reasons why Grad Cohort is beneficial to women, and then test those hypotheses through our comparative survey research.

Attention to racial and ethnic diversity is notably absent in the current work. Unfortunately, our sample of Grad Cohort participants was not large enough to ask intersectional research questions [e.g., is Grad Cohort particularly impactful for a particular racial group(s)]. Recent research on women's self-efficacy immediately after Grad Cohort suggests Asian and White women may benefit more than Black, Hispanic/Latina, and Middle Eastern women (Wright and Stout, 2016). We interpret this finding with caution, given that sample sizes in this particular analysis were small for some groups (e.g., Hispanic/Latina $n =$

17). Nonetheless, intersectional analysis is a critical next step to fully understanding the impact of Grad Cohort on women's commitment to computing careers, especially given the doubly underrepresented status of women of color in computing.

We acknowledge that women who participate in Grad Cohort may be fundamentally different than women who do not participate in Grad Cohort. Although we analytically controlled for a variety of factors that might predict women's professional goals and engagement in computing (institution characteristics, respondent's expected graduation date, race/ethnicity of the respondent, U.S. citizenship status, age, and whether or not the respondents had entered their Ph.D. program with a terminal master's degree), there are other variables that we were not able to control for that could have contributed to our results. For instance, Grad Cohort participants were recruited through announcements to departments affiliated with the Computing Research Association (CRA). Although we were able to control for the size and level of research activity of participants' vs. non-participants' home institutions, we were not able to control for the climate of those institutions that may have had an impact on our results. That is, the CRA and its affiliate institutions may both value diversity initiatives to a greater degree than institutions unaffiliated with the CRA. This discrepancy may foster different climates for women, such that CRA affiliate climates are warmer and non-affiliate climates are chillier. Thus, women at departments unaffiliated with the CRA may dis-identify with computing to a greater degree, and hold stronger entity beliefs about computing aptitude than Grad Cohort participants simply because non-participants' departments lack sensitivity to gender issues in computing. Because we do not have measures of our sample's professional goals, identity, and entity beliefs prior to the Grad Cohort intervention, we cannot be sure whether this speculation is true. However, our prior research documents increases in women's leadership self-efficacy, computing identity, and growth mindset after Grad Cohort compared to immediately before the workshop (Cundiff et al., 2014; Stout and Wright, 2015; Wright and Stout, 2016). This work suggests Grad Cohort may be at least in part responsible for the benefits documented in the current research.

It is also important to note the type of women who participates in Grad Cohort may be fundamentally different from non-participants in other ways. For instance, non-participant women may actively choose not to apply to participate in Grad Cohort, either because they feel they are self-sufficient enough without the workshop or because they do not want to be associated with the workshop. Or, women may have applied for but not been accepted to Grad Cohort. Alternatively, participants may be more proactive than women who do not apply to participate in Grad Cohort. Regarding the latter possibility, we take some comfort in the fact that the CRA-W does not use GPA as a means of selecting Grad Cohort participants, as GPA can serve as a proxy for motivation and diligence. We also believe our propensity score matching technique may have controlled for participants' vs. non-participants' proactive nature to some degree. For instance, students' home institutions may also serve as a proxy for student motivation (i.e., larger schools with stronger research programs may attract more ambitious and competitive students than less research intensive schools). Further, past research on the short term benefits of Grad Cohort indicate women get a boost in their confidence to become leaders after the event (Cundiff et al., 2014; Stout and Wright, 2015). This provides some evidence that Grad Cohort may be enhancing women's commitment to becoming the next generation of leaders in computing.

The benefits of randomized assignment in order to conduct more rigorous social science research need to be weighed against the benefits of including as many women as are interested in the Grad Cohort intervention. Grad Cohort provides an opportunity for women during an already stressful and isolating period of life (i.e., graduate school) to connect with other women who share a passion for computing. The CRA-W is expressly interested in sharing the Grad Cohort experience with as many women as possible, and has reservations about intentionally excluding women from Grad Cohort to generate a control condition for research. Knowing this, we view the current research findings as promising evidence that the program may have lasting impact on women's engagement in the field of computing. Given this, the CRA-W's long standing Grad Cohort program may help fortify women's commitment to pursing computing research careers after earning their Ph.D. and move the needle in the direction of greater gender diversity in computer science.

AUTHOR CONTRIBUTIONS

JS was the lead writer and analyst. BT and HW contributed to data collection and writing. LC, SD, and AH contributed to writing.

ACKNOWLEDGMENTS

This research was supported by a grant from the National Science Foundation, CNS-1246649, awarded to the Computing Research Association.

REFERENCES

Aiken, L. S., and West, S. G. (1991). *Multiple Regression: Testing and Interpreting Interactions.* Thousand Oaks, CA: Sage.

Aronson, J., and Rogers, L. (2008). "Overcoming stereotype threat," in *Positive Psychology: Exploring the Best in People,* Vol. 3, ed S. J. Lopez (Westport, CT: Praeger), 109–121.

Austin, P. C. (2011). An introduction to propensity score methods for reducing the effects ofconfounding in observational studies. *Multiv. Behav. Res.* 46, 399–424. doi: 10.1080/00273171.2011.568786

Blackwell, L. S., Trzniewski, K. H., and Dweck, C. S. (2007). Implicit theories of intelligence predict. achievement across an adolescent transition: a longitudinal study and an intervention. *Child Dev.* 78, 246–263. doi: 10.1111/j.1467-8624.2007.00995.x

Camp, T. (2012). Computing, we have a problem. *ACM Inroads* 3, 34–40. doi: 10.1145/2381083.2381097

Cejka, M. A., and Eagly, A. H. (1999). Gender-stereotypic images of occupations. correspond to the sex segregation of employment. *Pers. Soc. Psychol. Bull.* 25, 413–423. doi: 10.1177/0146167299025004002

Cheryan, S., Plaut, V. C., Handron, C., and Hudson, L. (2013). The stereotypical computer scientist: gendered media representations as a barrier to inclusion for women. *Sex Roles* 69, 58–71. doi: 10.1007/s11199-013-0296-x

Crocker, J., and Major, B. (1989). Social stigma and self-esteem: the self-protective properties of stigma. *Psychol. Rev.* 96, 608–630. doi: 10.1037/0033-295X.96.4.608

Cundiff, J. L., Stout, J. G., and Wright, H. M. (2014). *CRA-W Grad Cohort:Pretest/Posttest Evaluation Report*. Washington, DC: Computing Research Association:

Dasgupta, N. (2011). Ingroup experts and peers as social vaccines who inoculate the self-concept: the stereotype inoculation model. *Psychol. Inq.* 22, 231–246. doi: 10.1080/1047840X.2011.607313

Dasgupta, N., and Stout, J. G. (2014). Girls and women in science, technology, engineering and mathematics: STEMing the tide and broadening participation in STEM careers. *Policy Insights Behav. Brain Sci.* 1, 21–29. doi: 10.1177/2372732214549471

Dweck, C. S. (2006). *Mindset*. New York, NY: Random House.

Finn, J. D. (1989). Withdrawing from school. *Rev. Educ. Res.* 59, 117–142. doi: 10.3102/00346543059002117

Forbes, T. (2016). *The 10 Best-Paying STEM Jobs for Recent Grads.* Available online at: http://www.forbes.com/pictures/efkk45ekgkh/the-10-best-paying-stem-jobs-for-recent-grads/jobs-for-recent-grads/

Grant, H., and Dweck, C. S. (2003). Clarifying achievement goals and their impact. *J. Pers. Soc. Psychol.* 85, 541–553. doi: 10.1037/0022-3514.85.3.541

Hoever, I. J., van Knippeberg, D., van Ginkel, W. P., and Barkema, H. G. (2012). Fostering team creativity: perspective taking as key to unlocking diversity's potential. *J. Appl. Psychol.* 97, 982–996. doi: 10.1037/a0029159

Hong, Y. Y., Chiu, C., Dweck, C. S., and Wan, W. (1999). Implicit theories, attributions, and coping: a meaning system approach. *J. Pers. Soc. Psychol.* 77, 588–599.

Leung, K., Maddux, W., Galinsky, A. D., and Chiu, C.-Y. (2008). Multicultural experience enhances creativity: the when and how. *Am. Psychol.* 63, 169–181. doi: 10.1037/0003-066X.63.3.169

Major, B., and O'Brien, L. T. (2005). The social psychology of stigma. *Annu. Rev. Psychol.* 56, 393–421. doi: 10.1146/annurev.psych.56.091103.070137

Margolis, J., and Fisher, A. (2002). *Unlocking the Clubhouse: Women in Computing*. Cambridge, MA: The MIT Press.

Miller, D. I., Eagly, A. H., and Linn, M. C. (2015). Women's representation in science predicts national gender-science stereotypes: evidence from 66 nations. *J. Educ. Psychol.* 107, 631–644. doi: 10.1037/edu0000005

Rosenbaum, P. R. (2002). "Constructing matched sets and strata," in *Observational Studies*, ed P. R. Rosenbaum (New York, NY: Springer), 295–331.

National Science Foundation (2015a). *TABLE 9-5. Employed Scientists and engineers, by Occupation, Highest Degree Level, and Sex: 2013. [NCSES Data Tables: Women, Minorities, and Persons with Disabilities in Science and Engineering]*. Availaible online at: http://www.nsf.gov/statistics/2015/nsf15311/tables/pdf/tab9-5.pdf

National Science Foundation (2015b). *NCSES Data Tables: Women, Minorities, and Persons with Disabilities in Science and Engineering.* Available online at: http://www.nsf.gov/statistics/2015/nsf15311/tables.cfm

National Science Foundation (2016a). *TABLE 5-1. Bachelor's Degrees Awarded, by Sex and Field: 2004–14. [NCSES Data Tables: Women, Minorities, and Persons with Disabilities in Science and Engineering]*. Retrieved from http://www.nsf.gov/statistics/2015/nsf15311/tables/pdf/tab5-1-updated-2016-08.pdf

National Science Foundation (2016b). *TABLE 6-2. Master's Degrees Awarded to Women, by Field: 2004–14. [NCSES Data Tables: Women, Minorities, and Persons with Disabilities in Science and Engineering]*. Available online at: http://www.nsf.gov/statistics/2015/nsf15311/tables/pdf/tab6-2-updated-2016-08.pdf

National Science Foundation (2016c). *TABLE 7-2. Doctoral Degrees Awarded to Women, by Field: 2004–14. [NCSES Data Tables: Women, Minorities, and Persons with Disabilities in Science and Engineering]*. Available anline at: http://www.nsf.gov/statistics/2015/nsf15311/tables/pdf/tab7-2-updated-2016-08.pdf

National Science Foundation (2016d). *TABLE 8-1. SandE Postdoctoral Fellows in Academic Institutions, by Field, Citizenship, and Sex: 2014. [NCSES Data Tables: Women, Minorities, and Persons with Disabilities in Science And Engineering]*. Available online at: http://www.nsf.gov/statistics/2015/nsf15311/tables/pdf/tab8-1-updated-2016-06.pdf

Sheffield, S. L. (ed.). (2004). "Professionalizing women scientists," in *Women and Science: Social Impact and Interaction* (New Brunswick, NJ: Rutgers University Press), 127–156.

Smith, S. L., Choueiti, M., and Pieper, K. (2014). *Gender Bias without Borders.* Report prepared for the Geena Davis Institute on Gender in Media. Available online at: http://seejane.org/research-informs-empowers/

Spencer, S. J., Steele, C. M., and Quinn, D. M. (1999). Stereotype threat and women's math performance. *J. Exp. Soc. Psychol.* 35, 4–28. doi: 10.1006/jesp.1998.1373

Steele, C. M. (1997). A threat in the air: how stereotypes shape intellectual identity and performance. *Am. Psychol.* 52, 613–629 doi: 10.1037/0003-066X.52.6.613

Stout, J. G., and Dasgupta, N. (2011). When he doesn't mean you: gender-exclusive language as a form of subtle ostracism. *Pers. Soc. Psychol. Bull.* 37, 757–769. doi: 10.1177/0146167211406434

Stout, J. G., and Dasgupta, N. (2013). Mastering one's destiny mastery goals promote challenge and success despite social identity threat. *Pers. Soc. Psychol. Bull.* 39, 748–762. doi: 10.1177/0146167213481067

Stout, J. G., Dasgupta, N., Hunsinger, M., and McManus, M. (2011). STEMing the tide: using ingroup experts to inoculate women's self-concept in science, technology, engineering, and mathematics (STEM). *J. Pers. Soc. Psychol.* 100, 255–270. doi: 10.1037/a0021385

Stout, J. G., and Tamer, B. (2016). "Collaborative learning eliminates the negative impact of gender stereotypes on women's self-concept," in *Proceedings for the Annual Meeting of the American Society for Engineering Education* (New Orleans, LA).

Stout, J. G., and Wright, H. M. (2015). *Understanding the Immediate Impact of the CRA-W's Grad Cohort Program on Diverse Women*. Washington, DC: Computing Research Association.

U.S. News and World Report (2016). *Best Jobs 2015*. Available online at: http://money.usnews.com/careers/best-jobs/rankings

Woolley, A. W., Chabris, C. F., Pentland, A., Hashmi, N., and Malone, T. M. (2010). Evidence for a collective intelligence factor in the performance of human groups. *Science* 330, 686–688. doi: 10.1126/science.1193147

Wright, H. M., and Stout, J. G. (2016). *The CRA Committee on the Status of Women in Computing Research (CRA-W) Grad Cohort 2016: Evaluation Report*. Washington, DC: Computing Research Association.

Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Psychology

ORIGINAL RESEARCH
published: 20 February 2017
doi: 10.3389/fpsyg.2017.00236

Looking through the Glass Ceiling: A Qualitative Study of STEM Women's Career Narratives

*Mary J. Amon**

Developmental Cognitive Neuroscience Laboratory, Department of Psychological and Brain Sciences, Indiana University Bloomington, Bloomington, IN, USA

Although efforts have been directed toward the advancement of women in science, technology, engineering, and mathematics (STEM) positions, little research has directly examined women's perspectives and bottom-up strategies for advancing in male-stereotyped disciplines. The present study utilized Photovoice, a Participatory Action Research method, to identify themes that underlie women's experiences in traditionally male-dominated fields. Photovoice enables participants to convey unique aspects of their experiences via photographs and their in-depth knowledge of a community through personal narrative. Forty-six STEM women graduate students and postdoctoral fellows completed a Photovoice activity in small groups. They presented photographs that described their experiences pursuing leadership positions in STEM fields. Three types of narratives were discovered and classified: career strategies, barriers to achievement, and buffering strategies or methods for managing barriers. Participants described three common types of career strategies and motivational factors, including professional development, collaboration, and social impact. Moreover, the lack of rewards for these workplace activities was seen as limiting professional effectiveness. In terms of barriers to achievement, women indicated they were not recognized as authority figures and often worked to build legitimacy by fostering positive relationships. Women were vigilant to other people's perspectives, which was costly in terms of time and energy. To manage role expectations, including those related to gender, participants engaged in numerous role transitions throughout their day to accommodate workplace demands. To buffer barriers to achievement, participants found resiliency in feelings of accomplishment and recognition. Social support, particularly from mentors, helped participants cope with negative experiences and to envision their future within the field. Work-life balance also helped participants find meaning in their work and have a sense of control over their lives. Overall, common workplace challenges included a lack of social capital and limited degrees of freedom. Implications for organizational policy and future research are discussed.

Keywords: STEM women, leadership, Photovoice, career strategy, gender roles, organizational policy, Participatory Action Research, underrepresentation of women

OPEN ACCESS

Edited by:
Catherine Alison Hill, American Association of University Women, USA

Reviewed by:
Chiara Ghislieri, University of Turin, Italy
Alexander Pundt, University of Mannheim, Germany

****Correspondence:***
Mary J. Amon
mjamon@iu.edu

Specialty section:
This article was submitted to Organizational Psychology, a section of the journal Frontiers in Psychology

Received: *21 October 2016*
Accepted: *07 February 2017*
Published: *20 February 2017*

Citation:
Amon MJ (2017) Looking through the Glass Ceiling: A Qualitative Study of STEM Women's Career Narratives. Front. Psychol. 8:236. doi: 10.3389/fpsyg.2017.00236

INTRODUCTION

Research on the underrepresentation of women in science, technology, engineering, and mathematics (STEM) often focuses on top-down factors that influence recruitment, retention, and promotion. Such top-down factors tend to overlook women's unique perspectives and strategies. Women are agents of their own career success, with their own complex perceptions and bottom-up strategies within the workplace. Granting that individual experiences in the workplace give rise to personal narratives, common themes are likely to emerge across STEM women's experiences. The goal of this research is to examine the career narratives of STEM women, or the spoken account of their experiences pursuing leadership positions in STEM. Photovoice, a Participatory Action Research method, informed by a grounded theory perspective, was used to identify the barriers that STEM women perceive as especially challenging, as well as their bottom-up approaches for managing barriers to achievement.

Women prepare for college degrees in STEM at approximately equal rates as men. However, after matriculating into college, women are less likely to pursue degrees in these fields (Hill et al., 2010). While women are more likely than men to earn a bachelor's, Master's, or doctoral degree, they remain the minority of degree-earning STEM students (United States Census Bureau, 2010). This is particularly true for more advanced degrees, where graduation rates in STEM favor men 2.5:1 (National Science Foundation, 2015a). Women are excluded from STEM despite generally high levels of academic achievement. In high school, girls and boys take approximately equal credits in STEM fields, with girls earning higher grades on average (Shettle et al., 2007). In higher education, women earn better grades than men and are more likely to achieve post-secondary degrees at all levels (Buchmann and DiPrete, 2006; United States Census Bureau, 2010). Despite generally high levels of achievement, women who are proficient in math-intensive fields are more likely to choose careers outside of STEM and leave STEM careers as they advance in their education (Ceci et al., 2009).

Gender discrepancies become more pronounced at the professional level, a pattern that is evidenced across both academia and industry (Trower and Chait, 2002). Women account for nearly half of the United States workforce, but compose less than 30% of the positions in STEM (National Science Foundation, 2015b). STEM women advance more slowly and are more likely to leave their positions than male peers (Valian, 1999). Overall, the higher the rank in STEM the less likely it is to be occupied by a woman, making women particularly underrepresented in leadership positions.

The shortage of women from high-ranking positions is not exclusive to STEM fields. For example, while the average corporate board has 8.8 members, 36% of companies do not have any women on their board of directors and only 8% of boards have three or more women (Gladman and Lamb, 2012). However, the shortage of women is particularly striking when leadership and STEM intersect: at 61%, energy companies have the highest percentage of boards with no women, and in academia, only 31% of full-time STEM faculty and 27% of deans and department heads are women (National Science Foundation, 2015b).

Despite evidence that attrition of women from STEM disciplines increases as women progress through college, graduate school, professional, and leadership ranks, surprisingly little research has been conducted on the intersection between STEM and leadership (McCullough, 2011). In order to address this problem, it is essential to understand features of the workplace climate that are objectionable and unwelcoming to women. Qualitative research provides a unique opportunity to synthesize the complex experiences of STEM women by identifying common themes that underlie women's career narratives. To date, a small number of qualitative studies with student participants have highlighted the importance that STEM women place on social support, coursework success, and early and positive exposure to STEM disciplines (e.g., Hughes, 2010; Packard et al., 2011). For example, STEM women transitioning from a community college to a 4-year program identified social support in the form of helpful academic advisors and professors as significant resources for overcoming obstacles such as poor course experiences and limited finances (Packard et al., 2011). A study by Riffle et al. (2013) highlighted the spoken accounts of STEM faculty using semi-structured interviews. Men and women faculty members identified aspects of their work environment that facilitated success, including mentorship, social support, and work-life balance. However, there were gender differences in perceptions of departmental climate. Unlike men, women reported greater discrimination and sexism during interviews, less departmental collegiality, and holding less influence in their department. In addition, though men and women participants were found to have equal levels of productivity, women noted that their departments viewed their productivity as lower than their male counterparts (Riffle et al., 2013). Qualitative studies such as these lay the foundation for accounts of workplace gender inequality by beginning to draw attention to factors that are perceived as major obstacles and supports in pursuing STEM careers.

The present study expanded on this work by using Photovoice to examine the career narratives of STEM women graduate students and postdoctoral fellows pursuing leadership positions. Photovoice (Wang and Burris, 1997) is a method of group analysis that requires participants to take photographs that represent their viewpoint and present them during a group discussion. Participatory Action Research methods such as Photovoice recognize *experiential learning* as a legitimate source of knowledge and allow researchers to gather information about the targets' perspective. Photovoice is particularly well-suited for research on STEM women, as it was developed based on feminist theory and literature on critical consciousness (Wang, 1999). As defined by Weiler (1988), feminist methodology is characterized by an emphasis on women's subjective, everyday experiences. Critical consciousness literature argues that people's perspectives can be used to break a culture of silence and increase awareness of social issues (Freire, 1973). Photovoice was used to promote a critical dialog about how women's everyday experiences in male-dominated careers impact broader gender distribution. This approach is useful in synthesizing the complex issues that influence STEM women's career trajectories: First, as a consequence of identifying experiences common to STEM women, this approach is positioned to consolidate a number of topics relevant to the advancement of women in STEM (e.g., organizational climate and incentive structure). Second, Photovoice has direct ties to policy advocacy by providing a platform for STEM women to identify aspects of the work environment that they perceive as especially relevant to their career trajectories, including changes that need to be made to enhance their success. Third, qualitative research can facilitate the identification of new research directions useful for understanding and enhancing STEM women's career advancement.

The present study expands on previous qualitative studies of women's experiences in STEM in three key ways. First, STEM women graduate students and postdoctoral fellows were recruited from STEM leadership workshops, representing a group of women experienced in STEM and with explicit interest in leadership positions. Women in this career stage are making critical decisions about their career trajectory, with many opting for careers in education or healthcare over STEM occupations (Beede et al., 2011). Thus, participants have a unique vantage point as they are actively gaining insight into the advantages and disadvantages of STEM careers and navigating their career path. Second, this is the first study using Photovoice to examine STEM women's experiences and the first qualitative study to focus on STEM women in leadership. Photovoice gives participants the opportunity to identify and share aspects of their experiences that are most important to them and is more open-ended than methods like structured or semi-structured interviews. Literature on STEM women emphasizes a wide range of factors that influence women's career outcomes, from implicit stereotype cues to organizational policies (e.g., Valian, 1999; Smith and White, 2002; Murphy et al., 2007; Bilimoria and Lord, 2014). However, it remains unclear which of these aspects of the work environment that women find more or less challenging. Identification of themes underlying women's experiences in STEM via qualitative methods can be used to highlight their observations and perceptions of the field in a way that is atypical of most experimental research. Third, the present research recruited a relatively large and diverse group of participants. Forty-six participants completed the Photovoice exercise, which is considerably more than the median of 13 participants in Photovoice studies (Catalani and Minkler, 2010). The sample also included 16 international participants, representing 11 different countries.

Science, technology, engineering, and mathematics women graduate students participating in leadership workshops were invited to a an additional workshop session where they had the opportunity to present four photographs depicting their experiences with STEM leadership and discuss them in a small group setting. Specifically, participants were asked to share with a group two photographs depicting the past experience in STEM and two describing their future in STEM. Transcripts from the eight workshops sessions were coded borrowing from grounded theory framework (Glaser and Strauss, 1967). The grounded theory perspective forwarded by Strauss allows for basic research questions and predictions to guide analysis (Corbin and Strauss, 1990; Devadas et al., 2011). Accordingly, it was hypothesized that STEM women would acknowledge the effects of gender stereotypes in STEM, reflecting their common experience with gender stereotypes. Additional coding was carried out inductively to identify emergent themes in the raw data. The current article discusses the career strategies, barriers to achievement, and approaches for managing barriers to achievement described by STEM women, as well as implications for research and practice.

MATERIALS AND METHODS

Participants

Forty-six participants from a leadership workshop for STEM women enrolled in a second session in order to complete the Photovoice activity. Participants signed up for one of eight possible workshop sessions, with an average of six participants in each session. Participants from the final sample ranged in age from 21 to 51 years ($M = 29$, $SD = 6.13$). Thirty-five percent of the sample was international students, with participants representing 11 different countries. Sixty-four percent of participants identified as White, 22% Asian, 4% Black, 4% Hispanic, 4% Biracial, and 2% Native American. A variety of fields were represented from the natural sciences (50%), medicine and health (28%), and engineering (22%).

Procedure

Women graduate students and postdoctoral fellows in STEM fields from a large public research university were recruited to participate in leadership workshops via flyers and e-mails. Participants indicated their availability for eight different workshop groups. Whenever possible, they were matched into groups in order to have individuals from different academic disciplines in each session. Upon arriving to the first workshop session, participants were asked to sign an informed consent and complete a demographic survey. The first session included interactive activities designed to identify leadership role models and personal values, develop personal action plans, and practice conflict resolution. Prior to the end of the workshop, participants were invited back for a second session to complete the Photovoice activity.

In line with the goal to understand the broad range of issues related to women's advancement in STEM, Photovoice allowed for open-ended discussion about participants' experiences in STEM. Participants were asked to prepare two photographs describing past experiences with leadership and two pictures representing their future leadership aspirations. Participants were invited to take their own pictures or use images found online. Directions did not prompt participants to attend to a particular issue. Photographs were e-mailed to the researcher prior to workshop sessions in order to format them into a slide show for the Photovoice discussion. Audio and video equipment was positioned to record each workshop session. The Photovoice activity was transcribed, producing 80 single-spaced pages of transcription.

The Photovoice activity was held 1 week after the participants' original workshop sessions. Participants were invited to discuss their Photovoice pictures with the group, and participants determined the order of presentation (i.e., who presented and the order of photographs). Each individual projected their photographs onto a large screen at the front of the room and explained the meaning of each of their four photographs. After each individual presented a photograph, the workshop facilitator (i.e., a female graduate student) or participants were allowed to ask questions or comment. For example, a participant projected a picture of their messy desk while explaining how it relates to their past experience pursuing STEM leadership, in this case, noting that they juggle many projects and do not always have a healthy lifestyle due to high workplace demands. Other participants related to this narrative, noting that they too do not always have a healthy lifestyle or work-life balance even though they consider those things important. Within this structure, the workshop facilitator and participants were able to probe further comments. Individual narratives can elicit agreement or disagreement from peers as they discuss photographs in a small group setting, providing information about the typicality of a given experience. All research was carried out in accordance with the protocol approved by the University of Cincinnati's Institutional Review Board.

Data Analysis

The grounded theory approach to qualitative analysis forwarded by Glaser and Strauss (1967) provides a framework for text analysis. Grounded theory utilizes a constant comparative method whereby text is assigned to a category based on content and compared with other text included in the same category (Glaser and Strauss, 1967). Categories are created if text needs to be further differentiated, or if categories need to be integrated. Over the course of the analysis, categories are arranged into a hierarchy that is representative of their relationship to one another. This method of coding is used to uncover the full range of categories possible, their dimensions, the conditions under which it is pronounced, its consequences, and its relationship to other categories. Unlike many experimental studies that typically examine cause-and-effect relationships, qualitative research is often utilized at the discovery stage of research in order to develop new and testable theories.

Qualitative data was analyzed using QSR International's NVivo 10 software to aid in examining text and coding transcripts. The author and a trained research assistant independently coded the transcripts, condensing language into categories. Categories were defined using open coding, examining the transcripts line-by-line, allowing for patterns and categories to emerge through observation (Glaser and Strauss, 1967). Text was coded when it was identified as meeting specific criteria relevant to a categorical definition. To investigate the *a priori* research questions, additional coding examined career challenges and strategies. Category labels and definitions were shared between researchers, though they were blind to the text included within each category by the other researcher. When possible, categories were collapsed into higher-order categories based on researcher consensus until no new categories or sub-categories were identified. This is an indicator of theoretical saturation, such that additional data collection and coding is unlikely to identify new emerging themes (Locke, 2001; Kreiner et al., 2009).

After categories were independently coded, they were discussed in meetings to finalize coding (Kreiner et al., 2009). Consensual validation was used to refine category definitions and reduce bias (Kreiner et al., 2009). Agreement was reached on categories and content by the researchers and coding was adjusted. Only categories mentioned by 25% or more participants were included as themes (Dutton and Dukerich, 1991). Relationships across categories were then examined using axial coding, rendering nine primary themes (Strauss and Corbin, 1998). After identifying the most prominent thematic connections between categories and subcategories, three broader frameworks were identified using selective coding (Strauss and Corbin, 1998). These frameworks and their underlying themes were examined and adjusted by six study participants in order to verify its trustworthiness (Creswell, 2007). Three additional faculty-level researchers were also enlisted to review the findings for alternate themes and explanations (Lincoln and Guba, 1985; Creswell, 2007). Participants' descriptions of past experiences and future aspirations in STEM leadership were coded for themes across groups. Three complementary frameworks were identified from the participants' Photovoice narratives: Career motivation, barriers to participation, and buffering strategies. The conceptual frameworks and underlying themes are elaborated below (see **Tables 1** and **2**).

RESULTS

Framework 1: Motivation

In describing past experiences and future pursuits of "leadership," participants had a broad definition of leadership that extended beyond managing others to the achievement of individual and group goals. In terms of individual goals, STEM advancement was seen not only as a way to achieve career success, but also personal development (*Theme 1*): "Leadership is a good way to help me to improve myself. . .I don't want to just stay in one specific level." Leadership was also seen as a way to help others achieve their goals and develop positive relationships. As one participant put it, "I try to find a sky for me to fly, and. . .if I want to be a leader I also have to find a sky for the others."

Women noted a number of methods important to facilitating effective collaboration (*Theme 2*). Participants believed that collaboration could be enhanced through clear communication, justification of team goals, and individual recognition. Participants noted the importance of actively motivating colleagues, as exemplified by one participant's statement: "Appreciating their work and being respectful of them is really important; not treating them like your workers and giving them menial tasks but making them feel valuable to

TABLE 1 | Summary of themes and theoretical significance.

Theoretical framework	Theme number	Theme	First-order codes
Motivation	1	Collaboration	Work with one or more people toward a common goal.
	2	Social impact	Activities or goals that have social value and affect the surrounding community.
	3	Self-development	Work to advance personal skills and potential.
Barriers	4	Lack of authority	Lack of power or right to make decisions, influence, or enforce obedience.
	5	Vigilance	Monitoring environmental and interpersonal cues.
	6	Gender stereotypes	Generalizations about gender differences and roles.
Buffers	7	Accomplishment	Positive experiences or recognition.
	8	Social support	Positive social engagement that enhances psychological resources or leads an individual to believe that they are valued and accepted.
	9	Work-life balance	A comfortable balance between professional work and personal lifestyle.

TABLE 2 | Illustrative evidence for themes.

Theme	Illustrative quotations
Collaboration	"It was sort of like a musical kind of harmony, where somebody is playing 'the lead' obviously but then the backup is just as important."
Social impact	"I hope to be a leader amongst my peers professionally as well as in the community."
Self-development	"I want to improve myself, to get more."
Lack of authority	"I can give you a token. I can call you up and recognize you for your work and thank you. That's all I have. That's the only power."
Vigilance	"We haven't really butted heads with anybody or really said a whole lot. . .you just kind of listen and deal with it."
Gender stereotypes	"She's either going to be an authoritative b-word, or she's going to be like this motherly figure."
Accomplishment	"But the whole cause itself is really, really great. And I think it was a really good way for me to connect teaching, mentoring, and science."
Social support	"So I got a really good friend, good mentor, a very supportive family."
Work-life balance	"Even if it's 10 min [off of work] it shows that you're in control and you know what you want to get out of this."

the project." The value of working side-by-side with others was seen as a strategy for teaching other people positive work habits, and demonstrated participant's preference for a more egalitarian work environment. Overall, participants described their leadership style as transformational (Burns, 1978), where leaders work to motivate team members toward the achievement of a common goal.

Participants sought to develop a full range of skills within the workplace to influence others in a meaningful way. Teaching, mentorship, service, organizational, and applied work were all seen as opportunities for broader impact (*Theme 3*). Among those pursuing careers in research, their goals were often geared toward promoting the well-being of others (e.g., water conservation, disease control, and social programming). Other participants questioned how much impact research has in comparison to applied work. One woman stated that while she had never discussed career options within her department, she was strongly considering going into applied work, "I don't want to belittle it by saying 'cookie-cutter' or saying this is the 'typical route' that graduate students take, to be a professor. And that ignores the need for better science education at the lower levels." Whether interested in research or applied work, participants engaged in big picture thinking: Women not only desired to advance in their field, they saw leadership as a means of self-actualization (*Theme 1*), collaboration (*Theme 2*), and social impact (*Theme 3*).

Framework 2: Barriers

The second framework outlined the circumstances under which goal achievement became especially challenging. Participants generally preferred a transformational leadership style, but they did not always feel empowered as leaders. One participant noted, ". . .this is literally kind of like a struggle, not just finding leadership opportunities, but once you're in them I feel like I am kind of up against somebody most of the time." When women were in authority positions, they did not assume that subordinates would take their direction seriously and instead worked to build legitimacy by fostering positive relationships. The "fair-and-balanced" approach some women desired may have, in part, reflected their uneasiness in positions of authority (*Theme 4*). As one woman stated, "I can give you a token. I can call you up and recognize you for your work and thank you. That's all I have. That's the only power." Participants were primarily focused on increasing their social status through relationships, rather than increasing their personal power or access to resources (e.g., Sachdev and Bourhis, 1991).

Attempting positive relationships and social impact were costly in terms of time and energy. To support a positive and collaborative work environment, women were vigilant to other people's perspectives (*Theme 5*). Participants frequently noted the thoughts and feelings of others during their narratives. One participant stated, "We should always do well in our own business, but we also need to think about others, be considerate, and so everyone can be comfortable." Participants were also vigilant to how their own behavior might be evaluated by others. One participant described carefully watching her steps, "I'm walking around with my shoes untied. I always have to look and make sure I'm not going to trip and fall." She contrasted this with her "comfy shoes" that she wore at home. Another participant stated the importance of controlling other people's impressions of her, "Wear your dark-colored suit, flat shoes, and no jewelry."

Monitoring social interactions was particularly challenging when gender dynamics were involved (*Theme 6*). Participants noted the dichotomy between being the "motherly figure" and the "authoritative b-word," and sometimes felt the need to adapt their leadership style to the situation. A woman with industry experience stated, "I always work in a man environment, so I cannot be too soft. They just crush you." She contrasted this with working with women, explaining, "It's like if you're in this as equals, then they think you're not in it to get anything. Somehow you have to keep your feminine, soft side." When working with men, participants felt the need to mask emotions and appear confident, but among women they tried to act less threatening, more egalitarian, and attentive to emotion. Some women felt that situational pressures could be overcome by adopting a more individualized leadership style, and other women expressed their continuing journey to find a leadership identity. Upon hearing other participants discuss how they changed their behavior based on context, one woman noted, "All I can do is be a good person and be strong in what I do."

Framework 3: Buffers

The third framework illustrated coping strategies participants used to buffer against career challenges they encountered. Participants sought comfort in their achievements (*Theme 7*). Feelings of accomplishment reassured women that they were on the right career path. Participants often noted achievements in mentoring, service, and applied roles. In these positions women were more readily elevated into leadership, developed relationships with others, and gained respect. One woman noted about her teaching, "I've had great success with being a leader in that people really appreciate me and I have gotten really good feedback." For some women, finding comfort in their achievements meant being appreciative of their current positions. As one participant stated, "Whatever you do and what role you are in in your future career, even though it can be boring or a simple role, as long as you have positive thinking and you are smiling you can do this job very well." This perspective was controversial among other participants, some of whom argued that women are too easily satisfied with *just* having a job, rather than expecting to be treated fairly based on their qualifications.

Outside of their own accomplishments, participants found resiliency in social support offered by mentors, friends, and family (*Theme 8*). The encouragement of mentors helped them cope with negative experiences, and to envision their future within the field—as one participant said, "I do so many things now and I attribute it to my advisor giving me so many opportunities and just kind of encouraging me." However, the difficult balance between the ideal woman and ideal leader led to a lack of real world role models for some participants. For example, one participant stated, "I have role models for leadership, and I have role models for personal growth, but both of them together they don't really exist. And it's hard to even imagine a real, tangible opportunity." Perhaps because of this, some women adopted an informal definition of 'mentorship,' looking for guidance from coworkers, friends, and professionals outside of their field. Mentorship outside of formal supervision helped women navigate the politics of their fields.

Family was another important source of support and an arena where many women took on a leadership role. Participants discussed future leadership aspirations in terms of family, as numerous women considered motherhood as a significant leadership role. As one women explained, "I would like to become a mother someday. So that's another big kind of leadership thing that will be hard to balance." Work-life balance also helped women find meaning in their work and have a sense of control over their lives (*Theme 9*). One woman described the importance of taking time off work saying, "Even if it's 10 min, it shows that you're in control and you know what you want to get out of this."

DISCUSSION

The present study is the first to qualitatively examine the experiences and perspectives of STEM women using Photovoice as a Participatory Action Research method. Findings provide a basis for better understanding the complex ways that gender stereotypes surface in organizations, as well as the bottom-up strategies STEM women employ to cope with workplace challenges. Specifically, results provide a framework for understanding women's work preferences, challenges, and buffering strategies. In line with its history as a advocacy tool, Photovoice also generated insight into policies that can best support and enhance STEM women's career success.

While institutional policies were mentioned more or less indirectly, the frequency and depth of narrative surrounding interpersonal interactions suggests that this is often the most immediate and troubling aspect of the work environment for women. Women were mindful of other people's perspectives and actively worked to manage them. Participants described being held accountable for multiple, often conflicting, roles in the workplace related to gender and STEM. Women's perceptions of conflicting expectations, between acting "soft" and "hard" as they put it, is consistent with literature on role congruity and the evaluation of women in typically male-dominated fields. Role congruity theory states that, because men have traditionally occupied positions in science and leadership, career success in these fields are associated with masculine traits (Eagly and Karau, 2002). As a result, women are viewed as unfit for STEM, particularly in STEM leadership, and are also evaluated more negatively when occupying these roles. Women are viewed as less likely to succeed, less likely to be promoted, and less likely to become a leader when in male-dominated sectors than when in female-dominated professions (Garcia-Retamero and Lopez-Zafra, 2006). Women who succeed in spite of these stereotypes often experience backlash for stepping outside of their prescribed social role. For instance, women in senior management typically have less authority, less opportunity for advancement, and receive fewer rewards than their male peers (Jacobs, 1992). At first glance it might appear that STEM women are too image-focused and work unnecessarily hard to manage their interpersonal interactions, but these efforts may be a reaction to the negative evaluations commonly encountered by STEM women.

Women in this study responded to perceived gender role conflict with two primary strategies: First, some women adopted distinct behaviors within different contexts, remaining vigilant to cues regarding role expectations. This workplace strategy required role transitions throughout their day to accommodate workplace demands (cf. Schein, 1971; Van Maanen, 1982). Role transitions entail "the psychological (and, where relevant, physical) movement between roles, including disengagement from one role (role exit) and engagement in another (role entry; Burr, 1972; Richter, 1984)" (Ashforth et al., 2000). Each transition requires psychological preparation, as roles require varying levels of attention and arousal (Ashforth, 2001), and may therefore be costly in terms of cognitive and physical resources. Individuals vary in the extent to which their roles are segregated from one another (Ashforth, 2001); the more integrated roles are, the less challenging it is to transition between them. Along these lines, some women adopted a second workplace strategy and avoided numerous role transitions by adopting an individualized leadership style that they could comfortably apply across a variety of situations. Given the relatively large age range of participants, it is possible that older participants were more likely to have developed a stable sense of self and were less easily influenced by social pressures.

In addition to the interpersonal demands reported by STEM women, women often described being socially disconnected from both leadership and subordinates. Consistent with research that women are viewed as less competent leaders (e.g., Jacobs, 1992; Garcia-Retamero and Lopez-Zafra, 2006), even when women were in leadership positions, they noted they were not treated as authority figures. Participants appealed to subordinates by fostering positive relationships, working alongside them, or incentivizing them with rewards. Women also had a difficult time identifying mentors and role models who represented, not only a desirable career path, but also a desirable lifestyle. A lack of real world examples meant that women had a difficult time imagining how they would be able to succeed in STEM.

Women's focus on social interactions, vs. policy, as barriers to achievement suggests that women are more frequently and directly confronted with the former, and that these challenges are viewed as more personal in nature. The focus of narratives on social interactions may reflect a shifting tide where organizational policy may change over time to support more gender-neutral practices. Even so, gender stereotypes, societal norms, and organizational climate are more enduring and difficult to change. As one women stated, "Just because the policy changes does not mean [people's] beliefs change." Overall, women reported a lack of *social capital*, or "the aggregate of the actual or potential resources which are linked to possession of a durable network of more or less institutionalized relationships of mutual acquaintance or recognition" (Bourdieu, 1985, p. 248). Women devoted significant time and energy to fostering group cohesion and developing professional relationships: Monitoring social cues, accommodating social expectations, implementing strategies to enhance collaboration, and pursuing applied work and social impact all require significant effort. These efforts were not always rewarded, as women struggled to establish relationships with subordinates and mentors. Women also noted that they faced negative evaluation, from being belittled during presentations to being harshly questioned for their career decisions. Similar reports come from the faculty-level, as women professors generally report low-levels of collegiality (Riffle et al., 2013). Despite committing significant resources to maintaining positive relationships, women often failed to receive benefits from participation in groups (Portes, 1998).

Science, technology, engineering, and mathematics women encountered two distinct limitations in the workplace that restricted their social interactions and professional activities. First, women's workplace behavior was restricted by the potential for negative evaluation and its implied consequences. Women worked to overcome negative evaluation by maintaining a certain appearance, adopting different mannerisms based on role expectations, working to make sure people "liked" them, and monitoring their behavior for what could be perceived as "mistakes." Women felt that they were encouraged, implicitly or explicitly, to mold their behavior to avoid negative social evaluation. Second, women were limited by an incentive structure that rewarded a relatively narrow range of professional activities. Numerous women reported that their departments valued basic research over applied directions, and the pressure on academics to publish and pursue research trajectories without direct application caused some participants to question if their goals aligned with a career in STEM, vs. fields like health or education. Opportunities for self-development, collaboration, and social impact were identified as major motivational factors for STEM women—a lack of rewards for these activities may therefore hinder STEM women's professional advancement. The space that women in STEM are allowed to occupy is enclosed by narrow boundaries and is enforced by the potential for negative social evaluation and career stagnation. Compared to their male peers, STEM women have *fewer degrees of freedom* in the workplace.

Policy Implications

Though women's narratives often referenced the importance of interpersonal interactions to shaping their careers, institutional policies can foster a workplace climate conducive to collegiality and increased opportunity for a diverse faculty. The threat of negative evaluation significantly impacts women's daily activities. STEM leadership may benefit from an awareness of the chronic judgment that women are often subject to by both female and male coworkers and subordinates. Methods of formal evaluation used by departments and universities can be altered or weighted to take into account gender biases typical of student and departmental evaluations (Kaschak, 1978; Sprague and Massoni, 2005; Moss-Racusin et al., 2012). Departments can also reduce the threat of negative evaluation and increase women's social capital by promoting diversity and a positive workplace climate. In particular, institutions can explicitly advocate for workplace collegiality, offer structured networking opportunities, institute faculty mentorship programs along with mentorship training, and incentivize departmental and interdepartmental collaboration.

The ability to recruit, retain, and promote a diverse workforce hinges on the ability of an organization to value heterogeneous perspectives and contributions. In this study, numerous participants noted the value that they placed on applied scholarship. At an institutional level, criteria for promotion and tenure can be restructured to reward a more diverse set of workplace activities. For example, some women may place greater emphasis on applied work over publishing, the former of which can be explicitly incentivized. In addition, recognition for achievements, in the form of competitive grants and awards, can advance women's research and publicly recognize their achievements. Individuals who experience barriers to participation in STEM need sufficient reason to enter into and persevere within these stereotyped domains. Women can be encouraged to remain in STEM with opportunities for self-development, collaboration, and social impact. Organizations can incentivize these activities and emphasize these opportunities through organizational messaging.

In the present study, a fulfilling personal and family life is closely tied to STEM women's feelings of success and life satisfaction. This is consistent with research suggesting that policies promoting work-life balance are essential to recruiting, retaining, and advancing faculty in academia (Welch et al., 2011). A variety of initiatives can bolster STEM employee's support network and work-life balance (e.g., Kelly, 1999; Association for Women in Science, 2001; Tower and Dilks, 2015): Employee benefits can be structured to allow for flexible work hours, leadership can take into account family obligations during scheduling, organizations can offer paid maternity and paternity leave, and dual-career hires can be made a greater priority, as these issues may disproportionately influence female employees.

Future Directions and Limitations

One strength of qualitative research is its ability to formulate new research questions (Glaser and Strauss, 1967). While there is much work to be done to understand the complex array of factors that influence women's participation in STEM, the present study generated two distinct research questions to be explored further. First, a significant portion of women in this study described their strategy for dealing with conflicting demands in the workplace, particularly disparate role expectations for women vs. scientists in male-dominated domains. Some of these women adapted their behavior to different contexts based on situational cues; other women adopted a personal leadership style that they carried across contexts. Women in the latter tended to be older and more experienced scientists. It is unclear from this study if there is an association between seniority and leadership style. Future research should investigate the perspectives of women in more or less advanced positions in STEM to examine how factors influence women's participation in different ranks, as well as whether women in various career stages employ different strategies for dealing with workplace challenges. Along these lines, it is important to increase our understanding of which career strategies are more or less useful for overcoming barriers to achievement. Second, many participants preferred applied work over basic research. Additional research is needed to examine if this preference holds true across a broader sample. It is also essential to understand whether or not women are implicitly or explicitly encouraged by others to go into applied work over basic research. Women may be directed away from basic research, which is likely to be more male-stereotyped.

A limitation of this study is that participants did not play a significant role as decision-makers in the research project. Photovoice often emphasizes the involvement of participants in study design and implementation. However, participants retained significant independence in their personal contribution, and a number of participants were also recruited to help in data interpretation after data analysis was completed. In addition, material from the workshop women were recruited from may have cued women to talk about particular aspects of their career progression. An attempt was made to control for this possibility by making the original workshops activity-based. Overall, the workshop format was an effective recruitment method, and career narratives were largely unrelated to workshop material, which focused on values, conflict management, and role model identification.

Finally, the current study is limited in focusing on the experiences of STEM graduate students and postdoctoral fellows. For the purposes of this study, graduate women offer a unique perspective. Having persevered as an undergraduate in typically male-dominated fields and continuing into advanced training, they have made a considerable personal investment in their fields. They are also gaining a new perspective into the professional world ahead of them. As graduate women advance in STEM they remain vulnerable to the gender stereotypes that pervade these fields.

CONCLUSION

Women identify interpersonal interactions as limiting their professional opportunities more often than institutional policy. In particular, women report having less social capital and fewer degrees of freedom than their male counterparts. Their reports are largely consistent with research demonstrating women's lack of authority and the negative evaluation of women compared to men (Jacobs, 1992; Garcia-Retamero and Lopez-Zafra, 2006). The close relationship between women's career narratives and previous research findings supports that notion that qualitative research is not only useful in understanding the perceptions of a given population, but that group analysis is relatively reliable in describing their experiences. The findings also synthesize a number of the complex issues that influence STEM women's career trajectories.

The present work identifies strategies implemented by women to cope with organizational and interpersonal barriers to achievement. Recognition of achievements, social support, and work-life balance assured women that their efforts pursuing STEM leadership would pay off. In addition, some women managed conflicting role expectations by adapting their behavior based on context; other women adopted a more individualized leadership style that they could comfortably maintain across contexts and regardless of social demands.

Findings enhance understanding of how gender stereotypes manifest and impact women in male-dominated careers, and have a number of implications for organizational policy. By emphasizing the importance of positive interpersonal interactions and organizational climate to career success, women's narratives indicate the importance of organizational policies that incentivize collegiality and collaboration. Though barriers to achievement often occur at an interpersonal level, a variety of organizational policies can address these challenges by promoting fair workplace evaluation, positive climate, collaboration, work-life balance, and an incentive structure that rewards a variety of scholarly activities.

AUTHOR CONTRIBUTIONS

MA was responsible for the research question, study design, running participants, data analysis, and manuscript.

ACKNOWLEDGMENTS

I would like to thank the individuals who participated in this research for sharing their experiences and perspectives. I would also like to thank Dr. Luis H. Favela for his valuable edits and comments.

REFERENCES

Ashforth, B. E. (2001). *Role Transitions in Organizational Life: An Identity-Based Perspective*. Mahwah, N.J: Lawrence Erlbaume Associates.

Ashforth, B. E., Kreiner, G. E., and Fugate, M. (2000). All in a day's work: boundaries and micro role transitions. *Acad. Manag. Rev.* 25, 472–491. doi: 10.5465/AMR.2000.3363315

Association for Women in Science (2001). *Association for Women in Science*. Available at: http://www.awis.org/?WorkLife

Beede, D., Julian, T., Langdon, D., McKittrick, G., Khan, B., and Doms, M. (2011). *Women in STEM: A Gender Gap to Innovation*. Available at: http://www.esa.doc.gov/sites/default/files/womeninstemagaptoinnovation8311.pdf doi: 10.2139/ssrn.1964782

Bilimoria, D., and Lord, L. (2014). *Women in STEM Careers: International Perspectives on Increasing Workforce Participation, Advancement and Leadership*. Northampton, MA: Edward Elgar Publishing. doi: 10.4337/9781781954072

Bourdieu, P. (1985). "The forms of capital," in *Handbook of Theory and Research for the Sociology of Education*, ed. J. G. Richardson (New York, NY: Greenwood), 241–258.

Buchmann, C., and DiPrete, T. A. (2006). The growing female advantage in college completion: the role of family background and academic achievement. *Am. Sociol. Rev.* 71, 515–541. doi: 10.1177/000312240607100401

Burns, J. M. (1978). *Leadership*. New York. NY: Harper & Row.

Burr, W. R. (1972). Role transitions: a reformulation of theory. *J. Marriage Fam.* 34, 407–416. doi: 10.2307/350436

Catalani, C., and Minkler, M. (2010). Photovoice: a review of the literature in health and public health. *Health Educ. Behav.* 37, 424–451. doi: 10.1177/1090198109342084

Ceci, S. J., Williams, W. M., and Barnett, S. M. (2009). Women's underrepresentation in science: sociocultural and biological considerations. *Psychol. Bull.* 135, 218–261. doi: 10.1037/a0014412

Corbin, J. M., and Strauss, A. (1990). Grounded theory research: procedures, canons, and evaluative criteria. *Qual. Sociol.* 13, 3–21. doi: 10.1007/BF00988593

Creswell, J. W. (2007). *Qualitative Inquiry & Research Design: Choosing Among Five Approaches*, 2nd Edn. Thousand Oaks, CA: Sage.

Devadas, U. M., Silong, A. D., and Ismail, I. A. (2011). The relevance of Glaserian and Straussian grounded theory: approaches in researching human resource development. *Int. J. Model. Optim.* 11, 348–352.

Dutton, J. E., and Dukerich, J. M. (1991). Keeping an eye on the mirror: image and identity in organizational adaptation. *Acad. Manag. J.* 34, 517–554. doi: 10.2307/256405

Eagly, A. H., and Karau, S. J. (2002). Role congruity theory of prejudice toward female leaders. *Psychol. Rev.* 109, 573–598. doi: 10.1037/0033-295X.109.3.573

Freire, P. (1973). *Education for Critical Consciousness*. New York, NY: Continuum.

Garcia-Retamero, R., and Lopez-Zafra, E. (2006). Prejudice against women in male- congenial environments: perceptions of gender role congruity in leadership. *Sex Roles* 55, 51–61. doi: 10.1007/s11199-006-9068-1

Gladman, K., and Lamb, M. (2012). *Women on Boards Survey*. Available at: http://www.boardagender.org/files/GMI-Ratings-2012-Women-on-Boards-Survey-F.pdf

Glaser, B. G., and Strauss, A. L. (1967). *The Discovery of Grounded Theory: Strategies for Qualitative Research*. Chicago, IL: Aldine.

Hill, C., Corbett, C., and St. Rose, A. (2010). *Why So Few? Women in Science, Technology, Engineering, and Mathematics*. Washington, DC: American Association of University Women (AAUW).

Hughes, R. M. (2010). *The Process of Choosing Science, Technology, Engineering, and Mathematics Careers by Undergraduate Women: A Narrative Life History Analysis*. Ph.D. dissertation. Florida State University Libraries, Tallahassee, FL.

Jacobs, J. A. (1992). Women's entry into management: trends in earnings, authority, and values among salaried managers. *Adm. Sci. Q.* 37, 282–301. doi: 10.2307/2393225

Kaschak, E. (1978). Sex bias in student evaluations of college professors. *Psychol. Women Q.* 2, 235–242. doi: 10.1111/j.1471-6402.1978.tb00505.x

Kelly, E. (1999). Theorizing corporate family policies: how advocates built the 'business case' for 'family-friendly' programs. *Res. Sociol. Work* 7, 1169–1202.

Kreiner, G. E., Hollensbe, E. C., and Sheep, M. L. (2009). Balancing borders and bridges: negotiating the work-home interface via boundary work tactics. *Acad. Manag. J.* 52, 704–730. doi: 10.5465/AMJ.2009.43669916

Lincoln, Y. S., and Guba, E. G. (1985). *Naturalistic Inquiry*. Newbury Park, CA: Sage.

Locke, K. (2001). *Grounded Theory in Management Research*. London: Sage.

McCullough, L. (2011). Women's leadership in science technology, engineering and mathematics: Barriers to participation. *Forum Public Policy* 2011, 1–11.

Moss-Racusin, C. A., Dovidio, J. F., Brescoll, V. L., Graham, M. J., and Handelsman, J. (2012). Science faculty's subtle gender biases favor male students. *Proc. Natl. Acad. Sci. U.S.A.* 109, 16474–16479. doi: 10.1073/pnas.1211286109

Murphy, M. C., Steele, C. M., and Gross, J. J. (2007). Signaling threat: how situational cues affect women in math, science, and engineering settings. *Psychol. Sci.* 18, 879–885. doi: 10.1111/j.1467-9280.2007.01995.x

National Science Foundation (2015a). *Doctorate Degrees Awarded to Women*. Available at: http://www.nsf.gov/statistics/2015/nsf15311/tables/pdf/tab7-2.pdf

National Science Foundation (2015b). *Women, Minorities, and Persons with Disabilities in Science and Engineering*. Available at: http://www.nsf.gov/statistics/2015/nsf15311/digest/theme5.cfm#trends

Packard, B. W., Gagnon, J. L., LaBelle, O., Jeffers, K., and Lynn, E. (2011). Women's experiences in the STEM community college transfer pathway. *J. Women Minor. Sci. Eng.* 17, 129–147. doi: 10.1615/JWomenMinorScienEng.2011002470

Portes, A. (1998). Social capital: its origins and applications in modern sociology. *Ann. Rev. Sociol.* 24, 1–24. doi: 10.1146/annurev.soc.24.1.1

Richter, J. (1984). *The Daily Transition between Professional and Private Life.* doctoral dissertation. Boston University, Boston, MA.

Riffle, R., Schneider, T., Hillard, A., Polander, E., Jackson, S., DesAutels, P., et al. (2013). A mixed methods study of gender, STEM department climate, and workplace outcomes. *J. Women Minor. Sci. Eng.* 19, 227–243. doi: 10.1615/JWomenMinorScienEng.2013005743

Sachdev, I., and Bourhis, R. Y. (1991). Power and status differentials in minority and majority group relations. *Eur. J. Soc. Psychol.* 21, 1–24. doi: 10.1002/ejsp.2420210102

Schein, E. H. (1971). The individual, the organization, and the career: a conceptual scheme. *J. Appl. Behav. Sci.* 7, 401–426. doi: 10.1177/002188637100700401

Shettle, C. S., Roey, J., Mordica, R., Perkins, C., Nord, J., Teodorovic, J., et al. (2007). *The Nation's Report Card: America's High School Graduates: Results from the 2005 NAEP High School Transcript Study*. (NCES 2007-467). Washington, DC: U.S. Department of Education, National Center for Education Statistics.

Smith, J. L., and White, P. H. (2002). An examination of implicitly activated, explicitly activated, and nullified stereotypes on mathematical performance: it's not just a woman's issue. *Sex Roles* 47, 179–191. doi: 10.1023/A:1021051223441

Sprague, J., and Massoni, K. (2005). Student evaluations and gendered expectations: what we can't count can hurt us. *Sex Roles* 53, 779–793. doi: 10.1007/s11199-005-8292-4

Strauss, A., and Corbin, J. (1998). *Basics of Qualitative Research*. Thousand Oaks, CA: Sage.

Tower, L. E., and Dilks, L. M. (2015). Work/life satisfaction policy in ADVANCE universities: assessing levels of flexibility. *J. Divers. High. Educ.* 8, 157–174. doi: 10.1037/a0039372

Trower, C. A., and Chait, R. P. (2002). Faculty diversity: too little for too long. *Harv. Mag.* 104, 33–38.

United States Census Bureau (2010). *Census Bureau Reports Nearly 6 in 10 Advanced Degree Holder Age 25-29 are Women*. Available at http://www.census.gov/newsroom/releases/archives/education/cb10-55.html

Valian, V. (1999). *Why So Slow? The Advancement of Women*. Cambridge, MA: MIT Press.

Van Maanen, J. (1982). "Boundary crossings: major strategies of organizational socialization and their consequences," in *Career Issues in Human Resource Management*, ed. R. Katz (Englewood Cliffs, NJ: Prentice-Hall), 85–115.

Wang, C., and Burris, M. A. (1997). Photovoice: concept, methodology, and use for participatory needs assessment. *Health Educ. Behav.* 24, 369–387. doi: 10.1177/109019819702400309

Wang, C. C. (1999). Photovoice: a participatory action research strategy applied to women's health. *J. Womens Health* 8, 185–192. doi: 10.1089/jwh.1999.8.185

Weiler, K. (1988). *Women Teaching for Change: Gender, Class, and Power*. Westport, CT: Bergin & Garvey.

Welch, J. L., Wiehe, S. E., Palmer-Smith, V., and Dankoski, M. E. (2011). Flexibility in faculty work-life policies at medical schools in the Big Ten conference. *J. Womens Health* 20, 725–732. doi: 10.1089/jwh.2010.2553

Conflict of Interest Statement: The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Psychology

PERSPECTIVE
published: 18 July 2017
doi: 10.3389/fpsyg.2017.01178

Yearning to Give Back: Searching for Social Purpose in Computer Science and Engineering

Coleen M. Carrigan *

Social Sciences, California Polytechnic State University, San Luis Obispo, CA, United States

Computing is highly segregated and stratified by gender. While there is abundant scholarship investigating this problem, emerging evidence suggests that a hierarchy of value exists between the social and technical dimensions of Computer Science and Engineering (CSE) and this plays a role in the underrepresentation of women in the field. This ethnographic study of women's experiences in computing offers evidence of a systemic preference for the technical dimensions of computing over the social and a correlation between gender and social aspirations. Additionally, it suggests there is a gap between the exaltation of computing's social contributions and the realities of them. My participants expressed a yearning to contribute to the collective well-being of society using their computing skills. I trace moments of rupture in my participants' stories, moments when they felt these aspirations were in conflict with the cultural values in their organizations. I interpret these ruptures within a consideration of yearning, a need my participants had to contribute meaningfully to society that remained unfulfilled. The yearning to align one's altruistic values with one's careers aspirations in CSE illuminates an area for greater exploration on the path to realizing gender equity in computing. I argue that before a case can be made that careers in computing do indeed contribute to social and civil engagements, we must first address the meaning of the social within the values, ideologies and practices of CSE institutions and next, develop ways to measure and evaluate the field's contributions to society.

Keywords: gender, computer science and engineering, social purpose, feminism, ethnography, social/technical divide

OPEN ACCESS

Edited by:
Kathleen Buse,
Case Western Reserve University, United States

Reviewed by:
Lara Perez-Felkner,
Florida State University, United States
Christianne Corbett,
Stanford University, United States
Ellen B. Van Oosten,
Case Western Reserve University, United States

***Correspondence:**
Coleen M. Carrigan
cmcarrig@calpoly.edu

Specialty section:
This article was submitted to Gender, Sex and Sexuality Studies, a section of the journal Frontiers in Psychology

Received: *01 January 2017*
Accepted: *28 June 2017*
Published: *18 July 2017*

Citation:
Carrigan CM (2017) Yearning to Give Back: Searching for Social Purpose in Computer Science and Engineering. Front. Psychol. 8:1178. doi: 10.3389/fpsyg.2017.01178

INTRODUCTION: METHODS AND FRAMEWORKS

Computing knowledge is produced in highly segregated classrooms, labs, and workplaces, and many of these sites are rife with exclusionary practices (Cohen and Swim, 1995; Margolis and Fisher, 2002; Barker et al., 2005; Misa, 2011; Corbett and Hill, 2015). To understand this problem, I conducted a 2-year ethnographic study exploring several domains of women engineers' experiences in computing institutions. Main findings warrant further attention, including the role social aspirations play in the underrepresentation of women in Computer Science and Engineering (CSE). The data I present in this paper is a subsample of a large, complex dataset. It augments other qualitative studies that support connections between altruism, computing, and women (Hacker, 1981; Faulkner, 2000a,b; Margolis et al., 2000; Cuny and Aspray, 2001; Margolis and Fisher, 2002) and more recent quantitative studies that show similar results

(Diekman et al., 2010, 2016; Cech, 2013b, 2014; Garibay, 2015; Litchfield and Javernick-Will, 2015; Blanchard Kyte and Riegle-Crumb, 2017; Cheryan et al., 2017). These interdisciplinary studies advance the theory that social purpose is an important factor to consider in working toward gender equity in CSE. The data in this paper raises the question: if it is true that careers with social aspirations matter more to women more than men (Diekman et al., 2010; Canney and and Bielefeldt, 2015; Blanchard Kyte and Riegle-Crumb, 2017), then *how might this knowledge best be used to desegregate computer science and engineering?* I argue this question needs careful consideration and more qualitative investigations to ascertain social values in this field. Central to this inquiry are issues regarding the social applications of computing, the hierarchy of value between the social and the technical, and the gap between the exaltation of computing's social contributions vs. their realities.

My ethnography relied on the lived experiences of 42 people who work as computer scientists and engineers in elite corporations and universities. Significant findings convey connections between social aspirations, computing, and gender that suggest future pathways for collective inquiry. With approval from my institutional review board for research with human subjects, I engaged participants across a range of sites, including conferences, workplaces, and university campuses (the majority of schools were research-intensive universities and polytechnics). I interviewed CSE students, university faculty, and computing knowledge workers in industry settings—both women ($n = 38$) and men ($n = 4$) from multiple racial/ethnic identities and sexualities. I chose this sampling strategy in order to solicit insights into computer technology from people who must navigate both privilege and marginalization to persist in their field.

I performed semi-structured interviews, focus group interviews, life history case studies, and participant observation in classrooms, computing workplaces, and technology conferences (Bernard, 2006; Spradley, 2016a,b). I analyzed my data using grounded theory techniques (Strauss and Corbin, 1997; Cohen et al., 2000). Grounded theory allowed me to prioritize emerging themes and ideas rather than merely verify existing claims. I interpreted my participants' descriptions of their experiences being female in sites of CSE production using Smith's (1987) concept of "rupture." Rupture occurs in women's lives when they experience the tensions of being ruled by dominant group members while simultaneously a part of the ruling class.

I traced the concept of rupture in my participants' stories, via moments when they felt their personal aspirations in conflict with the cultural values of computing. I interpreted these stories within a consideration of yearning, a need to contribute meaningfully to society. Only female participants expressed this yearning. To explore women's desire to contribute across different social identities, I engaged hooks' concept of yearning: "the shared space and feeling [that] opens up the possibility of common ground where differences might meet and engage one another" (Hooks, 1990, p. 13). This understanding of how collective emotions challenge normative practices, behaviors, and values is a unifying force in social movements (Parker and Hackett, 2012; Dean, 2016) and may therefore prove useful in efforts to desegregate CSE.

YEARNING: "LEAVING THE WORLD A BETTER PLACE"

Too often, high aptitude girls and women ask: What are the social contributions of computer science and engineering? Many conclude it is a field detached from social and civil engagement and lacking community purpose. They are, therefore, inclined to take their talent elsewhere. For example, Olivia left her job as a software engineer at a renowned Fortune 50 tech company because she "yearned to give back." She questioned how she was benefiting society and if the computing products she helped create were even benefitting customers. She asked:

> What is the benefit of all this? There's *no social impact*. I'm just helping to make [the corporation] money. Helping the customer is not enough, because it's all about the bottom line—only [the corporation] benefits... I believe in the importance of giving back. It's a huge part of my story.

Because Olivia yearned to make social contributions but did not have the opportunity to do so in a computing corporation, she returned to university to earn a doctorate in Human Computer Interaction (HCI), a subfield in CSE that integrates the social and technical aspects of computing. By switching from software engineering to HCI, she persisted in the computing field while reconciling her work with her "altruistic identity" (Carlone and Johnson, 2007).

Becca, an early career programmer, also gravitated toward HCI. She used to believe CSE was "evil" until her faculty mentor, an expert in HCI, helped her see the social applications of programming:

> Conducting gendered HCI research made me realize that there were some really cool things about computer science I had never thought of... it's not just syntax and debugging, it's real, you know—real applications that can make a difference.

By choosing a subfield with social applications, Olivia and Becca found ways to both persist in the CSE field while also giving back to society. Others were concerned with the field's lack of reputation for altruism. Lynn, a software developer at a high-tech corporation, struggled with the social purpose of work in CSE, specifically the public's perception of the field:

> Lynn: Part of it is my fear that I'm doing something that I can't explain, and for some women that is appealing somehow.
> Interviewer: What do you mean, you can't explain to lay people?
> Lynn: Yeah, like explain to my mom what I do. In the field of medicine you can say, "I'm working on a cure for cancer," or "I'm helping people," and people might not know the details, they might not know the science behind it, but they understand the goal.
> Interviewer: Right, right. Which is...?
> Lynn: Some kind of social good, or leaving the world a better place...

Interviewer: So computer science doesn't have that?
Lynn: It does, it's just that it's not advertised; people don't know about it.

Lynn may be seeking to reconcile a normative gender identity with her labor in a nontraditional field (Foor and Walden, 2009). Perhaps this desire for one's social contribution to be recognized is why a significant number of participants in my 2-year study saw the biomedical field as a viable avenue to which they can contribute. Biomedicine in the US has "evolved out of tradition of service to suffering humanity" (Sobo and Loustaunau, 1997, p. 126) and thus may be at an advantage for attracting people who yearn to use their skills in service of the higher good. For example, Sylvia, a doctoral student in CSE, wants to use computer technology to enhance public health infrastructures. She explains:

> Because that's kind of just who I am. But it's also my mentor, she always talked about "*You really need to do something that would affect everyone*, you don't want to just... write it in a paper and then nothing happens... *you need to apply it* and *you need to be helpful*." That's why I've been working with the Public Health Department.

Sylvia not only yearns to enhance public welfare, she also had the encouragement from a trusted female mentor who overcame the challenges of the "double bind" (Malcom et al., 1976; Ong et al., 2011) to do the same. Sylvia's mentor gave heartfelt advice perhaps as a means of investing in her student's persistence and success in the CSE field.

Other participants, especially those in more senior positions, saw recruiting and mentoring women in computing as ways they could make social contributions. For example, Marina, senior leader in academic CSE, fulfilled her social change aspirations by encouraging and supporting other women in her field, and this work helped to mitigate symptoms of the "imposter syndrome:"

> I will always live with the part of me that feels I'm a total failure no matter what I do. But I know that I can walk up to... say... Anna and I can tell Anna and I can make her feel better about herself: "You're capable of doing pretty much anything you want with your life. You are extraordinary."

By advancing other women in computing, Marina feels she is doing her part to contribute to the world, quelling her own self-doubts. In this way, women's support of each other serves as both a recruiting and retention tool.

The difficulties of persisting as a marginalized community member may be mitigated if one feels that one's career is more than a personal drive for success but a cause for the greater good. Some of my participants in this study who yearned to make a difference persisted in CSE by concentrating in certain subfields where their technical skills have social application—specifically Human Computer Interaction (HCI), and public health and biomedicine—or by participating in gender equity practices in engineering education. On the one hand, that some areas of CSE provide opportunities for integrating practitioners' personal and professional commitments is promising. However, without further investigation of the *value of the social in CSE culture*, a culture that "continues to be driven by hegemonic masculinity," we risk creating gender-segregated subfields within computing (Bystydzienski and Brown, 2012, p. 17).

PROBING THE SOCIAL/TECHNICAL DIVIDE

CSE has tendencies to devalue and delegitimize socially applied knowledge, ideas, beliefs, and practices that are grounded in communal, people-oriented values (Faulkner, 2007; Hoh, 2009; Diekman et al., 2010) and can thwart the social aspirations of its practitioners (Cech, 2013a; Litchfield and Javernick-Will, 2015). Why does "engineering have a long history of casting aside social and humanistic knowledge" (Riley, 2014, p. 5)? Western society is governed by strict ideological binaries of public/private, male/female, logical/emotional, real/unreal, rationality/creativity, and the technical/social (Scheper-Hughes and Lock, 1987). Our technological society grants different valuation to each side of these binaries, privileging quantitative, abstract rationality, and subordinating social, material, qualitative inquiries of the world (Denzin et al., 2006; Foor and Walden, 2009; Richter and Paretti, 2009; Garibay, 2015). How can these cultural values and norms in computing—ones that denigrate the epistemic practices and findings of research with social applications (Diekman et al., 2010; Cech, 2013a)—be reconciled with the altruistic yearnings of its practitioners and widely accepted claims that computers promote human freedom and social advancement?

For example, Shawna, a doctoral student in CSE teamed up with an HCI professor to create applications for disabled computer users. In this collaboration, she not only faced resistance from her theory/algorithms advisor, but she also faced resistance from her peers:

> Shawna: The lab itself was always a bit boisterous... they just really were pushing the technology, you know, and focusing more on the computer part, as opposed to the human part. And I felt that whenever I brought up the human issues, that they were ignored, mainly. In fact, I earned the moniker, "Accessibility Bitch."
> Interviewer: Oh, my God! That is so offensive.
> Shawna: Yeah, actually, I took it as a compliment.
> Interviewer: Really, even with the "B" word?
> Shawna: Hey, I subscribe to the magazine.

Shawna's experiences evince the devaluation of the social in CSE. She uses humor to maintain confidence and pride in her efforts to use computers to support those with learning disabilities, despite the lack of support of her professor and hostility of her peers.

To leave epistemic injustices unexamined is a disservice to efforts to broaden participation in CSE fields. Diekman et al. (2010) suggest that an innovative way to attract more women to computing is to make it appear more socially applicable and in service of communal goals. To date, however, it appears that this promising solution may be thwarted by an endemic phenomenon in CSE culture that deems work with a social purpose to be irrelevant and outside the scope of an engineer's duties (Gilbert, 2008, 2009; Cech, 2014). Without interrogating the stubborn bond between masculinity and technology and confronting the epistemic bias that extols the technical at the expense of the social, we run the risk of creating pink-collar ghettos in CSE, subfields "labeled as inferior or "not real" engineering while male-dominated [sub]fields continue to garner social prestige and higher remuneration" (Bystydzienski and Brown, 2012, p. 4).

PUBLIC SERVICE OR PUBLIC RELATIONS?

Before launching concerted public relations efforts to promote the social benefits of CSE and attract students with altruistic motivations, the question of *retaining* these types of students and workers needs further consideration. Not only is there evidence of gender and racial bias in computing (Corbett and Hill, 2015; Seron et al., 2015), there is also a considerable gap between what political and industry leaders say computers do for society and the true impacts of high-tech knowledge and applications (Mander, 1991; Hakken, 2003; Toyama, 2015).

This gap helps explain participants' uncertainty about whether or not CSE work provides opportunities to give back to society. For example, Lynn, the software developer quoted above, told me that she and one of her professors built an application for an eye-tracking device intended to help people with disabilities; however, this application was eventually utilized for marketing purposes in order "to track where people look on the screen for retrospective [marketing] analysis." Her collaboration with this professor was a success and she was pleased that they published their findings. Lynn reflected that CSE professionals like the idea, or the *potential*, of applications for people with disabilities much more than the actual implementation of such applications:

> At the time I wanted to do something for people with disabilities, and [my professors] liked the drawing program with the eyes because it was exciting and sexy, but when you start talking about, like, practical accessibility issues, people kind of turn off.

Lynn had explicitly said she wanted a career that others recognized as socially valuable. The eye-tracker project, which began as an effort to help people, ultimately morphed into a high-tech company's surveillance of customers. This experience contributed to Lynn's suspicion that the computing industry is altruistic more in theory than practice.

The social benefits of computing are a speculative promise that lack evidence. Popular discourse and corporate advertisements emphasize the positive impacts of technological innovations (and often, their *potential* social benefit alone) while eliding more insidious applications and outcomes. For example, computers enable a centralization of power that makes the world's population highly vulnerable to surveillance, unemployment, weaponry, objectification, and instrumentalized rationality that undermines civil liberties and civic engagement. Also, high-tech corporations are "philosophically antitax and it's decimating" the states in which they operate (Duhigg and Kocieniewski, 2012, p. 10). Despite these dangers, Toyama (2015) notes that computer technology has "a cult-like hold" on our society and admits that he feels disloyal in his critique of its purported contributions to society (p. xv).

Critical analyses of computing require risking suspicions of disloyalty. Given that large-scale computing work largely takes place in US industrial, commercial, or military domains (Pawley, 2012), social justice efforts in high-tech fields must question some of the most powerful institutions in the world. Change agents can push computer scientist and engineers not only to "welcome people on the margins," but also to support local efforts of grassroots communities who are challenging hegemonic social relations like institutional racism, sexism, homophobia, classism, and environmental degradation (Pawley, 2012, p. 80). Capitalizing on the shared yearning of some CSE workers to contribute to the communal good may be a way to bridge computing's much-touted benevolentness and its actual outputs and impacts.

PATHS AHEAD

My participants' lives, careers, and aspirations not only challenge assumptions of who is allowed to participate in CSE work, but also the false binary between social and technical dimensions of computers. Before embarking on campaigns to laud the social benefits of computing knowledge and artifacts, let's check for evidence of these benefits first. This suggestion is not original. Probing the gap between what people *say* they do and what they *actually* do is one of the key tenets of cultural anthropological research (Guest, 2014) and the application of this methodology to scientists and engineers led to the field of science, technology, and society (STS) (Shapin et al., 1985; Franklin, 1995).

What evidence can change agents in CSE offer to convince skeptics that computing education is more than a boot camp for future employees of defense corporations and computing workplaces more than primary-colored playgrounds for a privileged few? How do we measure and evaluate the positive social contributions of CSE? Critiquing unjust practices within the field is a start. Combatting the disdain for socially relevant computing research in favor of technical knowledge and commodities is also necessary. Let's also questions the field's allegiances. For example, in its proprietary, classified form, computer knowledge production is a lucrative field that operates in tandem with state and corporate interests to erode community and social collectivity (Hakken, 2003; Coleman, 2013). What are the effects of collaborating with high-tech corporations in efforts to advance women in computing? Might we dare to question Bill Gates' claim that a laissez faire capitalist market and computing are inexorably entwined (Gates et al., 1995)?

Qualitative studies that examine the yearning of women in CSE across a range of cultural domains—race/ethnicity, sexuality, class, career stage, CSE subfields—may yield findings critical to broadening participation in this largely homogenous field. By examining structures of power through the lens of lived experience, we will not only deepen understandings of the cultural landscape of CSE, but also better determine what constitutes "good" science in the social/intellectual movement to end labor segregation in computer science and engineering.

CONCLUSION

Although women's values certainly differ, my research suggests that some women value contributing to society using their technological savvy. More research is needed on the role of social purpose in working toward gender equity in CSE. Future research will require pulling back and looking at the broader picture of how computing is operating in and affecting our society. By paying attention to moments of rupture in the lives of my research participants, an emotional phenomenon—a yearning to give back—emerged. Some female CSE specialists experience conflict when they seek to align their altruistic values with their careers. How can women's attempts to reconcile their social and career aspirations in CSE generate further insight into segregation in the field and ways to combat this vexing problem? Systemic intervention cannot come to fruition without unbundling normative values regarding labor, gender identities, and computer technology. If we are going to promote the social impact of CSE work, a thorough assessment of what constitutes the social good will be required, as well as an invigoration of the imagination to envision computing in service of social justice.

ETHICS STATEMENT

This study was carried out in accordance with the recommendations of the University of Washington Institutional Review Board (IRB) for research with human subject's with written informed consent from all subjects. All subjects gave written informed consent in accordance with the Declaration of Helsinki. The protocol was approved by the the University of Washington IRB (#39150-EG).

AUTHOR CONTRIBUTIONS

CC is the sole author of this manuscript and completed the research presented in this article independently, with the generous support of a American Association of University Women (AAUW) American Fellowship.

REFERENCES

Barker, L. J., Garvin-Doxas, K., and Roberts, E. (2005). "What can computer science learn from a fine arts approach to teaching?," in *Proceedings of the 36th SIGCSE Technical Symposium on Computer Science Education* (St. Louis), 421–425.

Bernard, H. R. (2006). *Research Methods in Anthropology: Qualitative and Quantitative approaches*. Lanham: Altamira Press.

Blanchard Kyte, S., and Riegle-Crumb, C. (2017). Perceptions of the social relevance of science: exploring the implications for gendered patterns in expectations of majoring in STEM fields. *Soc. Sci.* 6:19. doi: 10.3390/socsci6010019

Bystydzienski, J. M., and Brown, A. (2012). "I just want to help people": young women's gendered engagement with engineering. *Femin. Format.* 24, 1–21. doi: 10.1353/ff.2012.0027

Canney, N. E., and Bielefeldt, A. R. (2015). Gender differences in the social responsibility attitudes of engineering students and how they change over time. *J. Women Minor. Sci. Eng.* 21, 215–237. doi: 10.1615/JWomenMinorScienEng.2015011109

Carlone, H. B., and Johnson, A. (2007). Understanding the science experiences of successful women of color: science identity as an analytic lens. *J. Res. Sci. Teach.* 44, 1187–1218. doi: 10.1002/tea.20237

Cech, E. (2013a). Ideological wage inequalities? The technical/social dualism and the gender wage gap in engineering. *Soc. Forces* 91, 1147–1182. doi: 10.1093/sf/sot024

Cech, E. (2013b). The self-expressive edge of occupational sex segregation. *Am. J. Sociol.* 119, 747–789. doi: 10.1086/673969

Cech, E. (2014). Culture of disengagement in engineering education? *Sci. Technol. Hum. Values* 39, 42–72. doi: 10.1177/0162243913504305

Cheryan, S., Ziegler, S. A., Montoya, A., and Jiang, L. (2017). Why are some STEM fields more gender balanced than others? *Psychol. Bull.* 143, 1–35. doi: 10.1037/bul0000052

Cohen, L., and Swim, J. (1995). The differential impact of gender ratios on women and men: tokenism, self-confidence, and expectations. *Pers. Soc. Psychol. Bull.* 21, 876–884. doi: 10.1177/0146167295219001

Cohen, L., Manion, L., and Morrison, K. (2000). *Research Methods in Education*. New York, NY: Routledge.

Coleman, E. G. (2013). *Coding Freedom: The Ethics and Aesthetics of Hacking*. Princeton, NJ: Princeton University Press.

Corbett, C., and Hill, C. (2015). *Solving the Equation: The Variables for Women's Success in Engineering and Computing*. Washington, DC: AAUW.

Cuny, J., and Aspray, W. (2001). "Recruitment and retention of women graduates in computer science and engineering," in *The Computing Research Association's Committee on the Status of Women in Computing Research* (Washington, DC), 1–18.

Dean, J. (2016). *Crowds and Party*. Brooklyn, NY: Verso Books.

Denzin, N. K., Lincoln, Y. S., and Giardina, M. D. (2006). Disciplining qualitative research. *Int. J. Qualitat. Stud. Educ.* 19, 769–782. doi: 10.1080/09518390600975990

Diekman, A. B., Brown, E. R., Johnston, A. M., and Clark, E. K. (2010). Seeking congruity between goals and roles: a new look at why women opt out of science, technology, engineering, and mathematics careers. *Psychol. Sci.* 21, 1051–1057. doi: 10.1177/0956797610377342

Diekman, A. B., Steinberg, M., Brown, E. R., Belanger, A. L., and Clark, E. K. (2016). A goal congruity model of role entry, engagement, and exit understanding communal goal processes in STEM gender gaps. *Pers. Soc. Psychol. Rev*. 21, 142–175. doi: 10.1177/1088868316642141

Duhigg, C., and Kocieniewski, D. (2012). How apple sidesteps billions in taxes. *The New York Times*.

Faulkner, W. (2000a). Dualisms, hierarchies, and gender in engineering. *Soc. Stud. Sci.* 30, 759–791. doi: 10.1177/030631200030005005

Faulkner, W. (2000b). The power and the pleasure? A research agenda for "making gender stick" to engineers. *Sci. Technol. Hum. Values* 25, 87–119. doi: 10.1177/016224390002500104

Faulkner, W. (2007). Nuts and bolts and people: gender-troubled engineering identities. *Soc. Stud. Sci.* 37, 331–356. doi: 10.1177/0306312706072175

Foor, C. E., and Walden, S. E. (2009). "Imaginary engineering" or "re-imagined engineering": negotiating gendered identities in the borderland of a college of engineering. *NWSA J.* 21, 41–64. doi: 10.1353/nwsa.0.0078

Franklin, S. (1995). Science as culture, cultures of science. *Annu. Rev.* 24, 163–184. doi: 10.1146/annurev.an.24.100195.001115

Garibay, J. C. (2015). STEM student's social agency and views on working for social change: are STEM disciplines developing socially and civically responsible students? *J. Res. Sci. Teach.* 52, 610–632. doi: 10.1002/tea.21203

Gates, B., Myhrvold, N., Rinearson, P., and Domonkos, D. (1995). *The Road Ahead*. New York, NY: Viking.

Gilbert, A.-F. (2008). "Gender and educational codes in mechanical engineering and materials science: an ethnographic approach," in *Research on Engineering Education Symposium* (Bern), 1–5.

Gilbert, A.-F. (2009). Disciplinary cultures of mechanical engineering and materials science: gendered/gendering practices? *Equal Opportun. Int.* 28, 24–35. doi: 10.1108/02610150910933613

Guest, K. J. (2014). *Cultural Anthropology: A Toolkit for a Global Age*. New york, NY: Norton.
Hacker, S. L. (1981). The culture of engineering: woman, workplace, and machine. *Women's Stud. Int. Q.* 4, 341–353. doi: 10.1016/S0148-0685(81)96559-3
Hakken, D. (2003). *The Knowledge Landscapes of Cyberspace*. New York, NY: Psychology Press.
Hoh, Y. K. (2009). Using notable women in environmental engineering to dispel misperceptions of engineers. *Int. J. Environ. Sci. Educ.* 4, 117–131.
Hooks, B. (1990). *Yearning. Race, Gender and Cultural Politics*. Boston: South End Press.
Litchfield, K., and Javernick-Will, A. (2015). "I am an engineer AND": a mixed methods study of socially engaged engineers. *J. Eng. Educ.* 104, 393–416. doi: 10.1002/jee.20102
Malcom, S. M., Hall, P. Q., and Brown, J. W. (1976). *The Double Bind: The Price of Being a Minority Woman in Science*. Washington, DC: American Association for the Advancement of Science.
Mander, J. (1991). *In the Absence of the Sacred: The Failure of Technology and the Survival of the Indian Nations*. San Francisco, CA: Sierra Club Books.
Margolis, J., and Fisher, A. (2002). *Unlocking the Clubhouse: Women in Computing*. Cambridge, MA: The MIT Press.
Margolis, J., Fisher, A., and Miller, F. (2000). Caring about connections: gender and computing. *IEEE Sci. Technol.* 18, 13–20. doi: 10.1109/44.808844
Misa, T. J. (ed.). (2011). *Gender Codes: Why Women are Leaving Computing*. Hoboken, NJ: John Wiley & Sons.
Ong, M., Wright, C., and Espinosa, L. (2011). Inside the double bind: a synthesis of empirical research on undergraduate and graduate women of color in science, technology, engineering, and mathematics. *Harv. Educ. Rev.* 81, 172–209. doi: 10.17763/haer.81.2.t022245n7x4752v2
Parker, J. N., and Hackett, E. J. (2012). Hot spots and hot moments in scientific collaborations and social movements. *Am. Sociol. Rev.* 77, 21–44. doi: 10.1177/0003122411433763
Pawley, A. (2012). "What counts as engineering: toward a redefinition," in *Engineering and Social Justice: In the University and Beyond* (West Lafayette, IN: Purdue University Press), 59–86.
Richter, D. M., and Paretti, M. C. (2009). Identifying barriers to and outcomes of interdisciplinary in the engineering classroom. *Eur. J. Eng. Educ.* 34, 29–55. doi: 10.1080/03043790802710185
Riley, D. M. (2014). "What's wrong with evidence? epistemological roots and pedagogical implications of "evidence-based practice" in STEM education," in *American Society for Engineering Education* (Indianapolis), 1–9.
Scheper-Hughes, N., and Lock, M. M. (1987). The mindful body: a prolegomenon to future work in medical anthropology. *Med. Anthropol. Q.* 1, 6–41. doi: 10.1525/maq.1987.1.1.02a00020
Seron, C., Silly, S. S., Cech, E., and Rubineau, B. (2015). Persistence is Cultural: Professional Socialization and the Reproduction of Sex Segregation. *Work Occup.* 43, 178-214. doi: 10.1177/0730888415618728
Shapin, S., Schaffer, S., and Hobbes, T. (1985). *Leviathan and the Air-Pump*. Princeton, NJ: Princeton University Press.
Smith, D. E. (1987). *The Everyday World as Problematic: A Feminist Sociology*. Boston, MA: University of Toronto Press.
Sobo, E. J., and Loustaunau, M. O. (1997). *The Cultural Context of Health, Illness, and Medicine*: *Health and Fitness*. Westport, CN: Bergin & Garvey.
Spradley, J. P. (2016a). *The Ethnographic Interview*. Long Grove, IL: Waveland Press.
Spradley, J. P. (2016b). *Participant Observation*. Long Grove, IL: Waveland Press.
Strauss, A., and Corbin, J. M. (1997). *Grounded Theory in Practice*. Thousand Oaks, CA: Sage.
Toyama, K. (2015). *Geek Heresy: Rescuing Social Change from the Cult of Technology*. New York, NY: PublicAffair.

Conflict of Interest Statement: The author declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers
in Psychology

ORIGINAL RESEARCH
published: 30 June 2017
doi: 10.3389/fpsyg.2017.00875

Check for updates

Women's Reasons for Leaving the Engineering Field

Nadya A. Fouad[1]*, Wen-Hsin Chang[1†], Min Wan[2] and Romila Singh[3]

[1] Department of Educational Psychology, University of Wisconsin–Milwaukee, Milwaukee, WI, United States, [2] Department of Management, McCoy College of Business, Texas State University, San Marcos, TX, United States, [3] Lubar School of Business, University of Wisconsin–Milwaukee, Milwaukee, WI, United States

Among the different Science, Technology, Engineering, and Math fields, engineering continues to have one of the highest rates of attrition (Hewlett et al., 2008). The turnover rate for women engineers from engineering fields is even higher than for men (Frehill, 2010). Despite increased efforts from researchers, there are still large gaps in our understanding of the reasons that women leave engineering. This study aims to address this gap by examining the reasons *why* women leave engineering. Specifically, we analyze the reasons for departure given by national sample of 1,464 women engineers who left the profession after having worked in the engineering field. We applied a person-environment fit theoretical lens, in particular, the Theory of Work Adjustment (TWA) (Dawis and Lofquist, 1984) to understand and categorize the reasons for leaving the engineering field. According to the TWA, occupations have different "reinforcer patterns," reflected in six occupational values, and a mismatch between the reinforcers provided by the work environment and individuals' needs may trigger departure from the environment. Given the paucity of literature in this area, we posed research questions to explore the reinforcer pattern of values implicated in women's decisions to leave the engineering field. We used qualitative analyses to understand, categorize, and code the 1,863 statements that offered a glimpse into the myriad reasons that women offered in describing their decisions to leave the engineering profession. Our results revealed the top three sets of reasons underlying women's decision to leave the jobs and engineering field were related to: first, poor and/or inequitable compensation, poor working conditions, inflexible and demanding work environment that made work-family balance difficult; second, unmet achievement needs that reflected a dissatisfaction with effective utilization of their math and science skills, and third, unmet needs with regard to lack of recognition at work and adequate opportunities for advancement. Implications of these results for future research as well as the design of effective intervention programs aimed at women engineers' retention and engagement in engineering are discussed.

Keywords: women engineers, attrition decisions, reasons for attrition, person-environment fit, occupational turnover, women's career development

OPEN ACCESS

Edited by:
Deborah Anne O'Neil, Bowling Green State University, United States

Reviewed by:
Teresina Torre, Università di Genova, Italy
Alison Sheridan, University of New England, Australia

***Correspondence:**
Nadya A. Fouad
nadya@uwm.edu

†Present address:
Wen-Hsin Chang, Student Counseling Services, Iowa State University, Ames, IA, United States

Specialty section:
This article was submitted to Organizational Psychology, a section of the journal Frontiers in Psychology

Received: *20 January 2017*
Accepted: *12 May 2017*
Published: *30 June 2017*

Citation:
Fouad NA, Chang W-H, Wan M and Singh R (2017) Women's Reasons for Leaving the Engineering Field. Front. Psychol. 8:875. doi: 10.3389/fpsyg.2017.00875

INTRODUCTION

Researchers, educators, policy makers, economists, psychologists, and leaders in technology fields have decried the underrepresentation of women in Science, Technology, Engineering, and Math (STEM) fields. Billions of dollars of federal funding over the past 20 years have focused on developing interventions to increase the pipeline of middle and high school girls entering STEM fields (White House Office of Science and Technology Policy, 2013). For example, in fiscal year 2011, nearly 3 billion federal dollars were spent on STEM education, roughly a third to support and encourage underrepresented groups to enter STEM fields. The result is that 18% of engineers graduating in 2011 were women, an increase from the 15% of graduates in engineering in 1990 (National Science Foundation [NSF], 2014). Despite the gains in female engineering graduates, only 11.7% of women are practicing engineers, a figure that has been relatively constant for two decades. Clearly, many women engineers are leaving the field of engineering. Even though they are attracted to the field, and complete a rigorous program of studies to be prepared as engineers, something occurs to either prevent them from entering an engineering career or leave the field after they enter.

There have been many attempts to understand why women leave the engineering profession (e.g., Buse et al., 2013; Singh et al., 2013;American Association of University Women [AAUW], 2015; Fouad et al., 2016). Some have argued that women are not confident enough to be engineers (e.g., Cech et al., 2011), others reported that women are vulnerable to stereotype threat (Murphy et al., 2007; Block et al., 2011), and engage in more social coping (Morganson et al., 2010), or that women are dissatisfied with their pay and promotional opportunities (Hunt et al., 2012). Other research pointed out that women engineers may contemplate departure when they perceive their work and occupational environment as not meeting their needs (American Association of University Women [AAUW], 2015). Blickenstaff (2005) reviewed the many explanations for women's departure from a science career and concluded that many of these explanations have focused inappropriately on the need to remediate some aspect of girls and women. She argued that a series of solutions are needed, starting with a greater diversity in the workforce and emphasized the need to create an equitable workplace that would foster innovations that reflect diverse perspectives in design. Blickenstaff (2005) highlighted the need for changes to science education in order to increase the retention of women scientists, but her arguments are equally relevant for the field of engineering.

These studies provide valuable insights into the reasons why women may consider leaving their engineering workplaces and the engineering profession. However, with the exception of one study (Fouad et al., 2016) that compared women currently working in engineering with those that left the field, there is a paucity of research that understands the reasons why women engineers left the engineering profession. Just like "exit interviews" help human resource managers understand and address areas that need to be fixed within the organization, understanding the experiences of women engineers who *left* the profession can help shed light on workplace factors that were instrumental in their decisions to leave the field so that organizations can adequately address appropriate mechanisms to retain and engage women engineers.

We seek to make four contributions with this research. First, we use a national sample of women engineers from a variety of engineering disciplines that allows us to draw a comprehensive portrait of women engineers' workplace experiences that foreshadowed their occupational departure decisions. Second, by uncovering the reasons for departure from the perspective of women engineers who already left the engineering field complements the insights generated from research on women engineers that are contemplating leaving the field. Third, we identify a comprehensive set of workplace factors that are theoretically implicated in individuals' decisions to persist in, or depart from an occupation but have not yet been addressed in extant research. We do so by using a theoretical lens that allows us to capture the interface between individual and workplace factors that underlie persistence and departure decisions. Finally, we employ qualitative analysis that offers a rich supplement to the empirical research. By using qualitative analysis of comments from women engineers who recently departed from the engineering field, we are able to identify the factors that tipped their decision toward departure rather than persistence.

Theoretical Background and Research Questions

Occupational turnover is costly, especially in fields like engineering that are characterized by rigorous education and training requirements. In addition, occupational turnover costs get amplified in fields like engineering that have a high cost of entry and exit, and when reentry is difficult (Ng and Feldman, 2007). Occupations, defined as "collections of work roles with similar goals that require the performance of distinctive activities as well as the application of specialized skills or knowledge to accomplish these goals" (Dierdorff et al., 2009, p. 974), have been shown to exert a "top–down" influence (Cappelli and Sherer, 1991) on a variety of individual level outcomes and experiences.

TABLE 1 | Reinforcers, description, and number coded for women who left engineering.

Reinforcer	Description	Number of comments coded
Comfort*	Needs related to activity, independence, variety, compensation, security and working conditions	699
Safety	Needs related to company policies, supervision-human relations, and supervision-technical	383
Achievement*	Needs related to using abilities and achievement	282
Status*	Needs related to advancement, recognition, authority, and social status	252
Altruism	Needs related to co-workers, social service and moral values	239
Autonomy	Needs related to co-workers, social service and moral values	38

**Reinforcers found in engineering occupations (Rounds et al., 1981).*

In a series of studies, Dierdorff and his colleagues explain how occupations exert this "top–down" influence on individual behaviors and outcomes. According to Dierdorff and Morgeson (2013), any occupation encompasses several organizations, and jobs are embedded within the organization and occupation. They further note that occupations are characterized by their own "cultural features" (Morgeson et al., 2010, p. 353) and specific "occupational reinforcer patterns" (Dierdorff and Morgeson, 2013, p. 689) that promote or inhibit the satisfaction of needs and values of the employees working in the organizations. They also add that occupations enable or constrain the emergence of different work design elements that shape the manner in which work roles are enacted and jobs performed in any organization (Morgeson et al., 2010). Finally, they argue that occupational theories like the Theory of Work Adjustment (TWA) add unique value to our understanding of the links between occupational contexts and individual level outcomes because they "describe the influences occupational context exerts on individuals' behavior and attitudes, and suggest that congruence between individuals and their environments can explain various outcomes such as job satisfaction" (Morgeson et al., 2010, p. 353) and in our case, occupational turnover decisions.

The TWA (Dawis and Lofquist, 1984; Dawis, 2005), may be useful in explaining why women leave engineering since it was specifically developed to understand factors involved in people's decisions to leave an occupation or job (Juntunen and Even, 2012). The TWA belongs in the realm of person-environment theories within large class of occupational theories In general, person-environment fit theories capture the interface between individual and specific environment (job, organization, or occupation) factors that underlie the individuals' satisfaction, adjustment, and/or fit with the environment and are manifested in their decisions to persist in or leave that environment. One person-environment fit theory in particular, TWA originally focused on the process of adjustment to work (Dawis and Lofquist, 1984; Dawis, 2005; Swanson and Schneider, 2013), but it is also useful in predicting whether individuals would be satisfied with their jobs (or occupations) and how long they might remain in the job (or the occupation). Person-environment fit within TWA is considered to be reciprocal. The occupation (or environment) has requirements of the individual (his or her ability to do the job), and the individual has requirements of the environment (the environment's ability to satisfy his or her needs). According to TWA, if an individual's needs are met by the reward (reinforcers) in the occupation, he or she is predicted to be satisfied and will stay in the occupation. Conversely, if there is little correspondence between an individual's needs and the occupational reinforcers, and the individual cannot act to bring the two more in alignment, the individual will leave the occupation.

In terms of the person-environment fit framework, the TWA describes the person or the individual perspective through the construct of values and needs. Values are viewed as representing a grouping of needs. Dawis (2005) defined six crucial values: achievement, comfort, status, altruism, safety, and autonomy. Cluster analyses were used to identify three to six needs that corresponded to a particular value. *Achievement* values include using one's abilities in the work environment and the job providing the individuals with a meaningful sense of accomplishment. *Comfort* values capture various aspects of the work environment that provide security, compensation, good working conditions, engaging work, variety in work, and ability to be independent. *Status* values reflect the occupation's provision of opportunities for advancement, recognition, authority, and social status. *Altruism* values include having good relations with co-workers, doing things for other people, and doing work that does not feel morally wrong. *Autonomy* values include being able to be creative, having responsibility, and being able to be autonomous. Finally, *Safety* values reflect fair company policies, good supervisors who back up their workers and provide good training.

From the perspective of the environment, research underlying TWA has identified occupational ability patterns and occupational reward patterns in describing a wide variety of occupations. Early research on TWA established reinforcer patterns for STEM careers, including engineering (Rounds et al., 1981). For example, the occupation of engineering reinforces Achievement, Status, and Comfort. No studies have explicitly examined the STEM occupational reinforcers with women or their satisfaction with their engineering jobs and the engineering occupation, although a few studies have examined women's departure from STEM careers. It is possible that women leave the engineering field because of a need-reinforcer mismatch. They may, for example, have other needs for reinforcers not provided by the environment, such as altruism or autonomy as was illustrated in a study by Trower and Chait (2002). They surveyed women faculty in over 130 institutions and found that female faculty in STEM have lower job satisfaction than their male colleagues. The researchers found that difficulty of fitting into a department, opportunities to work with senior faculty, and institutional support were the most significant factors that impacted women faculty's level of job satisfaction. However, since this study only focused on women who worked in academic environments, the results may not apply to those who work outside of academic settings.

In a longitudinal study, Glass et al. (2013) examined women's departure from STEM fields over time. They found that women in STEM-related occupations were more likely to leave their occupational field than women in other professions. The researchers found that demographic and family characteristics of women in STEM jobs were not saliently different from women in non-STEM professional jobs (Glass et al., 2013). Moreover, some protective factors such as higher earning, egalitarian gender attitudes, and better work-life support might prevent women from leaving their occupations temporarily but did not prevent women from moving out of the STEM fields over time. The authors argued that one possible reason that women in STEM occupations often move to non-STEM jobs and occupations is the chilly climate that they experienced in their working conditions and environment. This view is further corroborated in an extensive study by Hewlett and Luce (2005). Hewlett and Luce's (2005) surveyed 2,493 Science, Engineering, and Technology (SET) professionals and conducted additional surveys of 1,910 men and women within three multinational companies and found that women SET professionals confronted a variety of "push" and "pull" factors that shaped their decisions to persist in or leave the field. The women SET professionals in their study reported that they loved their work, found it intellectually challenging and stimulating, and loved being able to use their hard-earned skills to make a contribution to society, these were the "pull" factors that kept these women highly committed and involved in their fields. Yet, these women faced extreme job pressures, narrow, murky career advancement opportunities, and often worked in workplace cultures, that were "at best unsupportive and at worst, downright hostile to women" (p. 7) that thwarted their attempts to succeed and thrive and "push" them out of the workplaces. Viewed in terms of the TWA, it is possible that there is a misalignment or a mismatch between the women's needs from their work environments and occupations and what their environment (job and/or occupation) offered and provided them.

Although these previous studies provided valuable information about the differences between women in STEM fields and non-STEM fields and indicated that promotion, higher job satisfaction, and job commitment might help companies keep their female workers, little is known specifically about whether women engineers' actual working conditions and experiences may underlie a "need-reinforcer" mismatch and act as a potential trigger for them to quit the engineering field. Using the TWA, we apply the lens of the six values and their corresponding needs to delve into, and categorize, the match/mismatch between the working conditions experienced by women engineers who worked in engineering and the needs they sought to satisfy in their workplaces. Such an approach will allow us to not only develop a deeper understanding of the key areas of person-environment match/mismatch but also help us document the different types of reasons and circumstances that precipitated a large group of women engineers to leave the engineering field after pursuing an engineering career. Given that there is little empirical literature and limited conceptual and theoretical guidance in this area, we offer the following research questions:

Research Question 1: Are women engineers' decisions to leave their jobs and the engineering field driven by a mismatch between their occupational needs and the reinforcers provided by the work environment?

Research Question 2: Will women engineers' attrition decisions be characterized by the same reinforcer pattern of values and needs of Achievement, Status, and Comfort as described by Rounds et al. (1981)?

Research Question 3: Will women engineers' attrition decisions be characterized by other reinforcer pattern of values and needs not captured by Rounds et al. (1981)?

MATERIALS AND METHODS

Procedure

The data were collected through an online survey in 2009. A survey link was sent to 70 universities with engineering departments across the United States. These universities were chosen from an annual list compiled by the American Society for Engineering Education (ASEE) that profiles the universities based on their record of graduating the most women engineers for that year; our list was based on ASEE compilation of 2008. Out of the 70 universities that were contacted, 30 universities and their engineering departments formally partnered with the researchers. The women engineering alumnae from these 30 universities were sent a link to the website; only those who agreed to the informed consent were given access to the survey.

Links to the survey website were also sent by these women alumnae to their female engineer colleagues, friends, and family members. A total of 5,562 women who had a bachelor's degree in engineering participated in this survey after completing the informed consent form.

Sample

About 10% (554) of these women never entered the field of engineering, 27% (1,464) chose to leave the engineering field, and 60% (3,324) were still working in engineering in 2009. In this qualitative study we focused on the comments of the 27% of the participants ($N = 1{,}464$) who left the profession of engineering having worked in engineering workplaces for a period of time.

Of the 1,464 women participants who chose to leave the engineering field, 65% identified themselves as white, 4% as Asian/Asian American, 3.8% as African American, 2% as Latina, 22% as Multi-racial, 1% as "other," and less than 1% self-identified as Native American. Regarding their marital status, 66% of women in this group were married, 23% were not married, 4% were in a committed relationship, 1% reported having separated from their spouse/partner, 1% were divorced, and 1% reported being widowed. About 60% of women in this group were parents. In addition, 19% of the women (279) left the engineering field less than 5 years ago. For this group, the average age of women ranged from 19 to 66 with a mean age of 35 years.

For other women who left engineering after having worked in this field, their ages ranged from 21 to 85 years. Almost half of these women reported having a full-time employed spouse. About 42% of women who left the engineering field reported at least 40 working hours per week in current non-engineering positions.

The annual salary reported by women who left the engineering field ranged from less than $ 25,000 to more than $ 250,000. Twenty-three percent of women reported an annual salary of less than $ 25,000, and 26% of participants reported an annual salary between $ 51,000 and $ 100,000. In the sample, 26% of women who left the engineering field reported that their total family income was higher than $ 151,000 per year.

The top five majors reported by the women who left the engineering field were: Industrial Engineering (20%), Mechanical Engineering (18%), Electrical Engineering (13%), Chemical engineering (13%), and Civil Engineering (11%). Among this group of women, 42% pursued an additional educational degree: 27% earned a M.S., 12% earned a MBA, 9% earned a B.S., 3% earned a M.A., and nearly 2% earned a Ph.D. Additionally, the top four reasons why these women chose to leave the engineering field were work-family imbalance (16%), loss of interest in engineering work (12%), lack of opportunities for advancement (11%), and dislike of engineering tasks (9%).

Survey Questions

The survey questions included both Likert type questions as well as open-ended questions. We used the responses to the two open ended questions for qualitatively analyzing that data and reporting the results in this paper. The two questions that were used for analyses were: what was their opinion and experience on why women leave engineering and what were their own experiences in engineering that they would like to share with researchers. Guided by TWA theory, the responses to the two questions were coded into six categories and used in the present study. Seven researchers from both a management department (one faculty member and one doctoral student) and a counseling psychology department (one faculty member and four doctoral students) coded the comments. In particular, each doctoral student coded 100 pages on average (with 3–6 statements on each page) and each faculty member coded 30 pages, and 10 pages overlapped. Thus, approximately 200 statements were coded by multiple raters. Any discrepancy in coding for a statement was flagged for discussion. After comparing the coding between researchers and doctoral students, we flagged 3% out of 1,863 comments and the discrepancies were reconciled.

RESULTS

The participants' comments were grouped into categories of mismatch between their values related to *Achievement* (needs related to using abilities and achievement); *Comfort* (needs related to activity, independence, variety, compensation, security, and working conditions); *Status* (needs related to advancement, recognition, authority, and social status); *Autonomy* (needs related to creativity, responsibility, and autonomy); *Altruism* (needs related to co-workers, social service, and moral values); or *Safety* (company policies, supervision-human relations, and supervision-technical). The factors, below, and in **Table 1**, are discussed in order of most frequently identified values (Comfort) to least (Autonomy).

Comfort

It comments were the most frequently identified as contributing to the needs-reinforcers mismatch in terms of how employees perceived their work environment, specifically the needs related to working conditions, pay, and security. There were 669 comments coded to the "Comfort" category of values.

Within the Comfort category of values, and the "working conditions" set of needs, those relating to work life imbalance stood out in their frequency. Many women reported that the engineering job was a busy one, to the point that it impacted their work-life balance. Many women reported that engineering jobs could be very demanding and "most companies expect +40 h." They reported being challenged to be able to work fulltime when they had small children at home. For example, one participant stated that "I often had meetings scheduled outside of childcare hours, had travel expectations, and heavy workloads were not decreased. Eventually I went to working part time as a consultant, working to support tests and launches primarily for satellites." The majority of women who left the engineering field stated that it was difficult for them to find part-time jobs in the engineering field, and that was the main reason they left the occupation altogether. However, it needs to be noted that not all of the women who left the engineering field had the same experience. A few had different experiences that related to their dissatisfaction with the nature of the work itself. One of these women commented, "sitting in front of a computer screen is fine and dandy when I have meaningful work, but I didn't have meaningful work that kept me busy 40 h a week." This particular respondent felt so strongly about the lack of meaningful work that she mentioned this was the only reason that made her decide to leave engineering.

Compensation was also an issue that was brought up by women engineers who left engineering. Some of them stated that the compensation they earned was not enough for them to pay childcare. As a result, it made sense for some them to quit their jobs and stay home to take care of their children on their own. For example, one of the participants shared that the "cost of childcare was very high... In my case, it became financially illogical to continue working, and my job satisfaction alone was not enough to keep me there." Still others noted that they realized that people usually had better compensation in a business position than in an engineering position and that pay discrepancy drives many to leave engineering. Many women engineers specifically mentioned a concern with the possibility of glass ceiling and stated that they were not paid equally compared to their male counterparts and noticed "a gap in pay between men and women at the same skill level." One respondent commented that having a lower salary than her male colleagues made her think about moving to another field to make more money. Another woman stated, "the career path in engineering does not allow for comparable income or management growth. There was a choice [for me] between further specialization and returning to an MBA."

Some women expressed that the engineering field could not provide them with steady employment. For example, one of the participants shared that "I never felt like I had job security because of layoffs and the threat of layoffs." Similarly, another stated, "I personally do not feel there is enough security working in industry." As noted above, there were only limited opportunities for part-time work in an engineering field for those who need to have more flexible working schedule. Furthermore, many women stated that it was "hard to take a break and then come back" to the engineering field. One of them stated, "leaving engineering and trying to come back is not an easy feat. That is why many women who take a break to care for their children, never return."

Working conditions also influenced individuals' decisions to not work in engineering anymore. For example, one of the participants shared, "I worked for an organization that was an old boys club. The industrial nature of the job was dirty, smelly, and hazardous. This company had been run by white men for so many years that these guys had no idea how to integrate women into their organization." Similarly, another woman stated, "the physical work environment in manufacturing is often loud, hot, cold, dusty, smelly, etc., and in early assignments, shift work or being on call may be required."

Safety

The second set of unmet needs was related to whether the organization's policies and practices were fair. There were 383 comments coded in this category. Even though some women reported that they had good relationships with their co-workers and liked the engineering tasks they were doing, the lack of mentoring support combined with discrimination from their supervisors, formed the key reasons in their decision to leave the field.

Many women talked about the need for female mentors and role models in the field. For instance, one of them wrote, "The biggest problem I experienced was lack of a female mentor. My last 2 years working as an engineer, I finally found a female mentor, however, she was the comptroller of the company, not an engineer. I had no female to whom I could look up to." Echoing a similar sentiment, one woman noted "It was also hard without having female mentors in the field. It would have helped to have someone to talk with about issues." One of the participants stated that she loved being an engineer, and "if I had had a female mentor, I may have stayed. But I felt very alone and didn't feel encouraged or inspired to continue." Assisting women engineers finding/ matching with female mentors could be critical to help them stay in the field.

Flagrant violations of some HR policies also contributed to women's decisions to leave the field of engineering. One of them disclosed that her boss suggested that she should sleep with their customers, and when she refused to do so, her boss filed sexual harassment claims on her. Some women reported that their bosses did not support them when they needed to have maternity leave or requested more flexible work schedules. For instance, one participant shared that her boss told her she would never return once she went on maternity leave. Others stated that their bosses were unwilling to let them work part-time. Still another woman tried to discuss with her boss when her job had increased to 70% of the time spent on traveling, including overnight travel. She stated that "I tried to transfer to a different position within the company and was unable to. My boss was totally unwilling to try and work out a compromise on the travel so I left."

Violation of other company policies also contributed to the woman engineers' decisions to leave the field. For example, one of the participants reported, "I found that ethical concerns were not well-addressed, and the company was more interested in papering over problems, often at very high expense, than actually solving them." Failure to accommodate disabled individuals was also noted as a factor that pushed some women away from the engineering field. For instance, one woman shared, "I am disabled and needed disability accommodations. I requested them and was turned down. In addition, my management purposely took away the few accommodations that I had received under another manager (like flexible working hours). I was put on display and required to regularly go into inaccessible rooms in order to do my job."

Achievement

The third most frequent set of unmet needs focused on needing to feel confident in using one's abilities and having meaningful work. How this mismatch between needs and environmental reinforcers influenced women's decisions to leave the engineering field can be found in 282 comments. Many women engineers left the field because they wanted to work in other environments that better utilized their abilities. For example, one of the participants stated that even though she was a top ranked engineer when she was working in the field and enjoyed engineering work, her passion in her life was teaching math and science to students. As a result, she decided to leave the engineering field. Similarly, another woman chose to switch to another field because the new field allowed her to use "the analytical, research, and writing skills that I developed during my engineering training and work, as well as use my compassion, creativity, multidisciplinary thinking, and cross-cultural values and skills." There were also some women who decided to change their career path because sometimes working in the engineering field was not the ideal place for them to apply their math and science skills. For instance, one of the women who loved math and science found that the engineering jobs she had "involved no math and little science." This became a factor that pushed her out of the field.

Some woman left the field because the engineering job did not give them a feeling of accomplishment. For example, one of the participants shared that a "big killer" in her engineering job was that she "learned nothing." Echoing her point of view, another participant reported that engineering "just wasn't a very fulfilling profession" and she also decided to leave the field. Another woman stated that she found the engineering culture unsatisfying and felt much more fulfilled after she changed her career to work in another field.

Status

Lack of recognition was another factor that pushed women out of the engineering field. There were 252 comments that fell into this category. It appears that some women did not feel they were being respected or received enough recognition in their work. For instance, one woman commented, "I could expect very little recognition, both financially and organizationally." Similarly, another participant stated that people often told her that she "had to work twice as hard to get half the recognition." In addition, one of the participants stated, "Excellence in engineering is not rewarded with promotions, raises, or even appropriate recognition."

Another significant factor that many women highlighted was related to the lack of opportunity for advancement. Some of them encountered challenges in terms of getting promotions in a male dominated field and felt that "that the climb up the ladder of advancement is littered with constant obstacles." Many of them expressed that other fields offered more advancement opportunities than the engineering field. For instance, one of them said that there are "more perceived opportunities for advancement in the business world." Some of them reported that they decided to leave engineering "not because of a dislike for engineering, gender discrimination, or other such inequality," but because "the opportunities for advancement (and financial gain) were greater [elsewhere]." Some women reported that they were promoted out into other fields. For example, one of them reported that "I left operations to become manager of the commercial group and whereas my engineering background was useful, it wasn't the main skill necessary to perform the job. I really liked Operations but in order to get promoted, one had to move up and out of Operations."

Altruism

The fifth set of unmatched needs was related to employees' relationships with their co-workers, doing things for other people, and doing work that is consistent with their moral values. There were 239 comments that were related to this category. Some women reported that they "wanted to work with people with social skills." One of them stated, "I left my job not because of dissatisfaction with engineering, but the people I worked with." Many of the participants talked about a "boys club" mentality that still exists in engineering. For example, one of the women shared, "There is still an "old boys club" where women are excluded from "male-bonding" events (poker games, golf, etc.). This informal channel of information is often where we can learn more about our managers and job expectations but puts us at a disadvantage because we aren't even invited to participate." Some decided to leave the engineering field because they wanted to feel like they were doing things for other people. For example, one of the women stated that she "wanted to feel the work I was doing mattered to my community." Another woman chose to change her career path and focus on improving healthcare, stating that's an area that "truly contributes to society."

Autonomy

The final set of needs refers to employees' needs to be autonomous. This category had the least number of comments; only 38 comments fell into in this domain. One of the women who left the engineering field shared that she wanted a change and wanted to have "more leadership/management roles, roles where there are more women, roles with more opportunities for growth, getting more broad experiences rather than depth in one area." Some chose to switch their career path because they wanted to try out the viability of some of their own ideas. For instance, one woman who left engineering stated, "I was bored (of designing the same product over and over, of reacting to the same mfg [manufacturing] defects, of working with the same rough clients, and when I finished my MBA, I went into management consulting."

Our first research question posed whether women engineers' decisions to leave their jobs and the field of engineering will be shaped by the need-reinforcer mismatch as posited by the TWA. Our results reveal that women's decisions to leave engineering reflected that the work environment did not fulfill their occupational values. Our second research question posed whether the occupational reinforcer values of Achievement, Comfort, and Status would characterize women engineers' decisions to leave the field. Although, we found the same three dominant values emerge in women's rationale for leaving engineering, the pattern we found (of Comfort, Achievement, and Status) was a little different from what Rounds et al. (1981) initially described. Finally, the last research question asked whether there will be other unmet needs that characterize women's decisions to leave the engineering field, and we found that unmet needs related to safety and altruism did play a likely role in women's decisions to leave their engineering work and field.

DISCUSSION

The purpose of this study was to provide a deeper and more comprehensive understanding of the reasons women engineers leave the field than what has been previously known. Using the TWA (Dawis, 1994), we undertook a qualitative analysis of comments made by 1,464 women engineers reflecting a wide variety of work experiences and conditions that factored into their decisions to leave their jobs and the engineering field. According to the TWA (Dawis, 1994), departure from a work environment is due to a mismatch between the needs an employee has and the reinforcers provided by the work environment in the organization, which is embedded within the occupation. TWA proposes six overarching needs: comfort, safety, achievement, status, altruism, and autonomy. The reinforcers found in engineering occupations are related to achievement, status, and comfort. We suggested that women would be more likely to leave an engineering occupation if their needs in these areas were not reinforced by the work environment. Overall, our results provide definitive answers to the three research questions.

The first research question posed whether women engineers' decisions to leave their jobs and the engineering field is driven by a mismatch between their occupational needs and the reinforcers provided by the work environment. As the results and comments reveal, there are clear indications that women's decisions to leave their jobs and the engineering field was shaped by a lack of fit between their needs and values and the reinforcements present in their work environment. The second research question asked whether women engineers' attrition decisions will exhibit the same reinforcer pattern of values and needs of Achievement, Status, and Comfort as described in Rounds et al.'s (1981) original study. Our results show that occupational values and needs related to Comfort, Safety, and Achievement predominantly characterized women engineers' attrition decisions, and this pattern closely paralleled the one suggested by Rounds et al. (1981). The final research question centered around the possible presence of a different reinforcer pattern of values than the one original characterized by Rounds et al. (1981). Our results showed the emergence of another set of occupational reinforcers related to status, altruism, and autonomy needs. These three needs were not identified by Rounds et al. (1981) in their original work on engineers. The following paragraphs discuss the meaning and implications of these findings.

Comfort needs emerged as the most dominant category of occupational needs that were misaligned with the reinforcers in the work environment and this mismatch undergirded women engineers' decisions to leave their workplaces and the field. A third of the comments were related to unmet comfort needs that were associated with perception of poor and/or inequitable compensation, poor working conditions, as well as an inflexible and demanding work environment that made it difficult to balance work and family roles. Many participants noted that it was challenging for women with young children at home to persist in the engineering field because of the heavy workload and travel expectations. However, many women also noted that they tried to find ways to actively alter the work environment to bring those needs more in alignment, but were not successful in advocating for part time work or flexibility in their jobs.

Unmet safety needs took the form of unfair, and sometimes illegal, organizational practices and policies. From the comments it appears that many women engineers experienced discrimination from their supervisors or sexual harassment but the system of filing a discrimination charge was not functioning well in the company they worked with at that time. In addition, the comments point to unmet safety needs in the form of non-existent systems and practices that would increase employees' engagement in the workplace. Specifically, we found that women engineers' unmet needs for mentoring in the work environment increased their feelings of isolation and made it hard to aspire for further advancement in the company.

These deeply troubling and unsatisfying job experiences are analogous to the "push" factors that Hewlett and Luce (2005) describe in their study on female SET professionals' decision to take the "career off-ramps" when confronted by hostile macho cultures, extreme job pressures, isolation in the work environment, and murky career advancement paths. These "push" factors were strong enough to override the "pull" factors that these women reported in terms of loving their work for its stimulating, intellectually challenging aspects and for being able to use their skills to make a difference in the world. Similar to the Hewlett and Luce (2005) female SET respondents, the women engineers in our study also left the field of engineering because they wanted to utilize their skills in another field; these comments reflected their unmet achievement needs. Some chose to study engineering because of suggestions from family or school counselors or because they were good at math and science, and eventually the unmet need to more effectively use their math and science skills than the current environment offered, led them to another career. Some participants also shared their eagerness to learn new things and contribute to the community, both of which were not being addressed by their current work environment.

Finally, many women described unmet needs linked to status, which reflected their needs for recognition and opportunities for advancement. Comments related to status needs related to their dissatisfaction with fewer advancement opportunities than their male co-workers and lack of recognition by their supervisors. This finding was consistent with the trends reported by Powell et al. (2009) in their study on women engineers.

Thus, as predicted, many women left engineering because the environment did not provide them the opportunity to meet their needs primarily related to comfort, safety, and achievement, despite their attempts to bring the needs and reinforcers more in line with each other. According to the TWA, the women's descriptions of attempts to change policies, talk with supervisors, or make modifications to their work environment, are considered attempts at active adjustment, that is, acting on the environment to reduce dissatisfaction. As the theory would predict, when those attempts fail, the individual will choose to leave the environment altogether, which is reflected in the pattern of findings from our study.

Cumulatively, our results indicate that fulfilling one's needs related to challenge, autonomy, and a sense of balance, parallels the same three dominant needs within the kaleidoscopic model (Maineiro and Sullivan, 2005) that emerge at different points in women's lives and careers. However, unlike Maineiro and Sullivan's (2005) model, and research by O'Neil and Bilimoria (2005), the current study did not take a longitudinal or a 'phased' view of women's careers.

The women in our group also noted two additional types of reinforcers that were not met in the engineering organizations they work for: safety and altruism. Safety comments were primarily related to lack of supervisor support and the unfair application of policies. Many women noted that the "boys club" culture in the engineering field still exists and many participants in our study stated that it made them feel like an outsider. These comments are consistent with other reported research on women's experiences in STEM occupations (Farrell, 2002; Gupta and Sharma, 2003; Hewlett and Luce, 2005). The lack of altruism needs indicated that working in engineering did not require a lot of interpersonal interactions. Some women engineers decided to change their career to allow them more opportunities for interpersonal interactions.

Practical Implications and Suggestions for Future Research

According to O'Neil et al. (2013, p. 103), "Career development occurs at the intersection of the individual and the organization." We contend that to the extent that organizations are the vehicles through which the occupational reinforcer patterns and values are made manifest, then career development may be viewed as occurring at the intersection of the individual, organization, and the occupation. In highlighting the person-environment fit issues that undergird women's decision to leave the engineering profession, it is important to place the results from this study within the larger context of women's career development. Our results revealed that women's individual competence and ability to connect with others is a significant factor in their career decision-making and progression and it parallels one of the patterns that O'Neil et al. (2008) identified in their overview of research on women's careers. The results also indicate that beyond the needs for competence, autonomy, challenge, and balance, women's career decisions are also shaped by issues of inequity – in compensation, advancement opportunities, and interpersonal treatment (in the form of harassment and discrimination). These issues were somewhat reflected in O'Neil and Bilimoria's (2005) characterization of the "pragmatic endurance" career phase which described women's perseverance through demanding organizational environments. Future models of women's career development need to more explicitly take into account the role of workplace inequities in shaping women's career choices and their overall career trajectory. In addition, we encourage researchers to employ inductive approaches to build theory that captures the complex interplay of occupational, organizational, and personal factors that shape technically skilled women's career choices and career trajectories.

Based on our findings, there are some suggestions that might be useful for employers and educators. First of all, women left engineering even though their needs were in line with the needs provided by the occupation, but not adequately reinforced through the organizations' work design, systems, and practices. In other words, engineering is a field that reinforces achievement, comfort, and status, and yet women expressed dissatisfaction with the lack of reinforcers in those areas as it manifested through the organizational practices and cultures. This would seem to be an area for intervention by employers, interventions that provide career development opportunities for employees, a sense of accomplishment at work, security, good compensation, good working conditions, and opportunities for advancement.

Many of the comments related to comfort focused on frustrations with the ability to manage multiple roles. Although many of participants' organizations had work-life benefits, women noted they were actively discouraged from using them. Clear communication from organizational leaders supporting the use of work-life benefits would be helpful as also clear messaging dissuading supervisors from imposing career penalties on women for using any work-life benefits. Having flexible work schedules, creating more part-time opportunities, or allowing employees to work remotely could also be beneficial for engineers who have care-giving responsibilities.

Organizational and HR leaders also need to send a clear message regarding a work environment that is free from harassment and discrimination and policies that reflect fair, equal, and respectful treatment of all individuals at work. Many of our participants stated that it would be helpful for them to have a woman supervisor or mentor to discuss the challenges they face in their work environment. Given the paucity of women engineers at all organizational levels, it might be challenging to fulfill this particular need, but companies could train their male supervisors to become more sensitive and responsive to challenges that their women engineers face.

Based on our results, companies could also train supervisors on how to provide positive feedback and encourage their subordinates. It might be helpful for companies to provide more training opportunities for their employees so that they can learn new skills and knowledge to apply in their work. Companies could create some social events to increase cohesiveness among employees. It might also be beneficial to let employees know why their work is important and how it could benefit other people in the community. In addition, organizations could create volunteer opportunities for their employees to partner with community members on mutually meaningful activities and projects.

Even though our study provides more detailed explanation of why women engineers leave the field, there are some limitations that need to be acknowledged and which serve as potential areas for future research to investigate. First of all, we did not directly ask women engineers the different things they needed to adjust in their work environment. This could be valuable for future researchers to find out what do women engineers need to cope with the challenges they face. It would be also important to document the successful strategies used by women engineers who have persisted in the engineering field and draw lessons from their efforts to actively alter their work environments to meet their occupational needs. Toward that end, scholars need to build new theories, refine existing theories, and/or integrate complementary theoretical frameworks to offer a more nuanced understanding of this phenomenon. Our use of the TWA framework provides some compelling new insights, explanations, and interpretations of this area of inquiry but there are additional theoretical and methodological ways to approach this multifaceted phenomenon. Second, since we solicited written responses to open ended survey questions, we did not have an opportunity to clarify the meaning of their comments. Future researchers should be encouraged to use multiple methods to capture women's work experiences and not be limited to one method of data collection. The final limitation that needs to be noted is the sample used in our study. Although we argued that it is important to capture the women engineers' voices and experiences, we emphasize that it is equally critical to understand male engineers' perspectives and work experiences that undergird their decisions to continue in, or leave, the field of engineering. In fact, it will be interesting to see whether some of the mismatch needs found in our study of women engineers also is an equally relevant driver of male engineers' decision to leave the field. As noted by Emslie and Hunt (2009), male engineers have been facing similar dilemmas of work-life balance. We encourage future research to explore whether TWA theory will be helpful in explaining the departure and persistence decisions of male engineers.

CONCLUSION

Our research was broadly anchored with the person-environment fit theoretical framework and we used the TWA (Dawis and Lofquist, 1984) to shed light on a little known facet of women engineers' work experiences, i.e., the degree to which the work environment fulfilled and matched women engineers' occupational needs, and the extent to which these unmet needs triggered their decisions to leave their engineering jobs and the occupation. Lee et al. (1999) noted that "Individuals experience unique circumstance when they leave" (p. 450) and our results contributed to the growing literature on understanding the drivers of occupational turnover decisions by uncovering some of these "unique circumstances" that galvanize women engineers to leave the engineering field that they worked and trained hard to enter.

ETHICS STATEMENT

The study was carried out in accordance with the recommendations of the Institutional Review Board at the University of Wisconsin-Milwaukee. The research protocol was approved by the IRB at the University of Wisconsin-Milwaukee.

AUTHOR CONTRIBUTIONS

NF and RS designed the study and collected the data; NF took the lead in writing significant parts of the manuscript; RS shared part of the writing. W-HC and MW took the lead in data cleaning and analysis, writing the methods and results section. All authors were involved in coding and resolving discrepancies. All authors contributed substantially to the final manuscript.

FUNDING

The data reported in this paper was part of a project that was funded by the National Science Foundation ("Women's Persistence in Engineering Careers: Contextual Barriers/Supports"; NSF # 0827553) and awarded to the first and the fourth co-authors on this paper. Any opinions, findings conclusions, and recommendations are the authors' and do not necessarily reflect the views of the National Science Foundation.

REFERENCES

American Association of University Women [AAUW] (2015). *Solving the Equation: The Variables for Women's Success in Engineering and Computing*. Washington, DC: AAUW.

Blickenstaff, J. C. (2005). Women and science careers: leaky pipeline or gender filter? *Gend. Educ.* 17, 369–386. doi: 10.1080/09540250500145072

Block, C. J., Koch, S. M., Liberman, B. E., Merriweather, T. J., and Roberson, L. (2011). Contending with stereotype threat at work: a model of long-term responses. *Couns. Psychol.* 39, 570–600. doi: 10.1177/0011000010382459

Buse, K., Bilimoria, D., and Perelli, S. (2013). Why they stay: women persisting in the engineering profession. *Career Dev. Int.* 18, 139–154. doi: 10.1108/CDI-11-2012-0108

Cappelli, P., and Sherer, P. D. (1991). "The missing role of context in OB: the need for a meso-level approach," in *Research in Organizational Behavior*, Vol. 13, eds L. L. Cummings and B. M. Staw (Greenwich, CT: JAI Press), 55–110.

Cech, E., Rubineau, B., Silbey, S., and Seron, C. (2011). Professional role confidence and gendered persistence in engineering. *Am. Sociol. Rev.* 76, 641–666. doi: 10.1177/0003122411420815

Dawis, R. V. (1994). "The theory of work adjustment as convergent theory," in *Convergence in Career Development Theories*, eds M. L. Savickas and R. W. Lent (Palo Alto, CA: CPP Books), 33–43.

Dawis, R. V. (2005). "The Minnesota theory of work adjustment," in *Career Development and Counseling: Putting Theory and Research to Work*, eds S. D. Brown and R. W. Lent (New York, NY: Wiley), 3–23.

Dawis, R. V., and Lofquist, L. H. (1984). *A Psychological Theory of Work Adjustment*. Minneapolis, MN: University of Minnesota Press.

Dierdorff, E. C., and Morgeson, F. P. (2013). Getting what the occupation gives. Exploring multi-level linkages between work design and occupational values. *Pers. Psychol.* 66, 687–721. doi: 10.1111/peps.12023

Dierdorff, E. C., Rubin, R. S., and Morgeson, F. P. (2009). The milieu of managerial work: an integrative framework linking context to role requirements. *J. Appl. Psychol.* 94, 972–988. doi: 10.1037/a0015456

Emslie, C., and Hunt, K. (2009). 'Live to Work' or 'Work to Live'? A qualitative study of gender and work–life balance among men and women in mid-life. *Gend. Work Organ.* 16, 151–172. doi: 10.1111/j.1468-0432.2008.00434.x

Farrell, E. F. (2002). Engineering a warmer welcome for female students. *Leadersh. Manag. Eng.* 2, 19–22. doi: 10.1061/(ASCE)1532-6748(2002)2:4(19)

Fouad, N. A., Singh, R., Cappaert, K., Chang, W.-h., and Wan, M. (2016). Comparison of women engineers who persist in or depart from engineering. *J. Vocat. Behav.* 92, 79–93. doi: 10.1016/j.jvb.2015.11.002

Frehill, L. M. (2010). Satisfaction: why do people give up engineering? Surveys of men and women engineers tell an unexpected story. *Mech. Eng.* 38–41.

Glass, J. L., Sassler, S., Levitte, Y., and Michelmore, K. M. (2013). What's so special about STEM? A comparison of women's retention in STEM and professional occupations. *Soc. Forces* 92, 723–756. doi: 10.1093/sf/sot092

Gupta, N., and Sharma, A. K. (2003). Gender inequality in the work environment at institutes of higher learning in science and technology in India. *Work Employ. Soc.* 17, 597–616. doi: 10.1177/0950017003174001

Hewlett, S. A., and Luce, C. B. (2005). Off-ramps and on-ramps: keeping talented women on the road to success. *Harv. Bus. Rev.* 83, 43–46.

Hewlett, S. A., Luce, C. B., Servon, L. J., Sherbin, L., Shiller, P., Sosnovich, E., et al. (2008). *The Athena Factor: Reversing the Brain Drain in Science, Engineering, and Technology (Harvard Business Review Research Report)*. Boston, MA: Harvard Business Publishing.

Hunt, J., Garant, J. P., Herman, H., and Munroe, D. J. (2012). *"Why Don't Women Patent?" NBER Working Paper 17888*. Cambridge, MA: National Bureau of Economic Research. doi: 10.3386/w17888

Juntunen, C. L., and Even, C. E. (2012). "Theories of vocational psychology," in *APA Handbook of Counseling Psychology: Theories, Research, and methods. APA Handbooks in Psychology*, Vol. 1, eds N. A. Fouad, J. A. Carter, and L. M. Subich (Washington, DC: American Psychological Association), 237–267. doi: 10.1037/13754-009

Lee, T. W., Mitchell, T. R., Holtom, B., McDaniel, L., and Hill, J. (1999). The unfolding model of voluntary employee turnover: a replication and extension. *Acad. Manag. J.* 42, 450–462. doi: 10.2307/257015

Maineiro, L. A., and Sullivan, S. E. (2005). Kaleidoscope careers: an alternate explanation for the "opt-out" revolution. *Acad. Manag. Exec.* 19, 106–123. doi: 10.5465/ame.2005.15841962

Morgeson, F. P., Dierdorff, E. C., and Hmurovic, J. L. (2010). Work design in situ: understanding the role of occupational and organizational context. *J. Organ. Behav.* 31, 351–360. doi: 10.1002/job.642

Morganson, V. J., Jones, M. P., and Major, D. A. (2010). Understanding women's underrepresentation in science, technology, engineering, and mathematics: the role of social coping. *Career Dev. Q.* 59, 169–179. doi: 10.1002/j.2161-0045.2010.tb00060.x

Murphy, M. C., Steele, C. M., and Gross, J. J. (2007). Signaling threat how situational cues affect women in math, science, and engineering settings. *Psychol. Sci.* 18, 879–885. doi: 10.1111/j.1467-9280.2007.01995.x

National Science Foundation [NSF] (2014). *Science and Engineering Indicators: 2014 (NSB14-01)*. Available at: http://www.nsf.gov/statistics/seind14/content/etc/nsb1401.pdf [accessed October 5, 2014].

Ng, T. W. H., and Feldman, D. C. (2007). Organizational embeddedness and occupational embeddedness across career stages. *J. Vocat. Behav.* 70, 336–351. doi: 10.1016/j.jvb.2006.10.002

O'Neil, D. A., and Bilimoria, D. (2005). Women's career development phases: idealism, endurance, and reinvention. *Career Dev. Int.* 10, 168–189. doi: 10.1108/13620430510598300

O'Neil, D. A., Hopkins, M. M., and Bilimoria, D. (2008). Women's careers at the start of the 21st century: patterns and paradoxes. *J. Bus. Ethics* 80, 727–743. doi: 10.1007/s10551-007-9465-6

O'Neil, D. A., Hopkins, M. M., and Bilimoria, D. (2013). "Sprinters, marathoners, and relay runners: profiles of women's career development over time," in *Handbook of Research on Promoting Women's Careers*, eds R. Burke, S. Vinnicombe, L. Moore, and S. Blake Beard (Cheltenham: Edward Elgar Publishing), 87–105.

Powell, A., Bagilhole, B., and Dainty, A. (2009). How women engineers do and undo gender: consequences for gender equality. *Gend. Work Organ.* 16, 411–428. doi: 10.1111/j.1468-0432.2008.00406.x

Rounds, J. B., Henley, G. A., Dawis, R. V., Lofquist, L. H., and Weiss, D. J. (1981). *Manual for the Minnesota Importance Questionnaire*. Minneapolis, MN: University of Minnesota.

Singh, R., Fouad, N. A., Fitzpatrick, M. E., Liu, J. P., Cappaert, K. J., and Figuereido, C. (2013). Stemming the tide: predicting women engineers' intentions to leave. *J. Vocat. Behav*. 83, 281–294. doi: 10.1016/j.jvb.2013.05.007

Swanson, J. L., and Schneider, M. (2013). *Minnesota Theory of Work adjustment Career Development and Counseling: Putting Theory and Research to Work*, 2nd Edn. Hoboken, NJ: John Wiley, 29–53.

Trower, C. A., and Chait, R. P. (2002). Faculty diversity: too little for too long. *Harvard Magazine*. Available at: http://harvardmagazine.com/2002/03/faculty-diversity.html (accessed March 12, 2009).

White House Office of Science and Technology Policy (2013). *Federal Science, Technology, Engineering, and Mathematics (STEM) Education Strategic Plan*. Available at: http://www.whitehouse.gov/sites/default/files/microsites/ostp/stem_stratplan_2013.pdf [accessed September 28, 2014].

Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Psychology

REVIEW
published: 26 May 2017
doi: 10.3389/fpsyg.2017.00716

Adolescent Girls' STEM Identity Formation and Media Images of STEM Professionals: Considering the Influence of Contextual Cues

*Jocelyn Steinke**

School of Communication and Department of Gender and Women's Studies, Western Michigan University, Kalamazoo, MI, United States

Popular media have played a crucial role in the construction, representation, reproduction, and transmission of stereotypes of science, technology, engineering, and mathematics (STEM) professionals, yet little is known about how these stereotypes influence STEM identity formation. Media images of STEM professionals may be important sources of information about STEM and may be particularly salient and relevant for girls during adolescence as they actively consider future personal and professional identities. This article describes gender-stereotyped media images of STEM professionals and examines theories to identify variables that explain the potential influence of these images on STEM identity formation. Understanding these variables is important for expanding current conceptual frameworks of science/STEM identity to better determine *how* and *when* cues in the broader sociocultural context may affect adolescent girls' STEM identity. This article emphasizes the importance of focusing on ***STEM identity relevant variables*** and ***STEM identity status*** to explain individual differences in STEM identity formation.

Keywords: media images, STEM stereotypes, perceptions of scientists, science/STEM identity formation

Edited by:
Catherine Alison Hill, American Association of University Women, United States

Reviewed by:
Dina Guglielmi, University of Bologna, Italy
Latha Poonamallee, Michigan Technological University, United States

****Correspondence:***
Jocelyn Steinke
jocelyn.steinke@wmich.edu

Specialty section:
This article was submitted to Organizational Psychology, a section of the journal Frontiers in Psychology

Received: *31 October 2016*
Accepted: *21 April 2017*
Published: *26 May 2017*

Citation:
Steinke J (2017) Adolescent Girls' STEM Identity Formation and Media Images of STEM Professionals: Considering the Influence of Contextual Cues. Front. Psychol. 8:716. doi: 10.3389/fpsyg.2017.00716

INTRODUCTION

Media images of STEM (science, technology, engineering, and mathematics) professionals have varied over the years – from mad scientists to absent-minded professors to brilliant geniuses to maniacal villains to socially awkward loners to life-saving heroes. Many of these images of scientists, technologists, engineers, and mathematicians, however, have presented what has been described as a public image problem for STEM (Congressional Commission on the Advancement of Women and Minorities in Science Engineering and Technology Development, 2000). An article in *Science* noted: "Science and scientists, many observers argue, have been taking a beating in the media. The press, the movies, and especially, television convey the image that scientific progress is hazardous and that scientists are frequently foolish, inept, or even villainous" (Maugh, 1978, p. 37). An article in *New Scientist* stated that "films have always been in two minds about scientists" (Robinson, 1976, p. 732), showing real-life scientists as "humanitarian idealists" (Robinson, 1976, p. 732) and fictitious scientists as "cracked, malevolent, sometimes drunk and always dangerous" (Robinson, 1976, p. 732). An article in *The Huffington Post* explained that many stories about science in popular media often "portray scientists as falling from grace" or "fumbling and quirky, or arrogant and egotistical" and view science and technology "with fear and suspicion, more often illustrating their misuse for evil rather than their use for good" (Moreno, 2014, p. 1).

Media images of STEM professionals not only have been unflattering and unfavorable but also often have been gender stereotyped. Research shows that gender stereotypes of STEM professionals in the media influence students' stereotyped perceptions of STEM (Steinke et al., 2007; Google-Gallup, 2015). When asked to draw or describe STEM professionals, adolescents most often depict STEM professionals as male – as well as white, middle-aged or elderly, unattractive, dressed in a lab coat and glasses, geeky or nerdy, socially awkward, and individuals who work alone (Mead and Metraux, 1957; Fort and Varney, 1989; Maoldomhnaigh and Mhaolain, 1990; Huber and Burton, 1995; She, 1995; Barman, 1996, 1999; Parsons, 1997; Song and Kim, 1999; Knight and Cunningham, 2004; Mercier et al., 2006; Scherz and Oren, 2006; Steinke et al., 2007; Buck et al., 2008; Laubach et al., 2012; Camcı-Erdoğan, 2013; Cheryan et al., 2013; Christidou et al., 2016; Sainz et al., 2016). Some variations in adolescents' gender-stereotyped perceptions of scientists have been noted based on differences in gender (Huber and Burton, 1995; She, 1995; Steinke et al., 2007; Buck et al., 2008; Laubach et al., 2012; Hammack and High, 2014; Christidou et al., 2016), age (Mercier et al., 2006), race and ethnicity (Parsons, 1997; Finson, 2003; Monhardt, 2003; Laubach et al., 2012; O'Brien et al., 2015), and nationality (Song and Kim, 1999; Sjoberg, 2000). However, when adolescent girls view STEM fields as masculine, their perceptions can negatively affect their identification, interest, and participation in STEM (Lips, 1995; Packard and Wong, 1999; Steinke, 2003, 2005; Cheryan et al., 2015; Kessels, 2015; Carli et al., 2016). Research shows that girls first start to lose interest in STEM fields around the age of 12 (American Association of University Women, 2000) and girls report being less interested in STEM careers than boys (Riegle-Crumb et al., 2011; Robnett and Leaper, 2013; Farkas and Leaper, 2016).

Despite increases in women's participation in some STEM fields, women still remain underrepresented in others such as economics, mathematics and statistics, computer science, engineering, and physics – fields that report disproportionate enrollment, retention, graduation, and employment rates for women (National Science Foundation, 2015). Three of four of these low participation fields have employment rates for women well below 50%, with women representing only 25.4% of all computer scientists and mathematicians, 14.8% of all engineers, and 11.8% of all physicists or astronomers (National Science Foundation, 2015). Studies focused on broadening participation in STEM have considered a variety of approaches and strategies and have identified many factors found to play a role in the underrepresentation of women in STEM (see, for example, Clewell and Campbell, 2002; Rosser, 2012). Determining the most effective strategies and best practices for recruiting and retaining women in low participation STEM fields like engineering and computer science remains a complex challenge (American Association of University Women, 2015). This issue is especially challenging because "the factors that remove women from the STEM pipeline can be seen as layers in a sex-based filter, though no single issue can be called the primary cause" (Blickenstaff, 2005, p. 384) and finding solutions to address a "complex problem like this requires a multi-faceted solution, and time to allow innovations to take effect" (Blickenstaff, 2005, p. 384).

To address the complex challenge of broadening the participation of girls and women in STEM, research and programmatic interventions have focused on an array of factors related to ***science identity*** or ***STEM identity***. Research focused on the concept of science/STEM identity has been prolific in recent years, yet definitions as well as operationalizations used to assess science/STEM identity have varied widely. Additionally, variables identified as important dimensions of science/STEM identity often have been derived from research based on relatively small samples. Relatively few conceptual frameworks of science/STEM identity (Carlone and Johnson, 2007; Herrera et al., 2012) have appeared in the literature. Current conceptual frameworks of science/STEM identity (Carlone and Johnson, 2007; Herrera et al., 2012) have highlighted several critical constructs and variables for advancing understanding of science/STEM identity formation and have acknowledged environmental factors as important sources of influence. However, these frameworks have yet to fully explicate the potential influence of constructs and variables related to the broader sociocultural context such as contextual cues conveyed by popular media images of STEM professionals. Considering these constructs and variables is critical in order to better understand science/STEM identity formation for individuals with science/STEM identities in a state of flux or non-commitment.

This review examines historical trends in the presentation of media images of STEM professionals focusing on the number of female STEM professionals compared to the number of male STEM professionals and the gender stereotyped portrayals of female STEM professionals on television and in film. Next, this review draws from several theories of information processing (social cognitive or social learning theory, gender schema theory) and identity (possible selves theory, social identity theory, ego identity theory/identity status theory, and identity-based motivation theory) to identify specific constructs and variables that advance understanding of the potential influence of broader sociocultural variables on adolescent girls' STEM identity during STEM identity formation. Finally, this review extends current conceptual frameworks of science/STEM identity by exploring *how* and *when* cultural images (as well as cultural values, cultural assumptions, cultural beliefs, and cultural stereotypes) of gender and STEM conveyed by cues in the broader sociocultural context might influence adolescent girls' STEM identity formation.

MEDIA IMAGES OF STEM PROFESSIONALS AND GENDER

Images of STEM professionals in popular media have for many years both created and perpetuated a cultural stereotype that depicts women as less likely than men to be present in STEM fields as well as less likely to be talented, successful, and valued in STEM fields. Early television programming conveyed gender stereotyped images of STEM professionals by mostly showing men as STEM professionals. Early television portrayals of scientists featured male scientists depicted as “jungle adventurers, space travelers, heroic physicians, and stereotypical ‘mad scientists”’ (LaFollette, 2013, p. 44). None of science popularizers or hosts on early television programs were women (LaFollette, 2013). This absence of women scientists on television conveyed “potent statements about the role and status of women in science” (p. 185). Although female STEM professionals have appeared more frequently in more recent television programming, the underrepresentation of female STEM professionals has persisted for years on prime-time programs broadcast between 2000 and 2008 (except for 2007) (Dudo et al., 2011), science television programs for children broadcast in 2006 and most likely to be watched by adolescents (Long et al., 2010), and some television documentaries (Hornig, 1990; Wagner and Caudill, 2003). Several more recent television programs have shown a greater number of women STEM professionals in primetime drama programs such as *CSI: Crime Scene Investigation*, *CSI: New York* and *CSI: Miami, Bones* and *Crossing Jordon* (Potter, 2008; Chandler, 2012; Warren et al., 2016) as well as some television documentaries (Steinke, 1997; Wagner and Caudill, 2003). A study of media portrayals of scientists appearing on the popular primetime television program, *The Big Bang Theory*, noted greater diversity of scientists portrayed on this program in regard to gender, ethnicity and STEM specialty, but noted that the women scientists on this program often find their work devalued or co-opted by male scientists (Weitekamp, 2015).

In addition to the relatively low numbers of female STEM professionals appearing on television, televised portrayals of female STEM professionals have often been limited and stereotyped. Female scientists appearing in children’s television science programs broadcast in 1994 typically were cast in secondary roles of lower prestige in the scientific community and shown as research assistants or students (Steinke and Long, 1996). More positive portrayals of women scientists appearing on children’s science programs were noted by a later study that found females were equally as likely as males to be labeled as scientists, to be older, and to be shown in the same status positions and noted that both female and male scientists spent equal amounts of time on screen (Long et al., 2001). A study focused specifically on television programs likely to be watched by adolescent viewers and broadcast in 2006 found depictions of male and female scientists were similar related to marital status, parental status, high status professional position; however, female scientist characters were outnumbered by male scientist characters by 2 to 1, appeared in fewer scenes, and were less likely to be shown as independent and dominant (Long et al., 2010). Another study described the infantilization and sexualization in the portrayal of Abby Sciuto, a woman scientist in the crime fiction television program *NCIS* (Bergman, 2012). A study of the primetime drama, *CSI*, noted that two of the female forensic scientists on the program, Catherine and Sara, were portrayed as making sacrifices in their personal lives for their careers, and Catherine often was portrayed in sexualized ways and depicted as an incompetent, single working mother (Warren et al., 2016). A recent study noted that two of the lead female scientists on *The Big Bang Theory*, Dr. Amy Farrah Fowler and Dr. Bernadette Wolowitz, “have been caught between their function as supporting characters for the male leads, and the potential to depict women as working scientists” (Weitekamp, 2015, p. 85).

Popular films, like television, also have perpetuated gender stereotypes of STEM professionals by showing fewer female than male STEM professionals. Studies have found that female STEM professionals have been outnumbered by male STEM professionals in 222 Hollywood fiction films across eight decades (Weingart et al., 2003), 122 film biographies of scientists (Elena, 1993), 23 popular films from 1991 to 2001 (Steinke, 2005), and films across 11 countries released in theaters from 2010 to 2013 which revealed a ratio of 7.6 STEM males to every one STEM female (Smith et al., 2014). A recent study found 42 popular films that featured female STEM professionals from 2002 to 2015 showed twice as many male STEM professionals as female STEM professionals in speaking roles (Steinke and Tavarez, 2016).

Portrayals of women as scientists, technologists, engineers, and mathematicians on the Big Screen have been diverse; however, many portrayals have focused on the appearance, femininity, and traditional gender stereotypes of female STEM professionals. Research found gender-stereotyped depictions in the 1943 film biography, *Madame Curie* (Elena, 1997), 60 feature films from 1929 to 1997 (Flicker, 2003), and 23 popular films from 1991 to 2001 that featured female scientists and engineers as primary characters (Steinke, 2005). Some progress in reducing gender-stereotyped portrayals of female STEM professionals was noted in a recent study of 62 female STEM characters in 42 popular films from 2002 to 2014 (Steinke and Tavarez, 2016). This study found more female STEM professionals were portrayed as equal contributing members of research teams and were depicted as competent although many portrayals still focused on the physical attractiveness of female STEM characters and some portrayals featured hypersexualization of these characters (Steinke and Tavarez, 2016).

MEDIA FRAMING OF GENDER AND STEM

Media images of scientists, technologists, engineers, and mathematicians on television and in films are cultural constructions that convey assumptions about gender and STEM (Steinke, 2005). These mass-mediated messages can “be read as expressions of power in society, and as attempts to change society or mold society” (Lang, 2013). Television serves as a significant force of cultural production (Dhingra, 2006, p. 92) in American society, and television images of STEM reflect “contemporary culture on screen” (Dhingra, 2006, p. 92) “by carefully selecting the stories it tells about science and the people who tell it” (Dhingra, 2006, p. 118). Films have a similar effect: “Hollywood cinema with its perceptually realistic images and linear narrative structures contextualizes science in a manner that can establish our primary cultural meanings of science more than any other media” (Kirby, 2011, pp. 39–40). These embedded meanings have the potential to influence viewers in many ways: “The film as one of the most influential media interacts in complex ways with its audiences, reflecting, shaping, and reinforcing images and identities" (Weingart, 2006, p. 35).

Research on media frames (Gitlin, 1980; Gamson and Modigliani, 1987; Gamson et al., 1992) describes the potential of media images to shape public perceptions. Media framing research highlights the active role of the mass media in presenting "media-generated images of the world" (Gamson et al., 1992, p. 374) that intentionally construct through specific frames (Goffman, 1974) a "public identity" (van Zoonen, 1992, p. 453) of society or social issues that can shape public views of social reality when audience members encounter and interpret these images (van Zoonen, 1992). Researchers argue that through the media's social construction of reality "[t]he lens through which we receive these images is not neutral but evinces the power and point of view of the political and economic elites who operate and focus it" (Gamson et al., 1992, p. 374). Media frames, however, represent a "mental picture of something not real or present" (Gamson et al., 1992, p. 374). Media frames also can be processed and interpreted differently by different audience members who are active processors of media content (Gamson et al., 1992). Thus, the influence of media frames varies by individual differences in audience members' experiences and backgrounds and by their attention to and responses to what they perceive as "psychologically relevant characteristics" (Lang, 2013, p. 19) of media content.

Media frames research suggests that media images of STEM professionals offer culturally constructed views of STEM. Media images of STEM professionals are a potentially important source of "vicarious contact" (Fujioka, 1999) with STEM professionals when direct contact with real-life STEM professionals is lacking. Research has found that television, in fact, does shape adolescents' work perceptions (Signorielli, 1993), television characters serve as professional role models that introduce adolescents to specific careers (Hoffner et al., 2006), and television characters influence adolescents' work-related values and aspirations (Hoffner et al., 2008). Research also shows that popular media play a role in affecting how children view scientists (Tan and Jocz, 2015), and adolescents often cite popular media as sources of their images of scientists, engineers, and computer scientists (Song and Kim, 1999; Scherz and Oren, 2006; Steinke et al., 2007; Google-Gallup, 2015). Studies have found that adolescents' exposure to media scientist characters can influence perceptions of scientists (Steinke et al., 2007) and have suggested that exposure to stereotyped media images of STEM professionals may affect interest in STEM (Lee, 1998) and influence self-identification with STEM careers (Steinke et al., 2007; Tan and Barton, 2008). Media frames research, however, points out that variations are likely to exist in adolescent girls' individual responses to and interpretations of socially constructed media portrayals of STEM professionals.

Fictional portrayals of STEM professionals in popular media may be particularly relevant and salient sources of influence during adolescence. One researcher explains: "We can easily perceive periods in the lives of some young people where what the psychologies call 'ego identity' is deliberately suppressed in [favor] of socially derived norms for actions" (Solomon, 1997, p. 413). Media portrayals of STEM professionals also may be especially salient for girls during adolescence because adolescence is an active time of identity formation (Erikson, 1968). Thus, exposure throughout childhood and into the adolescent years to media portrayals that support and perpetuate a socially constructed masculine image of these fields (Weinreich-Haste, 1981; Kelly, 1985; Hughes, 2001; Blickenstaff, 2005) may elicit gender biases that directly and indirectly affect adolescent girls' views of who belongs in STEM (see, for example, Steinke et al., 2007, 2009). Thus research in this area calls for further explication of *how* and *when* contextual cues like media images of STEM professionals are most likely to affect adolescent girls' STEM identity formation.

CONCEPTUAL FRAMEWORKS OF SCIENCE/STEM IDENTITY

Much research on broadening participation in STEM over the years has centered on questions related to *science identity* or perceptions of one's self as a scientist (Hazari et al., 2010, 2013). *Identity* is defined as a "core sense of self" (Jones and McEwen, 2000, p. 405), an understanding of one's self in relation to one's past and potential future (Brickhouse and Potter, 2001) and "an internal, self-constructed, dynamic organization of drives, abilities, beliefs, and individual history" (Marcia, 1980, p. 159) that explain and predict behaviors (Marcia, 1994). *Identity* is dynamic (Polman and Miller, 2010; Wieland, 2010). *Identity* is malleable and changes as individuals encounter and react to events, circumstances, and elements in their social environment (Gee, 2001; Ceglie, 2011). *Identity* is both *individually constructed* (Erikson, 1968) and *socially imposed* (Marcia, 1994). *Identity* is multidimensional, involving multiple intersecting social identities (Jones and McEwen, 2000). *Identity* operates within specific contexts and structures (Herrera et al., 2012).

A science or a STEM identity has been cited as important for understanding a wide range of STEM-related outcomes including engagement, interest, learning, motivation, persistence, and commitment. Several studies have focused on the development and negotiation of science identities and science identities-in-practice for girls in both formal and informal science educational contexts (Brickhouse et al., 2000; Brickhouse and Potter, 2001; Thompson and Windschitl, 2005; Tan et al., 2013). For example, research has highlighted the importance of developing a science identity, in particular, for African–American middle school female students' learning of science (Brickhouse et al., 2000) and for underrepresented minority students' science career commitment (Chemers et al., 2011). Research has argued that an identity lens provides the most comprehensive understanding of STEM persistence (Carlone and Johnson, 2007; Herrera et al., 2012) and has suggested that assessing students' science identities may be critical in predicting choice of STEM careers (Hazari et al., 2010) and encouraging student persistence in science and commitment to science careers (Trujillo and Tanner, 2014). While research on science/STEM identity has proliferated, relatively few conceptual models of science/STEM identity have appeared in the literature (Carlone and Johnson, 2007; Herrera et al., 2012).

A *science identity model* was developed by Carlone and Johnson (2007) based on their interviews with 15 women of color successful in science careers. Using an *a priori* definition to develop a prototype of a person with a strong science identity, they posited three interrelated dimensions of a science identity (competence, performance, recognition) that are influenced by one's gender, racial, and ethnic identities (Carlone and Johnson, 2007). Based on their interviews, they noted variations in these three dimensions of science identity related to differences in science identity trajectories (research scientist, altruistic scientist, disrupted scientist) (Carlone and Johnson, 2007). They offered a grounded model of science identity that acknowledged the interactions among one's racial, ethnic, and gender identities and the recognition dimension of a science identity (Carlone and Johnson, 2007). This model highlighted the important connection between science identity and commitment to science careers; however, this model was based on research with individuals with prior interest and a commitment to science careers and who had achieved science identities. Further exploration is needed to determine if different dimensions might be important for non-STEM identified individuals who follow different STEM identity trajectories and who are still actively exploring a STEM identity. Additional consideration also is needed of factors in non-STEM contexts that might influence the development of a STEM identity.

The *STEM identity model* developed by Herrera et al. (2012) was based on focus groups with 132 racially diverse graduate students in both STEM and non-STEM communities (Herrera et al., 2012). The STEM identity model integrates Carlone and Johnson (2007)'s model of science identity and Jones and McEwen's (2000) model of multiple social identities with findings from their focus group interviews to explain how STEM identity interacts with three social contexts: non-STEM contexts, STEM contexts, and the societal context (Herrera et al., 2012). This model viewed STEM identity formation as including both how one perceives oneself as being recognized by others (also identified by Carlone and Johnson's (2007) as an important dimension for achieving a science identity) in addition to how one perceives and positions oneself within STEM in light of identification with groups or communities in both STEM and non-STEM contexts situated within the larger societal context (Herrera et al., 2012). Recognition was operationalized as acknowledging historically oppressive contexts for underrepresented minority students (URM), recognizing the value of cultural knowledge, and recognizing URM students' skills, abilities, and networks (Herrera et al., 2012). In addition, they emphasized that students' "agency in the identity process" (Herrera et al., 2012, p. 10) and the ways students perceive themselves within STEM are just as important as recognition by others (Herrera et al., 2012). This model advanced understanding of STEM identity by specifying three different contexts that interact with STEM identity. This focus specifically highlighted the societal context as integral to understanding STEM identity. However, further explication of the potential influence of the societal context on STEM identity is needed related to how specific contextual factors affect STEM identity, the processes and pathways most likely to predict STEM identity achievement, and predictors of how and when specific factors in the societal context might influence exploration of and commitment to a STEM identity. While, this model positioned individuals as active agents in STEM identity formation and included both STEM and non-STEM individuals, further examination is needed of how sociocultural forces and change agents influence STEM identity formation for both STEM-identified and non-STEM identified individuals during intense periods of STEM identity exploration such as adolescence.

A summary of the constructs and variables of science/STEM identity described by these current conceptual frameworks are summarized in **Table 1**.

Both of these conceptualizations acknowledge the importance of social cues, particularly those in STEM environments, related to recognition as a scientist in influencing science/STEM identity (Carlone and Johnson, 2007; Herrera et al., 2012). Carlone and Johnson (2007) specifically noted challenges posed by the "institutional and historical meanings of being a scientist (being a white male)" (p. 1207) in achieving the recognition dimension of a science identity for women of color: "It is much easier to get recognized as a scientist if your ways of talking, looking, acting and interacting align with historical and prototypical notions of scientist" (p. 1207). Similarly, Herrera et al. (2012) emphasized that identity operates within contexts, highlighting the role of societal context, with its underlying social norms, social expectations, and social roles, on STEM identity development and enactment. Further explication is needed of the potential influence of contextual cues in the broader sociocultural context that are first experienced during the early years of childhood and throughout adolescence.

Extant conceptual frameworks of science/STEM identity have highlighted many important constructs and variables related to STEM identity; however, explanations of *how* and *when* variables like contextual cues in the broader sociocultural context might affect STEM identity formation have been left relatively unexplored. The following section draws from information processing theories and identity theories to consider the potential influence of broader cues in the sociocultural context, such as cues conveyed through media portrayals of STEM professionals. Little is known about *how* and *when* these contextual cues may affect STEM identity, and in particular, how they may affect STEM identity during active periods of STEM identity exploration. Understanding this issue has practical importance because of the continued underrepresentation of girls and women in STEM and the multitude of programs and interventions focused on broadening STEM participation. In order to better explain and predict the potential influence of contextual cues conveyed through media portrayals of STEM professionals on adolescent girls' STEM identity formation, several theories of information processing and identity from various disciplines are presented below. Collectively, these theories (1) advance understanding of *how* and *when* specific characteristics of media models affect adolescent girls' STEM identity formation and (2) *how* and *when* variations in STEM identity status

TABLE 1 | Conceptual frameworks of science/STEM identity.

	Science identity model (Carlone and Johnson, 2007)	STEM identity model) Herrera et al., 2012)
Population examined	15 women of color successful in STEM careers	132 racially diverse STEM and non-STEM graduate students
Constructs and variables related to Science/STEM identity	– Competence – Performance – Recognition	– Competence – Performance – Recognition
Social identities considered	– Gender – Racial/ethnicity	– Gender – Race/ethnicity – Religion/spirituality – Mental/physical ability – Socioeconomic status – Sexual orientation – Culture – Nationality/immigration status
STEM identity status	Achievement – professional scientists with prior interest and commitment to STEM careers	Achievement – successful STEM graduate students
Science identity trajectories	– Research scientist – Altruistic scientist – Disrupted scientist	None specified
Factors promoting Science/STEM identity	Recognition by others in scientific community	(1) Recognition by others in scientific community related to – URM students' unique contribution to STEM – Links between URM students' social identities and STEM identities (2) Self-recognition
Influence of cues in sociocultural context	Not considered	Acknowledged, but not directly examined

and identity processing lead to differences in the influence of media models on adolescent girls during STEM identity formation.

THEORETICAL PERSPECTIVES ON PROCESSING GENDER STEREOTYPES OF STEM

As previously described in this review, research has examined gender-stereotyped portrayals of STEM professionals appearing in popular media and has considered the potential influence of these media images on adolescent girls' perceptions of STEM professionals and STEM careers. Few studies, however, have examined specifically *how* and *when* these media images are most likely to exert influence or have considered *individual differences* in audience members' processing of these media images. Several theories of information processing and identity are described below in order to better explain the potential influence of media images of STEM professionals on adolescent girls' STEM identity formation.

Social Cognitive (Learning) Theory

Social cognitive theory, formerly social learning theory, explains *how* stereotypes in the media influence individuals' attitudes and behaviors. According to this theory, repeated observation of both actual models as well as symbolic models teaches cultural patterns of behaviors (Bandura, 1969, 1986). Social learning theory describes how children learn to imitate behaviors from others in their environments through the process of "identificatory learning" (Bandura et al., 1963, p. 533). Research dating back to the 1950s showed that viewers identified with film characters of the same sex and more accurately remembered the words and actions of characters with whom they identified (Maccoby and Wilson, 1957). This research also found that women were more likely than men to remember female characters who they perceived as important and more likely to remember the actions of female characters shown in romantic scenes (Maccoby and Wilson, 1957).

Social cognitive theory contributes to a broader understanding of *how* gender stereotypes of STEM professionals in popular media may affect adolescent girls' STEM identity formation in several important ways. First, it explains how vicarious exposure to media characters can lead to modeling the behavior of STEM characters in the media thereby influencing not only perceptions but also behavior. Second, social cognitive theory describes differences in the influence of media models based on specific characteristics or attributes of media models, such as the sex or other attributes of the media model. Social cognitive theory also suggests gender differences in how viewers are influenced by media models. Third, social cognitive theory indicates that individuals' identification with media models affects the extent of influence on individuals. *Thus, social cognitive theory suggests that media images of STEM* *professionals can be important models for adolescent girls and are most likely to influence adolescent girls when they share characteristics and traits perceived as similar or desirable by adolescent girls.*

Gender Schema Theory

Gender schema theory explains *how* networks of knowledge about gender, learned in part through identificatory learning, are developed and activated in children's memories (Bem, 1981). These networks or gender schemas are "cognitive structures that organize gender-related knowledge, beliefs, attitudes, and preferences" (Liben and Signorella, 1993). Gender schemas, just like other schemas, help children understand experiences and make decisions that influence their perceptions, beliefs, and behavior (Bem, 1993). Research suggests that portrayals of characters on television programs can shape and maintain gender schemas (Leaper et al., 2002), particularly if children identify with those characters (Miller and Reeves, 1976).

Gender schema theory contributes to a broader understanding of *how* and *when* gender stereotypes of STEM professionals in popular media may affect adolescent girls' STEM identity formation by emphasizing the dominant role of gender schemas during information processing. In societal contexts where gender is made salient (i.e., watching television programs or films that show images of female STEM professionals or that stereotype female STEM professionals), gender schemas may be more likely to be activated, becoming especially salient, dominant, important, and/or influential. One study noted that subtle contextual cues of incompatibility between gender and STEM, such as video games or posters or sci-fi movies that depict traditionally male interests, may pose a threat to gender-STEM compatibility (Cheryan et al., 2009). *Thus, gender schema theory suggests that female STEM professional media models may be especially salient for adolescent girls when they prioritize the processing of information about and from these models based on gender or when their gender schemas are activated.*

Social Identity Theory

Social identity theory explains *how* individuals negotiate and form an identity through multiple affiliations and disassociations with various social groups (Tajfel, 1978, 1982; Tajfel and Turner, 1979) as they strive to maintain a positive social identity through affiliation with in-groups rather than out-groups (Tajfel and Turner, 1979). According to this theory, "[s]ocial structures (e.g., of gender, class, 'race') thus play an important role in shaping the identities, choices, and aspirations that people perceive as possible and desirable" (Archer et al., 2012, p. 970). Individuals develop identity schemas, cognitive structures of "complex, rich, affectively charged, interrelated concepts about the self" (Korte, 2007, p. 168), that serve as "internal organizations of stored information and meanings operating as frameworks for interpreting experiences" (Stryker and Serpe, 1994, p. 18).

Social identity theory contributes to a broader understanding of *how* gender stereotypes of STEM professionals in the media may affect adolescent girls' STEM identity formation in a couple of important ways. First, social identity theory highlights the active role of individuals in maintaining varied social or group identities or in-group affiliations they most support (Burke and Reitzes, 1991; Stets and Burke, 2000). As adolescent girls contemplate their future careers, they actively negotiate multiple identities that include personal relationships, family roles, and cultural values (Thompson and Windschitl, 2005). Second, it acknowledges the importance and centrality of those particular identities to which an individual holds a strong commitment (Burke, 1991; Burke and Reitzes, 1991). Research shows that a central identity may change over time (Settles et al., 2009) and identity interference can occur from conflicting identities (Settles, 2004; Ahlqvist et al., 2013). *Social identity theory suggests that girls are most likely to identify with media models of female STEM professionals who they perceive belong to similar and/or desirable in-groups (i.e., gender, race, ethnicity, and other in-groups). This theory also suggest that girls are most likely to identify with media models of female STEM professionals when they view both themselves and females as part of or belonging to a STEM in-group. Additionally, this theory suggests that gender-stereotyped media models of STEM professionals may elicit identity interference for adolescent girls if exposure to these model leads them to perceive that a female gender identity and a STEM identity are incompatible.*

Possible Selves Theory

Possible selves theory describes *how* current and future representations of who one is and who one might become motivate behavior (Markus and Nurius, 1986) and "translate into life choices" (Lips, 2007, p. 51). According to this theory, an individual's self-concept "is viewed as a system of affective-cognitive structures or schemas about one's self" (Markus and Nurius, 1986, p. 955). Self-concepts include an individual's perceptions of their possible selves (Markus and Nurius, 1986). Possible selves correspond to both current representations of who one is as well hypothetical images of who one might become in the future (Strahan and Wilson, 2006). Possible selves present both hoped for and feared representations of self (Markus and Nurius, 1986). Possible selves are influential because they motivate behavior related to life goals (Markus and Nurius, 1986; Strahan and Wilson, 2006), such as academic achievement (Oyserman et al., 2004), career aspirations (Markus and Nurius, 1986), and future career selection (Lips, 2007). Research also has found that possible selves and strategies to attain particular possible selves are sensitive to contextual cues that can make stereotypes more accessible and salient (Bi and Oyserman, 2015).

Possible selves theory contributes to a broader understanding of *how* gender stereotypes of STEM professionals in the media may affect adolescent girls STEM identity formation in a couple of ways. First, it highlights how media models might inspire both current and future representations of one's self. Second, it emphasizes that media models representing hoped-for future selves can motivate behavior related to career aspirations. Adolescent girls' development of possible selves based on cultural representations of gender conveyed by media portrayals of STEM professionals also may motivate behavior related to pursing STEM careers and may affect STEM identity. *Possible selves theory suggest that gender-stereotyped media models of STEM professionals present images of potential, possible selves. The ways female STEM professionals are portrayed by media models may influence whether adolescent girls view these models as hoped-for or feared-possible selves and whether they inspire to a future career in STEM.*

Ego Identity Formation Theory and Identity Status

Ego identity formation theory emphasizes *when* gender stereotypes of STEM professionals in the media are most likely to affect adolescent girls' STEM identity formation. Ego identity formation theory describes the psychological processing or *exploration* of particular components of identity (gender, race, ethnicity, etc.) that eventually leads to commitment to a specific component identity (Erikson, 1968; Umana-Taylor et al., 2004). Erikson (1968) describes identity formation as a mostly unconscious "process of simultaneous reflection and observation, a processing taking place on all levels of mental function" (p. 22). Research shows that conceptions of identities are always changing because they are reflexive (Stets and Burke, 2000), dynamic (Wieland, 2010; Ahlqvist et al., 2013) and not "just states or traits of an individual that are relatively fixed" (Burke and Reitzes, 1991, p. 847). Identity is developed through exploration and commitment across a variety of identity domains, including vocational or occupational choice (Erikson, 1968; Umana-Taylor et al., 2004).

Extending Erikson's theory, Marcia (1994) classified individuals according to one of four identity statuses based on the degree of *exploration and commitment* (Marcia, 1994) during decision making. *Moratorium identity status* describes those who have explored but not yet committed to an identity (Marcia, 1994). *Diffuse identity status* describes those who have not yet explored and not committed to an identity (Marcia, 1994). *Foreclosed identity status* describes those who have not explored, instead accepting others' choices as their own, and have committed to an identity (Marcia, 1994). *Achieved identity status* describes those who have both explored and committed to an identity (Marcia, 1994).

Ego identity theory and identity status theory contribute to a broader understanding of *when* gender stereotypes of STEM professionals in the media may affect adolescent girls STEM identity development in two important ways. First, these theoretical perspectives acknowledge an individual's active consideration of a STEM identity based on the degree of exploration and commitment to that identity. Second, these theoretical perspectives outline two critical conditions (STEM exploration plus STEM commitment) needed for achievement of a STEM identity (**Figure 1**). *Ego identity theory and identity status theory suggest that gender-stereotyped media models of STEM professionals are most likely to be influential for adolescent girls who are actively exploring a STEM identity and may not be as influential for adolescent girls who have already committed to a STEM identity.*

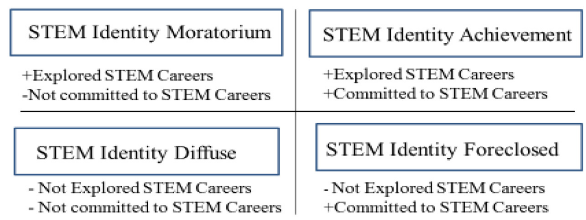

FIGURE 1 | Science identity status based on Marcia's (1980) identity status theory.

Identity-Based Motivation Theory

Identity-based motivation theory describes both *how* and *when* people's current and active identities motivate their behavior based on the ways in which contextual cues actively shape identity in a particular context (Oyserman, 2014, 2015a). According to identity-based motivation theory, (1) contextual cues trigger identities that are dynamically constructed and determine which personal and social identities are perceived as most accessible in that moment, (2) accessible identities influence action-readiness based on perceived necessity and relevance, and (3) activated, accessible identities influence behavior depending on perceptions of difficulty (Oyserman, 2014, 2015a,b). The premise of identity-based motivation theory is that "thinking is influenced by the context in which it occurs" (Oyserman, 2015a, p. 2). Identity-based motivation theory focuses on the underlying process for determining the circumstances in which aspects of identity matter for behavior perceived to be difficult (Oyserman, 2015b).

Identity-based motivation theory contributes to a broader understanding of both *how* and *when* gender stereotypes of STEM professionals in the media may affect adolescent girls STEM identity formation in a number of important ways. First, it highlights the dynamic, changing nature of identity. Second, it considers how contextual cues – described as "features in the environment" (Oyserman, 2015a, p. 2) – influence identity and directly trigger "what comes to mind when people consider who they are" (Oyserman, 2015a, p. 2). Third, it describes how specific identities are accessed and then influence action based on perceptions of necessity and relevance. Fourth, it explains how activated identities motivate behavior depending on perceptions of how difficult the behavior is (Oyserman, 2015b). *Identity-based motivation theory provides a more comprehensive and considered approach to understanding the potential influence of gender-stereotyped media models of STEM professionals on adolescent girls' STEM identity. Specifically, this theory suggests that media models are most likely to influence adolescent girls who are actively exploring a STEM identity and are likely to exert influence when they trigger or make accessible a STEM identity and when adolescent girls perceive behaviors related to achieving a STEM identity as necessary and relevant to them and not too difficult to achieve.*

A summary of potential media model effects on identity formation as described by these theories are presented in **Table 2**.

TABLE 2 | Theories describing potential model influence related to identity formation.

	Social cognitive theory	Gender schema theory	Social identity theory	Possible selves theory	Ego-identity theory/identity status theory	Identity-based motivation theory
Traits and attributes of models	Vicarious models, media models	Same-sex models	Same-social identity group models	Possible-self-models	—	Same-social identities models
Identity relevant characteristics of models	Similar; important; or desirable	Gender-compatible	In-group compatible	Hoped-for self, both current and future	—	Accessible and attainable (not too difficult)
Conditions for model influence	—	—	—	—	Degree of exploration and commitment to identity	Identity triggered by contextual cues; accessible; attainable
Type of model influence explained	How	How and When	How	How	When	How and When

The theories described above identify additional constructs and variables important for understanding *how* and *when* images of STEM professionals in popular media are most likely to influence STEM identity formation for adolescent girls. In order to better understand the influence of gender-stereotyped media images of STEM professionals on STEM identity, it is important to consider the ***STEM identity relevant variables*** perceived by adolescent girls and the ***STEM identity status*** of adolescent girls. As these theories have highlighted, the influence of media models of STEM professionals on adolescent girls' STEM identity will vary depending on (1) differences in media model characteristics, (2) differences in adolescent girls' perceptions of the psychological relevance of different traits and attributes of the models, (3) differences in adolescent girls' STEM identity status (degree of exploration and commitment), and (4) differences in adolescent girls' accessibility to a STEM identity and perceived attainability of behaviors related to STEM identity achievement. The implications for future theory development and research in this area are described in the section that follows.

EXTENDING CONCEPTUALIZATIONS OF STEM IDENTITY

Extant theories of information processing and identity offer useful insights for extending current conceptualizations of science/STEM identity. Current conceptualizations have identified several individual, social, and contextual factors that influence STEM identity (Carlone and Johnson, 2007; Herrera et al., 2012). However, extending these conceptual frameworks to include variables of potential influence related to the broader sociocultural context will further advance understanding of how gender-stereotyped images of STEM professionals can influence adolescent girls' STEM identity formation. Specifically, consideration of these variables highlights the importance of recognizing individual differences in perceptions of ***STEM identity relevant variables*** as well as individual differences in ***STEM identity status***. Drawing additional constructs and variables from the theories described above to extend current theoretical conceptualization of STEM identity not only helps better predict *how* and *when* contextual cues, including gender stereotypes, affect STEM identity achievement but also highlights the dynamic nature of STEM identity that is particularly pronounced during adolescence when STEM identity exploration is especially active. This extension of current conceptualizations of science/STEM identity has important implications for future research and practice.

The constructs and variables derived from extant theories of information processing and identity outlined in this review help provide a more comprehensive and nuanced conceptualization of STEM identity. As the theories described above suggest, understanding the potential influence of cultural representations of gender and STEM may potentially be particularly relevant for adolescent girls who frequently encounter gender-stereotyped media images of STEM professionals, who perceive these images to be salient, who perceive being female and STEM to be incompatible social identities, who have spent less time on STEM identity exploration, and who have not yet committed to a STEM identity. The section that follow discusses specific constructs drawn from the theories reviewed above and represents an initial step toward re-conceptualizing STEM identity to more fully develop an understanding of the potential influence of contextual cues on adolescent girls' STEM identity formation.

Differences in Media Model Characteristics

The creation of more and more diverse media models of female STEM professionals may be critical for challenging and changing the dominant masculine image of STEM professionals. Research has shown that female role models can have a positive impact, in particular, on adolescent girls' attitudes toward science (Evans et al., 1995) and their stereotyped perceptions of STEM professionals (Hughes et al., 2013). One study that focused on the influence of diverse, female role models for non-STEM-identified adolescent girls noted signs of more positive endorsement of a STEM identity, which was indirectly assessed based on changes in measures of STEM interest and science and math self-concepts (Hughes et al., 2013). While this research focused exclusively on the impact of real-life female role models in a STEM environment, specifically a STEM camp (Hughes et al., 2013), additional research needs to assess individual differences in identification with a diverse array of media models and examine how individual differences in identities, including differences in identity centrality for multiple salient identities, affect identification with media models. It is important to extend research that has argued for "matched role models" (Gilmartin et al., 2007, p. 984) and consider which specific characteristics of are models are most "psychologically relevant" (Lang, 2013) for adolescent girls. Future research should focus on the ***identity relevant characteristics*** of media models of female STEM professionals to further understanding of most effective strategies and interventions for promoting a STEM identity.

Extensions of conceptual framework of STEM identity to include the influence of contextual cues from media models would provide a broader understanding of the greater array of contextual cues on STEM identity formation. Media models provide "vicarious contact" (Fujioka, 1999) with STEM professionals when direct contact with real-life STEM professionals is lacking. However, little is known about how inspiring media images of STEM professionals that deviate from the prevailing stereotypical media images of STEM professionals might act as important role models for adolescent girls during science identity formation. Several theories of the theories reviewed above (social learning theory, gender schema theory, social identity theory) emphasize that specific attributes or characteristics of media models are important for assessing influences on STEM identity. Thus, future research focused on carefully controlled studies of specific media model attributes or characteristics (gender, race/ethnicity, perceived similarity, perceived desirability) and direct measures of STEM identity are important for advancing understanding of the potential influence of media models of STEM professionals on adolescent girls' STEM identity achievement.

Differences in Psychological Relevance of Media Model Characteristics

Existing conceptual frameworks of science/STEM identity recognize the importance of integrating a science/STEM identity with other social identities (Carlone and Johnson, 2007; Herrera et al., 2012). In seeking ways to promote the formation of a STEM identity for students, it is important to know how they "are engaging in science and how this is related to who they think they are (what communities of practice the participate in), e.g., good student, a basketball player, a gossip, and who they want to be (what communities practice they aspire to), e.g., a teacher, a mother, a gemologist, an obstetrician" (Brickhouse et al., 2000, p. 443). This research suggests that the social identities of media models matter and also are likely to influence STEM identity formation. Future research focused on a wider array of characteristics of media models related to their social identities is needed to determine which characteristics are most salient and most likely to affect change in STEM identity for adolescent girls.

Possible selves theories highlights unique differences in individuals' processing of information about possible identities in light of hoped for future selves and future goals. Additional research should not only examine which characteristics of media models of STEM professionals are most salient, but also which characteristics are most salient for different individuals with different future life and career goals. Differences related to individuals' backgrounds and experiences also need to be considered in order to describe variations in processing, interpretations, and effects of various media model characteristics. Communication scholar Annie Lang has argued for research that takes into account the "psychologically relevant characteristics" (Lang, 2013, p. 19) of media content. Advancing conceptual understanding of the influence of contextual cues on STEM identity will require research that considers the psychological relevance of a diverse array of characteristics of media models related to the ***STEM identity relevant variables*** of the media models.

Differences in STEM Identity Status and Potential Influence of Media Models

Current conceptual frameworks of science/STEM identity have focused primarily on individuals *committed to or in the process of committing* to a STEM identity (Carlone and Johnson, 2007; Herrera et al., 2012). This focus on STEM-identified individuals has been helpful in identifying factors, such as recognition by others in the scientific community and recognition of other social identities, found to be important for the achievement of a STEM identity. Extending this work by considering how non-STEM-identified individual currently *exploring* and who have yet to commit to a STEM identity is needed to determine factors that impede or hinder the achievement of a STEM identity. *Science identity* has been described as an "evolving construct" that "falls along a continuum – or multiple continuums, different for different groups of students with different sets of experiences and contexts" (Gilmartin et al., 2007, p. 982). However, relatively few studies have considered science/STEM identity as a continuous variable based on individual differences in the degree of exploration and commitment to a STEM identity or individual differences in STEM identity status (Perez et al., 2013). This approach is particularly important when assessing STEM identity formation for non-STEM identified (or non-STEM committed) individuals and for individuals like adolescents who are undergoing a particularly active period of identity exploration.

Ego identity theory and identity status theory explain that individuals exhibit one of four possible STEM identity statuses depending on their exploration of and commitment to a STEM identity (**Figure 1**). Future research assessing the influence of contextual cues on STEM identity formation need to focus on the dynamic, fluctuating nature of identity and specifically how differences in the degree of STEM identity exploration and commitment moderate the potential influence of these contextual cues. STEM-committed compared to non-STEM-committed adolescent girls may be less likely to be influenced by gendered stereotyped media images of STEM professionals. Future research needs to assess STEM identity status and differences in STEM identity status and how it varies over time using longitudinal studies that advance understanding of changes in STEM identity during different developmental stages.

Differences in Accessing and Perceptions of Attainment and Difficulty of a STEM Identity

Current conceptual frameworks of science/STEM identity have focused on identifying specific dimensions of STEM identity and specific factors related to STEM identity formation (Carlone and Johnson, 2007; Herrera et al., 2012) but have left relatively unexplored individuals' management of a STEM identity and the ways in which STEM identity motivates STEM-related behaviors like taking STEM courses, selecting a STEM major, and choosing a STEM career. A better understanding of the motivations for engaging in identity work will help better predict how a STEM identity is enacted.

Identity-based motivation theory describes how identity can motivate such behavior. Identity-based motivation theory suggests how media models might trigger or make accessible a STEM identity – and influence their impact (perceived attainability, perceived difficulty) in motivating behavior during STEM identity formation. Future research needs to focus on how contextual cues like media models trigger a STEM identity and influence perceptions of attainability and difficulty of STEM-related behaviors for adolescent girls.

Research dating back to the mid-1990s has focused on science or STEM identity as critical for broadening participation in STEM (for a review of research published between 1995 and 2006, see Brotman and Moore, 2008). Additional meta analyses of this literature and additional testing of constructs and variables identified from existing theories as well as new research related to other constructs and variables that may influence STEM identity will do much to advance current conceptualizations of STEM identity. Further consideration of how to define the concept of science/STEM identity is needed and will facilitate the development and use of more direct and consistent operationalizations to assess science/STEM identity. Current conceptualizations of science/STEM identity position science/STEM identity as a collective construct for all science or STEM disciplines; however, STEM identity formation may not necessarily involve the same constructs and variables, follow the same process, or manifest identity status in the same ways for each specific STEM discipline (see, for example, Hazari et al., 2010 for an explication of a physics identity framework that adds *interest* as an additional construct or variable). It may be necessary to consider a multitude of identity statuses that vary by science identity, technology identity, engineering identity, and mathematics identity and consider the degree of exploration and commitment for each of these – individual – STEM identities. Specifically, a STEM identity may not be the same across all STEM fields. Identity as related to the array of possible and multiple STEM identities may differ in several important yet to be determined ways.

CONCLUSION

Expanding current conceptualizations of STEM identity to consider individual differences in perceptions of ***STEM identity relevant variables*** and by ***STEM identity status*** (the degree of exploration and commitment to a STEM identity) offers promising directions to advance theory, research, and practice related to broadening the participation of girls and women in STEM. Closing the gender gap in low participation STEM fields is critical not only for achieving equity in society (Laughter and Adams, 2012) but also for advancing innovative ideas and approaches needed to ensure future economic progress and competitiveness (Rosser, 2012). An array of factors at home, in schools, and in media contribute many different constructs and variables that collectively may have different effects at different times and in different contexts for individuals of different backgrounds, experiences, perspectives, personalities, and identities. Expanding current conceptualizations of science/STEM identity to consider *how* and *when* contextual cues in the sociocultural environment affect STEM identity may be particularly useful for developing a more comprehensive and nuanced approach to understanding STEM identity.

Additional theoretical reconceptualization of STEM identity and future research focused on a wider array of relevant contexts in which STEM identity work is enacted will aid in developing a more comprehensive theoretical framework in several ways. First, additional research employing multiple and varied methodologies and longitudinal studies will provide insights about the many constructs and variables at the individual, social, and broader sociocultural levels as well as at the intersections of these different levels of analysis. Second, research that considers variations related to ***STEM identity relevant variables*** will help determine the most salient variables related to STEM identity for various populations. Third, in order to advance understanding of the dynamic nature of STEM identity formation, future research focused on variations in ***STEM identity status*** will help determine differences in the influence of constructs and variables based on fluctuations in STEM identity. Collectively, this research will help determine best practices and the most effective interventions for broadening the participation of girls and young women in a variety of different contexts related to STEM.

This review draws from several extant theories of information processing and identity to describe the potential influence of cues from the sociocultural context (i.e., gender stereotypes of STEM professionals) on STEM identity formation. Greater consideration of *how* and *when* contextual cues conveyed through images of STEM professionals in popular media might affect STEM identity formation offers new insights to extend existing conceptual theoretical frameworks of science/STEM identity and advance understanding of STEM identity formation for adolescent girls. Identifying factors that help explain how long-held, gender stereotypes of STEM professionals derived from popular media may shape STEM identity can better inform effective interventions specifically those intended for non-STEM identified adolescent girls. Researchers have argued that how girls "describe personal relevance when they are engaged across different contexts relevant to their identities" (Thompson and Windschitl, 2005, p. 18) is dependent on their (1) perceptions of who they are, (2) who they are becoming in the future, and (3) personal relationships with family and friends (Thompson and Windschitl, 2005). Future theoretically driven research in this area may be especially important for developing a deeper understanding of adolescent girls' STEM identity formation when they encounter contextual cues transmitted by popular media that promote a masculine image of STEM professionals who adolescent girls dismiss as not relevant and describe as just "not like me" (MacDonald, 2014).

AUTHOR CONTRIBUTIONS

The author confirms being the sole contributor of this work and approved it for publication.

FUNDING

Funding for this research was provided by a College of Arts and Sciences Discovery and Dissemination Award (CDD), a Preparation and Publication of Papers, and Exhibition of Creative Works (PPP&E) award, and support from the School of Communication at Western Michigan University.

REFERENCES

Ahlqvist, S., London, B., and Rosenthal, L. (2013). Unstable identity compatibility: how gender rejection sensitivity undermines the success of women in science, technology, engineering, and mathematics fields. *Psychol. Sci.* 24, 1644–1652. doi: 10.1177/0956797613476048

American Association of University Women (2000). *Tech-savvy: Education Girls in the New Computer Age*. Washington, DC: AAUW Educational Foundation.

American Association of University Women (2015). *Solving the Equation: The Variables for Women's Success in Engineering and Computing*. Washington, DC: American Association University Women.

Archer, L., Dewitt, J., Osborne, J., Dillon, J., Willis, B., and Wong, B. (2012). "Balancing Acts": elementary school girls' negotiation of femininity, achievement, and science. *Sci. Educ.* 96, 967–989. doi: 10.1002/sce.21031

Bandura, A. (1969). "Social-learning theory of identificatory processes," in *Handbook of Socialization Theory and Research*, ed. D. A. Goslin (Chicago, IL: Rand McNally College Publishing Company), 213–262.

Bandura, A. (1986). *Social Foundations of Thought and Action: A Social Cognitive Theory*. Englewood Cliffs, NJ: Prentice-Hall.

Bandura, A., Ross, D., and Ross, S. A. (1963). A comparative test of the status envy, social power, and secondary reinforcement theories of identificatory learning. *J. Abnorm. Soc. Psychol.* 67, 527–534. doi: 10.1037/h0046546

Barman, C. R. (1996). How do students really view science and scientists? *Sci. Child.* 34, 30–33.

Barman, C. R. (1999). Completing the study: high school students' views of scientists and science. *Sci. Child* 36, 16–21.

Bem, S. L. (1981). Gender schema theory: a cognitive account of sex typing. *Psychol. Rev.* 88, 354–364. doi: 10.1037/0033-295X.88.4.354

Bem, S. L. (1993). *The Lenses of Gender: Transforming the Debate on Sexual Identity*. New Haven, CT: Yale University Press.

Bergman, K. (2012). Girls just wanna be smart? The depiction of women scientists in contemporary crime fiction. *Int. J. Gen. Sci. Technol.* 4, 313–329.

Bi, C., and Oyserman, D. (2015). Left behind or moving forward? Effects of possible selves and strategies to attain them among rural Chinese children. *J. Adolesc.* 44, 245–258. doi: 10.1016/j.adolescence.2015.08.004

Blickenstaff, J. C. (2005). Women and science careers: leaky pipeline or gender filter? *Gen. Educ.* 17, 369–386. doi: 10.1080/09540250500145072

Brickhouse, N., Lowery, P., and Schultz, K. (2000). What kind of girl does science? The construction of school science identities. *J. Res. Sci. Teach.* 37, 441–458. doi: 10.1002/(SICI)1098-2736(200005)37:5<441::AID-TEA4>3.0.CO;2-3

Brickhouse, N., and Potter, J. T. (2001). Young women's scientific identity formation in an urban context. *J. Res. Sci. Teach.* 38, 965–980. doi: 10.1002/tea.1041

Brotman, J. S., and Moore, F. M. (2008). Girls and science: a review of four themes in the science education literature. *J. Res. Sci. Teach.* 45, 971–1002. doi: 10.1002/tea.20241

Buck, G. A., Clark, V. L. P., Leslie-Pelecky, D., Lu, Y., and Cerda-Lizarraga, P. (2008). Examining the cognitive processes used by adolescent girls and women scientists in identifying science role models: a feminist approach. *Sci. Educ.* 92, 688–707. doi: 10.1002/sce.20257

Burke, P. J. (1991). Identity processes and social stress. *Am. Sociol. Rev.* 56, 836–849. doi: 10.2307/2096259

Burke, P. J., and Reitzes, D. C. (1991). An identity theory approach to commitment. *Soc. Psychol. Q.* 54, 239–251. doi: 10.2307/2786653

Camcı-Erdoğan, S. (2013). Gifted and Talented Students' Images of Scientists. *Turk. J. Giftedness Educ.* 3, 13–37.

Carli, L. L., Alawa, L., Lee, Y., Zhao, B., and Kim, E. (2016). Stereotypes about Gender and science: women $\neq$ scientists. *Psychol. Women Q.* 40, 244–260. doi: 10.1177/0361684315622645

Carlone, H. B., and Johnson, A. (2007). Understanding the science experiences of women of color: science identity as an analytic lens. *J. Res. Sci. Teach.* 44, 1187–1218. doi: 10.1002/tea.20237

Ceglie, R. (2011). Underrepresentation of women of color in the science pipeline: the construction of science identities. *J. Women Minor. Sci. Eng.* 17, 271–293. doi: 10.1615/JWomenMinorScienEng.2011003010

Chandler, M. A. (2012). *Women at Forefront of Booming Forensic Science Field*. Available at: https://www.washingtonpost.com/lifestyle/magazine/women-at-forefront-of-booming-forensic-science-field/2012/07/27/gJQAkASRPX_story.html

Chemers, M. M., Zurbriggen, E. L., Syed, M., Goza, B. K., and Bearman, S. (2011). The role of efficacy and identity in science career commitment among underrepresented minority students. *J. Soc. Issues* 67, 469–491. doi: 10.1111/j.1540-4560.2011.01710.x

Cheryan, S., Master, A., and Meltzoff, A. N. (2015). Cultural stereotypes as gatekeepers: increasing girls' interest in computer science and engineering by diversifying stereotypes. *Front. Psychol.* 6:49. doi: 10.3389/fpsyg.2015.00049

Cheryan, S., Plaut, V. C., Davies, P. G., and Steele, C. M. (2009). Ambient belonging: how stereotypical cues impact gender participation in computer science. *J. Pers. Soc. Psychol.* 97, 1045–1060. doi: 10.1037/a0016239

Cheryan, S., Plaut, V. C., Handron, C., and Hudson, L. (2013). The stereotypical computer scientist: gendered media representations as a barrier to inclusion for women. *Sex Roles* 69, 58–71. doi: 10.1007/s11199-013-0296-x

Christidou, V., Bonoti, F., and Kontopoulou, A. (2016). American and greek children's visual images of scientists: enduring or fading stereotypes? *Sci. Educ.* 25, 497–522. doi: 10.1007/s11191-016-9832-8

Clewell, B. C., and Campbell, P. B. (2002). Taking stock: where we've been, where we are, where we're going. *J. Women Minor. Sci. Eng.* 8, 255–284. doi: 10.1615/jwomenminorscieneng.v8.i3-4.20

Congressional Commission on the Advancement of Women and Minorities in Science Engineering and Technology Development (2000). *Land of Plenty: Diversity as America's Competitive Edge in Science, Engineering and Technology*.

Washington, DC: Congressional Commission on the Advancement of Women and Minorities in Science Engineering and Technology Development.

Dhingra, K. (2006). Science on television: storytelling, learning and citizenship. *Stud. Sci. Educ.* 42, 89–124. doi: 10.1080/03057260608560221

Dudo, A., Brossard, D., Shanahan, J., Scheufele, D. A., Morgan, M., and Signorielli, N. (2011). Science on television in the 21st century: recent trends in portrayals and their contributions to public attitudes toward science. *Commun. Res.* 38, 754–777. doi: 10.1177/0093650210384988

Elena, A. (1993). Exemplary lives: biographies of scientists on the screen. *Public Underst. Sci.* 2, 205–223. doi: 10.1088/0963-6625/2/3/002

Elena, A. (1997). Skirts in the lab: Madame Curie and the image of the woman scientist in the feature film. *Public Underst. Sci.* 6, 269–278. doi: 10.1088/0963-6625/6/3/005

Erikson, E. H. (1968). *Identity: Youth and Crisis*. New York, NY: Norton.

Evans, M. A., Whigham, M., and Wang, M. C. (1995). The effect of a role model project upon the attitudes of ninth-grade science students. *J. Res. Sci. Teach.* 32, 195–204. doi: 10.1002/tea.3660320208

Farkas, T., and Leaper, C. (2016). Chivalry's double-edged sword: how girls' and boys' paternalistic attitudes relate to their possible family and work selves. *Sex Roles* 74, 220–230. doi: 10.1007/s11199-015-0556-z

Finson, K. D. (2003). Applicability of the DAST-C to the images of scientists drawn by students of different racial groups. *J. Elem. Sci. Educ.* 15, 15–26. doi: 10.1007/BF03174741

Flicker, E. (2003). Between brains and breasts-women scientists in fiction film: on the marginalization and sexualization of scientific competence. *Public Underst. Sci.* 12, 307–318. doi: 10.1177/0963662503123009

Fort, D. C., and Varney, H. L. (1989). How students see scientists: mostly male, mostly white, and mostly benevolent. *Sci. Child.* 26, 8–13.

Fujioka, Y. (1999). Television portrayals and African-American stereotypes: examination of television effects when direct contact is lacking. *Journal. Mass Commun. Q.* 76, 52–75. doi: 10.1177/107769909907600105

Gamson, W. A., Croteau, D., Hoynes, W., and Sasson, T. (1992). Media images and the social construction of reality. *Annu. Rev. Sociol.* 18, 373–393. doi: 10.1016/S0013-7006(10)70014-2

Gamson, W. A., and Modigliani, A. (1987). "The changing culture of affirmative action," in *Research in Political Sociology*, Vol. 3, eds R. G. Braungart and M. M. Braungart (Greenwich, CT: JAI), 137–177.

Gee, J. P. (2001). Identity as an analytic lens for research in education. *Rev. Res. Educ.* 25, 99–125.

Gilmartin, S., Denson, N., Li, E., Bryant, A., and Aschbacher, P. (2007). Gender ratios in high school science departments: the effects of percent female faculty on multiple dimensions of students' science identities. *J. Res. Sci. Teach.* 44, 980–1009. doi: 10.1002/tea.20179

Gitlin, T. (1980). *The Whole World is Watching*. Berkeley: University of California Press.

Goffman, E. (1974). *Frame Analysis: An Essay on the Organization of Experience*. Boston, MA: Northeastern University Press.

Google-Gallup (2015). *Images of Computer Science: Perceptions Among Students, Parents and Educators in the U.S.* Gallup, NM: Google-Gallup.

Hammack, R., and High, K. (2014). Effects of an after school engineering mentoring program on middle school girls' perceptions of engineers. *J. Women Minor. Sci. Eng.* 20, 11–20. doi: 10.1615/JWomenMinorScienEng.2014006726

Hazari, Z., Sadler, P. M., and Sonnert, G. (2013). The science identity of college students: exploring the intersection of gender, race, and ethnicity. *J. Coll. Sci. Teach.* 42, 82–91.

Hazari, Z., Sonnert, G., Sadler, P. M., and Shanahan, M.-C. (2010). Connecting high school physics experiences, outcome expectations, physics identity, and physics career choice: a gender study. *J. Res. Sci. Teach.* 47, 978–1003. doi: 10.1002/tea.20363

Herrera, F. A., Hurtado, S., Garcia, G. A., and Gasiewski, J. (2012). A model for redefining STEM identity for talented STEM graduate students. *Paper Presented at the American Educational Research Association Annual Conference*, Vancouver, BC.

Hoffner, C., Levine, K. J., Sullivan, Q. E., Crowell, D., Pedrick, L., and Berndt, P. (2006). TV characters at work: television's role in the occupational aspirations of economically disadvantaged youths. *J. Career Dev.* 33, 3–18. doi: 10.1177/0894845305282768

Hoffner, C., Levine, K. J., and Toohey, R. A. (2008). Socialization to work in late adolescence: the role of television and family. *J. Broadcast. Electron. Media* 52, 282–302. doi: 10.1080/08838150801992086

Hornig, S. (1990). Television's NOVA and the construction of scientific truth. *Crit. Stud. Mass Commun.* 7, 11–23. doi: 10.1080/15295039009360160

Huber, R. A., and Burton, G. M. (1995). What do students think scientists look like? *Sch. Sci. Math.* 95, 371–376. doi: 10.1111/j.1949-8594.1995.tb15804.x

Hughes, G. (2001). Exploring the availability of student scientist identities within curriculum discourse: an anti-essentialist approach to gender-inclusive science. *Gen. Educ.* 13, 275–290. doi: 10.1080/09540250120063562

Hughes, R. M., Nzekwe, B., and Molyneaux, K. J. (2013). The single sex debate for girls in science: a comparison between two informal science programs on middle school students' STEM identity formation. *Res. Sci. Educ.* 43, 1979–2007. doi: 10.1007/s11165-012-9345-7

Jones, S. R., and McEwen, M. K. (2000). A conceptual model of multiple dimensions of identity. *J. Coll. Stud. Dev.* 41, 405–414.

Kelly, A. (1985). The construction of masculine science. *Br. J. Sociol. Educ.* 6, 133–154. doi: 10.1080/0142569850060201

Kessels, U. (2015). Bridging the gap by enhancing the fit: how stereotypes about STEM clash with stereotypes about girls. *Int. J. Gen. Sci. Technol.* 7, 280–296.

Kirby, D. A. (2011). *Lab Coats in Hollywood: Science, Scientists, and Cinema*. Cambridge: The MIT Press.

Knight, M., and Cunningham, C. (2004). Draw an engineer test (DAET): development of a tool to investigate students' ideas about engineers and engineering. *Paper presented at the Proceedings of the 2004 American Society for Engineering Education Annual Conference & Exposition*, Salt Lake City, UT.

Korte, R. F. (2007). A review of social identity theory with implications for training and development. *J. Eur. Ind. Train.* 31, 166–180. doi: 10.1108/03090590710739250

LaFollette, M. C. (2013). *Science on American Television: A History*. Chicago, IL: University of Chicago Press.

Lang, A. (2013). Discipline in crisis? the shifting paradigm of mass communication research. *Commun. Theory* 23, 10–24. doi: 10.1111/comt.12000

Laubach, T. A., Crofford, G. D., and Marek, E. A. (2012). Exploring native american students' perceptions of scientists. *Int. J. Sci. Educ.* 34, 1769–1794. doi: 10.1080/09500693.2012.689434

Laughter, J. C., and Adams, A. D. (2012). Culturally relevant science teaching in middle school. *Urban Educ.* 47, 1106–1134. doi: 10.1177/0042085912454443

Leaper, C., Breed, L., Hoffman, L., and Perlman, C. A. (2002). Variations in the gender-stereotyped content of children's television cartoons across genres. *J. Appl. Soc. Psychol.* 32, 1653–1662. doi: 10.1111/j.1559-1816.2002.tb02767.x

Lee, J. D. (1998). Which kids can "become" scientists? Effects of gender, self-concepts, and perceptions of scientists. *Soc. Psychol. Q.* 61, 199–219. doi: 10.2307/2787108

Liben, L. S., and Signorella, M. L. (1993). Gender-schematic processing in children: the role of initial interpretations of stimuli. *Dev. Psychol.* 29, 141–149. doi: 10.1037/0012-1649.29.1.141

Lips, H. M. (1995). Through the lens of mathematical/scientific self-schemas: images of students' current and possible selves. *J. Appl. Soc. Psychol.* 25, 1671–1699. doi: 10.1111/j.1559-1816.1995.tb01812.x

Lips, H. M. (2007). Gender and possible selves. *New Dir. Adult Contin. Educ.* 114, 51–59. doi: 10.1002/ace.256

Long, M., Boiarsky, G., and Thayer, G. (2001). Gender and racial counter-stereotypes in science education television: a content analysis. *Public Underst. Sci.* 10, 255–269. doi: 10.1088/0963-6625/10/3/301

Long, M., Steinke, J., Applegate, B., Lapinski, M. K., Johnson, M. J., and Ghosh, S. (2010). Portrayals of male and female scientists in televised programs popular among middle school-age children. *Sci. Commun.* 32, 356–382. doi: 10.1177/1075547009357779

Maccoby, E. E., and Wilson, W. C. (1957). Identification and observational learning from films. *J. Abnorm. Soc. Psychol.* 53, 76–87. doi: 10.1037/h0043015

MacDonald, A. (2014). *STEM-identity: Why Have We Spent 30 Years Getting it Wrong?* Available at: http://www.ncub.co.uk/blog/stem-identity.html

Maoldomhnaigh, M. O., and Mhaolain, V. N. (1990). The perceived expectation of the administrator as a factor affecting the sex of scientists drawn by early adolescent girls. *Res. Sci. Technol. Educ.* 8, 69–74. doi: 10.1080/0263514900080106

Marcia, J. E. (ed.) (1980). *Identity in Adolescence*. New York, NY: Wiley.
Marcia, J. E. (1994). "The empirical study of ego identity," in *Identity and Development: An Interdisciplinary Approach*, 4th Edn, eds H. A. Bosma, T. G. Graafsma, H. D. Grotevan, and D. J. D. Levita (Belmont, CA: Wadsworth).
Markus, H., and Nurius, P. (1986). Possible selves. *Am. Psychol.* 41, 954–969. doi: 10.1037/0003-066X.41.9.954
Maugh, T. H. (1978). The media: the image of the scientist is bad. *Science* 200:37. doi: 10.1126/science.200.4337.37
Mead, M., and Metraux, R. (1957). Image of scientist among high-school students. *Science* 126, 384–390. doi: 10.1126/science.126.3270.384
Mercier, E. M., Barron, B., and O'Connor, K. M. (2006). Images of self and others as computer users: the role of gender and experience. *J. Comput. Assist. Learn.* 22, 335–348. doi: 10.1111/j.1365-2729.2006.00182.x
Miller, M. M., and Reeves, B. (1976). Dramatic TV content and children's sex-role stereotypes. *J. Broadcast.* 20, 35–50. doi: 10.1080/08838157609386373
Monhardt, R. M. (2003). The image of the scientist through the eyes of Navajo children. *J Am. Indian Educ.* 42, 25–39.
Moreno, C. S. (2014). *Hollywood's War on Science*. New York, NY: The Huffington Post.
National Science Foundation (2015). *Women, Minorities, and Persons with Disabilities in Science and Engineering: 2015*. Arlington, VA: National Science Foundation.
O'Brien, L. T., Blodorn, A., Adams, G., Garcia, D. M., and Hammer, E. (2015). Ethnic variation in gender-STEM stereotypes and STEM participation: an intersectional approach. *Cultur. Divers. Ethnic. Minor. Psychol.* 21, 169–180. doi: 10.1037/a0037944
Oyserman, D. (2014). "Identity-based motivation: core processes and intervention examples," in *Motivational Interventions: Advances in Motivation and Achievement*, Vol. 18, eds S. Karabenick and T. C. Urdan (Bingley: Emerald Group Publishing Ltd), 213–242.
Oyserman, D. (2015a). "Identity-based motivation," in *Emerging Trends in the Social and Behavioral Sciences*, eds R. Scott and S. Kosslyn (Hoboken, NJ: John Wiley & Sons), 1–11.
Oyserman, D. (2015b). *Pathways to Success Through Identity-Based Motivation*. Oxford: Oxford University Press.
Oyserman, D., Bybee, D., Terry, K., and Hart-Johnson, T. (2004). Possible selves as roadmaps. *J. Res. Pers.* 38, 130–149. doi: 10.1016/S0092-6566(03)00057-6
Packard, B. W.-L., and Wong, E. D. (1999). "Future images and women's career decisions in science," in *Paper Presented at the Annual Meeting of the American Educational Research Association*, Montreal, QC.
Parsons, E. C. (1997). Black high school females' images of the scientist: expression of culture. *J. Res. Sci. Teach.* 34, 745–768. doi: 10.1002/(SICI)1098-2736(199709)34:7<745::AID-TEA5>3.0.CO;2-M
Perez, T., Cromley, J. G., and Kaplan, A. (2013). The role of identity development, values, and costs in college STEM retention. *J. Educ. Psychol.* 106, 315–329. doi: 10.1037/a0034027
Polman, J. L., and Miller, D. (2010). Changing stories: trajectories of identification among African American youth in a science outreach apprenticeship. *Am. Educ. Res. J.* 47, 879–918. doi: 10.3102/0002831210367513
Potter, D. (2008). *CSI Effect' Draws more Women into Science [Electronic Version]*. Available at: http://www.nbcnews.com/id/26219249/ns/technology_and_science-science/t/csi-effect-draws-more-women-forensics/#.WA4ey8kg1qo
Riegle-Crumb, C., Moore, C., and Ramos-Wada, A. (2011). Who wants to have a career in science or math? Exploring adolescents' future aspirations by gender and race/ethnicity. *Sci. Educ.* 95, 458–476. doi: 10.1002/sce.20431
Robinson, D. (1976). Scientists of the silver screen: stolid starry-eyed humanitarians or dangerous demented doctors? *New Sci.* 23, 732–734.
Robnett, R. D., and Leaper, C. (2013). Friendship groups, personal motivation, and gender in relation to high school students'. *STEM Career Interest. J. Res. Adolesc.* 23, 652–664. doi: 10.1111/jora.12013
Rosser, S. V. (2012). *Breaking into the Lab: Engineering Progress for Women in Science*. New York, NY: New York University Press. doi: 10.18574/nyu/9780814776452.001.0001
Sainz, M., Meneses, J., Fabregues, S., and Lopez, B. (2016). Adolescents' gendered portrayals of occupations in the field of information and communication technologies. *Int. J. Gen. Sci. Technol.* 8, 181–201.
Scherz, Z., and Oren, M. (2006). How to change students' images of science and technology. *Sci. Educ.* 90, 965–985. doi: 10.1187/cbe.12-06-0091
Settles, I. H. (2004). When multiple identities interfere: the role of identity centrality. *Pers. Soc. Psychol. Bull.* 30, 487–500. doi: 10.1177/0146167203261885
Settles, I. H., Jellison, W. A., and Pratt-Hyatt, J. S. (2009). Identification with multiple social groups: the moderating role of identity change over time among women-scientists. *J. Res. Pers.* 43, 856–867. doi: 10.1016/j.jrp.2009.04.005
She, H.-C. (1995). Elementary and middle school students' image of science and scientists related to current science textbooks in Taiwan. *J. Sci. Educ. Technol.* 4, 283–294. doi: 10.1007/BF02211260
Signorielli, N. (1993). Television and adolescents' perceptions about work. *Youth Soc.* 24, 314–341. doi: 10.1177/0044118X93024003004
Sjoberg, S. (2000). *Science and Scientists: The SAS-Study: Cross-Cultural Evidence and Perspectives on Pupils' Interests, Experiences and Perceptions*. Oslo: University of Oslo.
Smith, S. L., Choueiti, M., and Pieper, K. (2014). *Gender Bias without Borders: An Investigation of Female Characters in Popular Films Across 11 Countries*. Los Angeles, CA: University of Southern California.
Solomon, J. (1997). Girls' science education: choice, solidarity and culture. *Int. J. Sci. Educ.* 19, 407–417. doi: 10.1080/0950069970190404
Song, J., and Kim, K.-S. (1999). How Korean students see scientists: the images of the scientist. *Int. J. Sci. Educ.* 21, 957–977. doi: 10.1080/095006999290255
Steinke, J. (1997). A portrait of a woman as a scientist: breaking down barriers created by gender-role stereotypes. *Public Underst. Sci.* 6, 409–428. doi: 10.1088/0963-6625/6/4/006
Steinke, J. (2003). Media images of women engineers and scientists and adolescent girls' conceptions of future roles. *Paper Presented at the WEPAN Conference*, Chicago, IL.
Steinke, J. (2005). Cultural representations of gender and science: portrayals of female scientists and engineers in popular films. *Sci. Commun.* 27, 27–63. doi: 10.1177/1075547005278610
Steinke, J., Lapinski, M., Crocker, N., Zietsman-Thomas, A., Williams, Y., Evergreen, S. H., et al. (2007). Assessing media influences on middle school-aged children's perceptions of women in science using the Draw-A-Scientist Test (DAST). *Sci. Commun.* 29, 35–64. doi: 10.1177/1075547007306508
Steinke, J., Lapinski, M., Long, M., VanDerMaas, C., Ryan, L., and Applegate, B. (2009). Seeing oneself as a scientist: media influences and adolescent girls' science career-possible selves. *J. Women Minor. Sci. Eng.* 15, 279–301. doi: 10.1615/JWomenMinorScienEng.v15.i4.10
Steinke, J., and Long, M. (1996). A lab of her own? Portrayals of female characters on children's educational science programs. *Sci. Commun.* 18, 91–115. doi: 10.1177/1075547096018002001
Steinke, J., and Tavarez, P. M. P. (2016). Cultural representations of gender and science: portrayals of female STEM professionals in popular films 2002-2015. *Paper Presented at the Association for Education in Journalism and Mass Communication*, San Francisco, CA.
Stets, J. E., and Burke, P. J. (2000). Identity theory and social identity theory. *Soc. Psychol. Q.* 63, 224–237. doi: 10.2307/2695870
Strahan, E. J., and Wilson, A. E. (2006). "Temporal comparisons, identity, and motivation: The relations between past, present, and possible future selves," in *Possible Selves: Theory, Research and Applications*, eds C. S. Dunkel and J. L. Kerpelman (New York, NY: Nova Science Publishers, Inc.).
Stryker, S., and Serpe, R. T. (1994). Identity salience and psychological centrality: equivalent, overlapping, or complementary concepts? *Soc. Psychol. Q.* 57, 16–35. doi: 10.2307/2786972
Tajfel, H. (1978). *Differentiation Between Social Groups: Studies in the Social Psychology of Intergroup Relations*. London: Academic Press.
Tajfel, H. (1982). Social psychology of intergroup relations. *Annu. Rev. Psychol.* 33, 1–39. doi: 10.1146/annurev.ps.33.020182.000245
Tajfel, H., and Turner, J. C. (1979). "An integrative theory of intergroup conflict," in *The Social Psychology of Intergroup Relations*, eds W. G. Austin and S. Worchel (Monterey, CA: Brooks Cole), 33–47.
Tan, A.-L., and Jocz, J. A. (2015). Spiderman and science: how students' perceptions of scientists are shaped by popular media [Electronic Version]. *Public Underst. Sci.* doi: 10.1177/0963662515615086 [Epub ahead of print].
Tan, E., and Barton, A. C. (2008). Unpacking science for all through the lens of identities-in-practice. *Cult. Stud. Sci. Educ.* 3, 43–71. doi: 10.1007/s11422-007-9076-7

Tan, E., Barton, A. C., Kang, H., and O'Neill, T. (2013). Desiring a career in STEM-related fields: how middle school girls articulate and negotiate identities-in-practice in science. *J. Res. Sci. Teach.* 50, 1143–1179. doi: 10.1002/tea.21123

Thompson, J. J., and Windschitl, M. (2005). "Failing girls": understanding connections among identity negotiation, personal relevance, and engagement in science learning from underachieving girls. *J. Women Minor. Sci. Eng.* 11, 1–26. doi: 10.1615/JWomenMinorScienEng.v11.i1.10

Trujillo, G., and Tanner, K. D. (2014). Considering the role of affect in learning: monitoring students' self-efficacy, sense of belonging, and science identity. *CBE Life Sci. Educ.* 13, 6–15. doi: 10.1187/cbe.13-12-0241

Umana-Taylor, A. J., Yazedjian, A., and Bamaca-Gomez, M. (2004). Developing the ethnic identity scale using Eriksonian and social identity perspectives. *Identity* 4, 9–38. doi: 10.1207/S1532706XID0401_2

van Zoonen, E. A. (1992). The women's movement and the media: constructing a public identity. *Eur. J. Commun.* 7, 453–476. doi: 10.1177/0267323192007004002

Wagner, J. D., and Caudill, S. R. (2003). Women scientists: 9.3 minutes of fame? *Science* 300:1875. doi: 10.1126/science.300.5627.1875b

Warren, S., Goodman, M., Horton, R., and Bynum, N. (2016). Stemming the tide: the presentation of women scientists in CSI. *Int. J. Gen. Sci. Technol.* 8, 360–381.

Weingart, P. (2006). Chemists and their craft in fiction film. *HYLE Int. J. Philos. Chem.* 12, 31–44.

Weingart, P., Muhl, C., and Pansegrau, P. (2003). Of power maniacs and unethical geniuses: Science and scietists in fiction film. *Public Underst. Sci.* 12, 279–287. doi: 10.1177/0963662503123006

Weinreich-Haste, H. (1981). "The image of science," in *The Missing Half: Girls and Science Education*, ed. A. Kelly (Manchester: Manchester University Press), 216–229.

Weitekamp, M. A. (2015). 'We're physicists': gender, genre and the image of scientists in The Big Bang Theory. *J. Pop. Telev.* 3, 75–92. doi: 10.1386/jptv.3.1.75_1

Wieland, S. M. B. (2010). Ideal selves as resources for the situated practice of identity. *Manag. Commun. Q.* 24, 503–528. doi: 10.1177/0893318910374938

Conflict of Interest Statement: The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Psychology

REVIEW
published: 19 April 2017
doi: 10.3389/fpsyg.2017.00598

Establishing the Research Agenda for Increasing the Representation of Women in Engineering and Computing

Kathleen Buse[1], Catherine Hill[2] and Kathleen Benson[2]*

[1] *Department of Design & Innovation, Weatherhead School of Management, Case Western Reserve University, Cleveland, OH, USA,* [2] *Research Department, American Association of University Women, Washington, DC, USA*

While there is an extensive body of research on gender equity in engineering and computing, there have been few efforts to glean insight from a dialog among experts. To encourage collaboration and to develop a shared vision of the future research agenda, a 2 day workshop of 50 scholars who work on the topic of gender in engineering and computing was held at a rural conference center. The structure of the conference and the location allowed for time to reflect, dialog, and to craft an innovative research agenda aimed at increasing the representation of women in engineering and computing. This paper has been written by the conference organizers and details the ideas and recommendations from the scholars. The result is an innovative, collaborative approach to future research that focuses on identifying effective interventions. The new approach includes the creation of partnerships with stakeholders including businesses, government agencies, non-profits and academic institutions to allow a broader voice in setting research priorities. Researchers recommend incorporating multiple disciplines and methodologies, while expanding the use of data analytics, merging and mining existing databases and creating new datasets. The future research agenda is detailed and includes studies focused on socio-cultural interventions particularly on career choice, within undergraduate and graduate programs, and for women in professional careers. The outcome is a vision for future research that can be shared with researchers, practitioners and other stakeholders that will lead to gender equity in the engineering and computing professions.

Keywords: gender equality, women, engineering, computing

OPEN ACCESS

Edited by:
Margaret M. Hopkins, University of Toledo, USA

Reviewed by:
Donna K. Ginther, University of Kansas, USA
Alison Sheridan, University of New England, Australia

****Correspondence:***
Kathleen Buse
krb50@case.edu

Specialty section:
This article was submitted to Organizational Psychology, a section of the journal Frontiers in Psychology

Received: *14 December 2016*
Accepted: *31 March 2017*
Published: *19 April 2017*

Citation:
Buse K, Hill C and Benson K (2017) Establishing the Research Agenda for Increasing the Representation of Women in Engineering and Computing. Front. Psychol. 8:598. doi: 10.3389/fpsyg.2017.00598

INTRODUCTION

In 2015 women comprised 25% of computer scientists and 12% of engineers in the USA. This is at a time when women comprise 47% of the total labor force and 52% of managers and professionals. Women's representation in other demanding professions belie this underrepresentation in engineering and computing as women comprise 63% of auditors and accountants, 54% of business professionals, 38% of physicians and surgeons, and 35% of lawyers (US Bureau of Labor Statistics, 2015).

The topics of science, technology, engineering, and mathematics (STEM) and "women in STEM" continue to attract attention in the public discourse and in academia. Women's under-representation in these professions has inspired an influx of research over the past four decades, as summarized in recent reports (Hill et al., 2010; Corbett and Hill, 2015). Meta-analyses (Kanney et al., 2014) have identified trends in research, documenting what is known and what needs to be known about gender equity in engineering and computing. Although the problem is well documented, understanding how to overcome the obstacles to women's full participation in the technical workforce, particularly empirical research on effective interventions, remains a challenge.

The purpose of this paper is to present the ideas and recommendations from a gathering of researchers who worked to create a research agenda to increase the representation of women in engineering and computing. The conference was designed to encourage collaboration among researchers and to craft an innovative research agenda to accelerate the progress of women in engineering and computing. This paper has been written by the conference organizers using detailed notes and session transcripts. The authors intend for this paper to provide the context and the specifics for a concise, prioritized research agenda to be released by the American Association of University Women (AAUW) in the spring of 2017. Together, the paper and the research agenda provide a path forward for researchers and those who depend upon research to increase the numbers of women who pursue, thrive and excel in engineering and computing professions.

This paper begins by explaining the motivation and logistics behind the research conference followed by a high-level overview of the research and a discussion of effective evidence-based interventions. Next the researchers' vision for a new collaborative approach to the work is described including: the creation of an oversight group; an intentional effort to impact the depth and breadth of research studies by using multiple disciplines, multiple methods and simultaneously studying multi-levels; leveraging data, merging and mining existing data sources, using data analytics to create knowledge and providing opportunities for researchers to convene on a regular basis. Finally, a description is provided of recommended research studies contextually categorized as societal and cultural influences, undergraduate and graduate programs, and the workplace. The outcome is a path forward for researchers, practitioners and other stakeholders that will lead to gender equity in the engineering and computing professions.

BACKGROUND

An extensive literature review (Corbett and Hill, 2015) highlighted recent research that identifies the critical factors underlying the under-representation of women in engineering and computing. These factors include stereotypes and biases embedded in society, in college curriculum, and in the workplace. The agenda for the research conference was organized around these factors.

Leading researchers were selected to attend the conference through an application process. Those attending worked as professors and research scientists in fields that spanned engineering, computer science, education, psychology, sociology, gender studies, management, and public policy. Others worked as administrators in higher education or directors of non-profits. All had some connection with research focused on increasing gender equality in engineering and/or computer science, with many having NSF-funded research.

The conference was structured to include large group sessions and small group discussions. Informal gatherings and meals allowed for continued discussion and debate. The large group sessions reviewed logistics, provided overarching goals for the smaller sessions, and the opportunity for the facilitators of the small group to share and synthesize outcomes. The small group discussions were used to create a discourse among the researchers on what we know and what we need to know in three critical areas: (1) the impact of implicit gender bias and stereotype threat on individuals in the context of career choice, persistence in undergraduate and graduate programs, and in the workplace; (2) evidence-based interventions to increase women's representation in engineering and computing; and (3) creating a specific research agenda. All discussions focused on how research informed, and should inform, practice by employers, policy maker, and individuals.

Included in the body of knowledge of the factors impacting women's under-representation in engineering and computing are stereotypes, a cognitive shortcut that categorizes people on the basis of characteristics such as gender, race, or age. A bias is a semi-permanent belief based on repeated exposure to stereotypes (Banaji and Greenwald, 2013). A meta-analysis of gender and leader stereotypes found no evidence of decreased stereotyping over time (Koenig et al., 2011).

Both men and women show biases toward women in scientific roles (National Research Council, 2007; Hill et al., 2010; Moss-Racusin et al., 2012; Corbett and Hill, 2015). While overt bias is less common today than in the past, implicit biases remain common (Banaji and Greenwald, 2013). Implicit, or unconscious, bias occurs when a person consciously rejects stereotypes but unconsciously makes evaluations based on stereotypes. The social psychologists Mahzarin Banaji and Anthony Greenwald introduced the concept of implicit bias in 1995, building on earlier findings showing that individuals' actions are not always under their conscious control. Banaji and Greenwald (2013) believe that implicit bias often expresses itself through in-group favoritism, which can be hard to detect. For example, despite finding no evidence of an explicit preference for male or female managers, researchers found that male participants implicitly associated positive managerial characteristics (i.e., competent, executive, productive) with men. The opposite was true for female participants, who associated women with positive managerial characteristics; however, this effect was much weaker.

Banaji and Greenwald continued to develop understanding of implicit biases including a methodology to reveal individual implicit biases (Banaji, 2001; Banaji and Greenwald, 2013). The Implicit Attitudes Test (IAT) is an empirically sound, popular and well-known tool. Faking bias or non-bias is almost impossible as response time is used (Greenwald et al., 1998; Banaji, 2001). The IAT is available to individuals through implicit.harvard.edu.

A concept related to implicit bias is a *stereotype threat*. This arises when individuals are negatively influenced due to a stereotype within a role or activity. Negative stereotypes affect individuals' performance when they attempt difficult tasks in the domains in which they are negatively stereotyped (Logel et al., 2012). Stereotype threat can reduce working memory and, because of its relationship with stress, anxiety, and disengagement, can lead to a wide variety of negative outcomes.

Bias and Career Choice

Both explicit and implicit bias impacts career choice for girls (Lent et al., 1994; Correll, 2001). Biases also impact self-esteem (Greenwald and Banaji, 1995), self-efficacy (Marra et al., 2009; Buse et al., 2013) and stereotype threat (Schmader, 2002). Career choice is impacted by parents, family members and teachers (Lent, 2005).

Media and social media are central to cultural stereotypes, bias, and social norms. Gender bias is pervasive in all forms of media, especially in entertainment. While this phenomenon is well documented, in general, less attention has been paid to women and girls in mathematically demanding fields such as engineering and computing. The depiction of women as professionals, particularly in movies and television is biased because it rarely represents today's reality. In a study of prime time television shows no women were portrayed as engineers (Geena Davis Institute on Gender in Media, 2014).

Women are more likely to be assigned "supportive" roles in engineering undergraduate teams as opposed to "technical" roles (Laughlin et al., 2007). Women undertaking challenging math problems do equally as well as men but think they have performed worse (Forbes and Schmader, 2010). The academic performance of women students in undergraduate science class is underestimated by their male peers (Grunspan et al., 2016). Faculty members, both men and women, show biases in favor of male students (Moss-Racusin et al., 2012). Students rate male professors higher than female professors. (MacNell et al., 2015), and bias impacts graduation rates and persistence in engineering and computing (Correll, 2001; Buse et al., 2013).

Evidence-based Interventions

The body of research on the underrepresentation of women in engineering and computing is substantial, yet little research has been done on effective, evidence-based interventions. One area where interventions have been effective has been in recruiting, retaining and graduating women from undergraduate programs. For example, Harvey Mudd College has reached gender parity in graduation rates in their schools of engineering and computing with an intentional, focused effort (Klawe, 2014) and Carnegie Mellon University has increased the number and percent of women with computer science degrees (Frieze et al., 2012). A large Midwest university has successfully changed the admission procedures to increase the number of women recruited to their school of engineering (Holloway et al., 2014). Best practices have been compiled by WEPAN (Women in Engineering ProActive Network, 2016) and NCWIT (National Center for Women and Information Technology, 2016). The ADVANCE program from National Science Foundation has worked to increase the number and percent of women faculty in science and engineering programs by focusing on institutional transformation (National Science Foundation, 2015).

DISCUSSION: BUILDING CAPACITY TO ACCELERATE THE RESEARCH

Gender inequality has been described by researchers as a grand challenge (Joshi et al., 2015). Novel insights, innovation, and a broader community to conduct research are important facets of accelerating the rate of change in women's representation in engineering and computing. Impacting real world outcomes was a common focus across the discussions among scholars. A number of concrete ideas to build capacity in the research community were put forward including: (1) additional effort to impact the depth and breadth of research studies by using multiple disciplines and multiple methods; (2) leveraging data, merging and mining existing data sources, using data analytics to create knowledge; and (3) providing opportunities for researchers to convene on a regular basis.

EXPANDING THE DEPTH AND BREADTH OF RESEARCH

An oversight group of researchers and practitioners is recommended to lead the new approach to increasing women's representation in engineering and computing. The role of the oversight group is to establish priorities, track progress, develop process metrics and outcome measurement while encouraging practitioners and researchers to collaborate. Further, the oversight group could allocate funding and seek new sources of funding. A key responsibility of the group would be to raise consciousness of those in power to understand the bias and barriers limiting women's achievement in engineering and computing. Since those in power are mostly men, this would include more men in the discourse. The oversight group would develop an effective method to disseminate research into practice in ways that change society, organizations, workplaces, leaders and individual women.

Practice-oriented groups like SIGCS (special interest group on computer science education), WEPAN (Women in Engineering Programs and Advocates Network), SWE (Society of Women Engineers), NCWIT (National Center for Women and Information Technology), Anita Borg Institute, National Academy of Sciences, Engineering and Medicine Committee on Women in Science, Engineering and Medicine, IEEE Women in Engineering and others could be part of the oversight group.

Stakeholders who would benefit from an increased representation of women in the engineering and computing professions are also expected to be part of this group. These stakeholders include corporations, government agencies and other institutions employing those in the engineering and computing professions. Universities that offer engineering and computing degrees and employ faculty in these areas are also important stakeholders.

Multi-disciplinary

An intentional effort to include multiple disciplines while simultaneously studying multi-levels using multiple methods is essential to accelerate the rate of achievement for women in engineering and computing. The depth and breadth of the research studies will be impacted by using multiple disciplines, multiple methods and simultaneously studying multi-levels.

Currently, the researchers addressing the under-representation are mostly women Ph.D.s in the fields of sociology, psychology, and management. To broaden the impact and the outcomes, the researchers recommend recruiting researchers from additional disciplines. In particular, more economists, engineers, computer scientists, feminist scholars, career scholars, organizational behavior and industrial psychologists are needed in the research studies. Additional researchers who are male would offer a different framework and their participation in this research is encouraged. The role of researchers from practice should be explored as these researchers have access to women who are working in the professions.

Multiple Methods

The researchers call for studies that utilize multiple types of research methods. An overall framework should be developed, possibly by the oversight group or a specially designated group. From this overall framework multiple theories, methods, and outcome measure could be developed. Types of studies deemed to be important include qualitative, quantitative, ethnographic, meta-analyses, longitudinal, and mixed methods. Employing multiple methods can augment and explain complex or contradictory results, and provide important information on emergent and unexpected themes (Driscoll et al., 2007).

Theoretically framed studies are important so as to build upon prior knowledge and expertise of researchers. More studies should be completed within the workplace so as to understand the complexities of the under-representation of women. Workplace experiences matter as well as context matter in moving the research agenda forward.

Studies of women and men in the workplace are especially needed—studies that include hundreds of firms. Researchers should make contact often and create a longitudinal database. Existing data such as personnel records and performance review can aid understanding of workplace experiences. Social media, blogs, and Facebook and Twitter posts can be used to obtain data. Longitudinal and mixed methods studies are recommended.

It is important that the under-representation of women in engineering and computing be framed and discussed as a societal issue. Too often it has been labeled as a "women's issue." The oversight group should emphasize and ensure that the societal impact of women's equality be emphasized. For example, the problem should be framed in terms of social justice and how the role of women in engineering and computing will impact the wage gap and other social issues related to gendered careers.

Consciousness raising and questioning decisions made by those in power are important but not enough to enable change. The researchers recognize that those in power don't always understand women's experience in the workplace.

DATA, DATA MINING, AND DATA ANALYTICS

The under-representation of women in engineering and computing, like any complex problem, can only be solved with a data-driven approach. The new approach to research in this area should use the latest techniques and tools to collect and analyze data. Data, data-based approaches, and data analysis are the foundation of science and technology. The National Academy of Engineering discusses the importance of data or informatics in higher quality and more effective medical care. "As computers have become available for all aspects of human endeavors, there is now a consensus that a systematic approach to health informatics—the acquisition, management, and use of information in health—can greatly enhance the quality and efficiency of medical care and the response to widespread public health emergencies" (National Academy of Engineering, 2016b). The researchers believe this to be true of the work to advance women in the engineering and computing professions. The integration of data and data analysis, especially the role of "big data" and "data analytics" is important according to the researchers to solve the under-representation of women in engineering and computing.

There are numerous national longitudinal surveys of students, doctoral recipients, etc., that are in the area of engineering and computer science (for example, the NSF survey earned doctorates available at[1]). These surveys are under-utilized because (1) researchers do not know they exist, and (2) they are difficult to access. The researchers recommend that an effort be undertaken to locate and assemble all sources of data on students and workers. The effort should include making the existing data easier to find and to use. For example, the Survey of Doctoral Recipients, funded by the National Science Foundation[2] captures detailed demographic data longitudinally; it has no measures of psychological well-being, no measures that might indicate the impacts of bias, nor any information on future career plans. The researchers recommend adding information related to the micro-processes related to bias, adding a qualitative component and developing a method to randomize participants. This would include identifying people in particular industries, geographic areas, or parents, etc.

Neurosynth is a platform for large-scale, automated synthesis of functional magnetic resonance imaging (fMRI) data. It takes thousands of published articles reporting the results of fMRI studies, chews on them for a bit, and then spits out images. It is recommended that a website be developed that compiles the studies on women in engineering and CS, focusing on providing specific information on interventions that enable change.

Data can be compiled from colleges and universities, including, but not limited to admissions offices, registrars, and

[1] https://www.nsf.gov/statistics/2017/nsf17306/survey.cfm
[2] https://www.nsf.gov/statistics/2017/nsf17306/survey.cfm

career services. This data could be available to study differences between men and women, those who persist versus those who leave engineering and CS. Also, alumni offices have data on jobs and organizations of alums.

Corporations collect data on employees, including job progression, training and performance evaluations. Merging the corporate data with other sources could provide a rich source of knowledge on when, how and why women achieve in the workplace.

Specifically, the researchers recommend using and merging existing data sources, leveraging corporate, institutional and governmental databases. A common set of measure and metrics to create knowledge and accelerate change should be created. Novel technologies should be investigated including the use of biometrics and team level data, with a focus on identifying best practices and replication. The scale up from experiments to practice is important along with validity in replicating studies. The use of data mining techniques to identify those times women or girls choose to opt out is important to identify as well as how course content and social media impact achievement. Another recommendation from the researchers is to combine sources of data with micro-factors with larger factors. For example, add psychometric factors to qualitative and quantitative databases. Include demographics, such as number of children that professionals support.

A CONFERENCE OF RESEARCHERS AND PRACTITIONERS

The last of the recommendations on changing the approach to research is to provide opportunities for researchers to convene on a regular basis to discuss the status of research, review recent discoveries and identify gaps in knowledge. At the conference, the researchers mentioned over and over again how this was the first time they were able to meet to collaborate with multiple researchers who shared the same research focus. Formal and informal interactions engaged and enlightened the researchers. Collaborations were formed and an agreement to stay in contact were made by many and were included in the comments in the post-conference survey.

The use of social media is recommended as another method to connect researchers. Communities could be established within Facebook or LinkedIn to connect researchers and have an ongoing discussion. Additionally, it could be useful for researchers to intentionally share presentations and status updates. Upcoming conferences and funding opportunities can also be shared.

Connections are necessary with government institutions, with corporations and other stakeholder organizations. Currently, there are limited opportunities for researchers to interact or conduct research within organizations where women are employed as engineers and computing professionals. One exception is women in academic engineering and computing. The ADVANCE program is credited with institutional transformations resulting in increases in the number and percent of women in STEM faculty across the US (National Science Foundation, 2015). Since 2001, the National Science Foundation has awarded more than 300 grants to 200 plus institutions.

Funding should be made available for researchers to attend practitioner conferences and practitioners to attend scholarly conferences. Providing many opportunities for practitioners and researchers to meet and discuss progress will allow interventions to happen organically. The oversight committee can aid in removing barriers to progress.

RECOMMENDATIONS FOR SPECIFIC RESEARCH STUDIES

This section provides a summary of the specific studies that the researchers recommend to increase women's representation in engineering and computing. These projects have been grouped into the following categories: (1) Societal and cultural influences on girls and women, (2) Measuring and overcoming implicit bias, (3) Factors influencing career choice in the K-12 environment, (4) Undergraduate and graduate studies, and (5) The workplace.

SOCIETAL AND CULTURAL INFLUENCES ON GIRLS AND WOMEN

Research is needed to determine interventions are most likely to increase the number of girls selecting engineering and computing professions. Broad-based studies have been suggested by the researchers. These studies must address the intersectionality of gender with other factors, including but not limited to economic status, race and ethnicity, sexual orientation, differently abled and others that may influence career decisions.

The researchers recommended building on current understanding of the emergence of gender roles and gender identity and how these influence career decisions related to engineering and computing. The influence of institutional and organizational factors are important to study, as are non-verbal forms of communication of the gender roles and gender identity. Further, work is recommended on when and how interventions can change current perceptions of gender roles and gender identity related to career choice. For example, studies can follow middle school girls involved in maker camps or coding camps. These types of experiences are proliferating, but longitudinal research studies are necessary to determine the impact on engineering or computing as a career choice.

The impact of government, institutional and organizational policies and the impact of rewards (e.g., to parents, to communities or institutions) are important areas to study. The researchers are interested in understanding the factors that allow some girls to overcome cultural biases and choose engineering and computing. An outcome of this research would include recommendations on how communities can overcome cultural stereotypes related to financial independence where boys are expected to have a career, girls are expected to be mothers.

Researchers recommend that a large-scale effort be coordinated to change the images of engineering and computing.

The focus would be to show engineering and computing as inclusive cultures that are professions that change the world. Providing recurring, positive images of engineering and computing as collaborative professions, where women can change the world will change the stereotypes.

The first suggestion to change the stereotypes is to work with marketing and public relations professionals to determine how best to present positive images of a diverse engineering and computer workforce. Positive images of career women portrayed in the media have been credited with an increase in non-traditional career paths. For example, the character of Abby on the television show CSI has created the "Abby Effect" where more girls have chosen forensic science as a career path (Barry, 2012). The public relations work could include additional positive media representations, such as the "Next MacGyver" (The Next MacGyver, 2015). This project is intended to have a female engineer depict the 1980's character "MacGyver," a creative inventor and problem solver.

Further, the researchers suggest broad depictions of people working in engineering and computing who are changing the world with their work. For example, Facebook engineers and computing professionals have created a tool where individuals can tell their family and friends they are safe during a disaster (Facebook, 2014). Pre-kindergarten through middle school children can be influenced by various media including games, social media, television, and movies. It is important to ensure that these media sources will provide positive role models for both girls and boys. Because research has shown that parents have the greatest influence on their children's career choice (Lent, 2005), campaigns targeted at young parents and even at expectant parents would aid in developing a positive and realistic image of engineering and computing as a future career path for any child, whether it be a boy or a girl.

MEASURING AND OVERCOMING IMPLICIT BIAS

A limited number of studies have shown that implicit bias exists toward women in science-related careers (Moss-Racusin et al., 2012) and this type of bias can be measured within individuals (Banaji, 2001). Researchers must continue to understand the impact of implicit bias on women in engineering and computing, but a shift is recommended toward understanding how to overcome these types of subtle bias. Specifically, studies are needed on how girls and women recognize and respond to implicit bias in ways that help overcome the bias.

Research projects that are recommended include understanding what can be done to change implicit bias within individuals and how to reduce the impact of other people's implicit bias on girls and women. Specific research questions related to measuring and overcoming implicit bias include the following. What is the best way for girls and women to respond to implicit bias? Can girls and women intervene to prevent implicit bias from impacting them? Is one intervention effective, or do multiple interventions results in significant change to last a lifetime? Do these interventions need to happen in intervals? Does awareness of one's biases decrease one's level of bias? Each of these research questions can only be answered with valid and reliable measurement systems. The researchers recommend leveraging the IAT and continue the development of measurement system to recognize and reduce the impact of implicit bias in individuals and in society.

FACTORS INFLUENCING CAREER CHOICE IN THE K-12 ENVIRONMENT

Studies are recommended for understanding which types of programs within the Kindergarten through Grade 12 school environment are most likely to result in more girls choosing engineering and computing. Some research questions are detailed here: Do stand-alone programs work or is it necessary to have multiple experiences throughout the K-12 years? What is the impact of role models, specifically women role models who work in engineering and computing? How best can women in the professions impact students' career choice? What types of interactions are important to show girls that careers are compatible with women's lives? How and when should family members have career discussions with children? Are role models who are family members more effective than non-family members? How important is the context of the role model? For example, are family members who are role models more effective than TV characters? When and how are female role models more impactful than male role models? Is the age of role models important to middle school girls?

Clearly identifying pathways to the engineering and computing professions are important research studies. What are the various pathways to success in engineering and computing professions? Are there different rates of success for these different pathways? What is the impact of community colleges and technical vocation programs in high schools? Do these programs lead more girls to choose non-traditional careers in the STEM professions? How do in-school programs targeted at career choice impact the choice of profession especially for girls? How can maker spaces in schools be used to effectively impact career choices related to engineering and computing?

Researchers should work to define age appropriate curriculum in engineering and computing for those in kindergarten through high school. It is recommended that this curriculum include cultural sensitivity, hands-on examples, real-life applications, measurements for learning, teacher and parent guides, and role models in the school. New curriculum should include awareness of how the engineering and computing professions make an impact. An example is the work of engineers and computer scientists in the space program, or in disease detection and prevention. Studies are recommended on how to train teachers to emphasize the connections between important societal problems and the professions of engineering and computing. For example, one of the Engineering Grand Challenges is to provide access to clean water for all people (National Academy of Engineering, 2016a). The impact of these ideas on all children should be studied, including any benefit in attracting a more diverse population to engineering and computing.

Qualitative, longitudinal studies are recommended for children beginning in kindergarten with the purpose of identifying factors that increase and decrease interest in engineering and computing and if it changes over time. It is recommended that researchers study the effect of when students are taking scientific classes and how it impacts career choice. For example, in the U.S., physics is usually taken in the senior year of high school. If moved to a lower grade, would it impact the number of women in engineering?

The integration of engineering and computing into grade schools and the impact on career decisions for both girls and boys is important to study. The researchers recommend longitudinal studies that compare the impact on career choice for integrating engineering and computing concepts into day-to-day coursework versus schools that have separate classes teaching making or coding concepts. Comparing schools which have no programming related to engineering and computing concepts would also provide valuable information on the impact of such a program on career choice for both girls and boys.

Studies are recommended on the work of code.org and Hour of Code and other programs promoting engineering and computer science so as to understand if these interventions are effective in increasing the number of girls who choose engineering or computing careers. The research questions include the following. What types of interventions are most likely to increase interest for girls? How long do the interventions need to be? How can these be integrated into additional schools and communities? What are the characteristics of those interventions that result in more girls choosing engineering and CS careers?

A final recommendation from the researchers is based on feminist studies which hypothesize that there is really no such thing as completely objective or unbiased work. But currently, science and math are taught in ways that are objective and fact-based. The subjectivity of concepts is minimized. The researchers recommend creating a research agenda that explores how objective and fact-based curriculum impacts the success of students, particularly girls and other under-represented minorities. The study should explore methodologies where scientific work is viewed in a more subjective manner. This could be done by engaging students in a discussion of the subjectivity within the sciences and math fields. For higher level courses in computer science and engineering, research is recommended where students are taught to think more about the objectivity and subjectivity in these fields. Will this type of study open minds to the different kinds of work that can be accomplished? And will it allow students to have more ownership over their own biases as part of the way of doing the work?

UNDERGRADUATE AND GRADUATE PROGRAMS

While there is much known about the complexity of problems facing women in undergraduate and graduate programs, research offers few practical strategies to increase the recruitment, retention, and graduation of women in engineering and computing. Beginning with the recruitment process, the impact of recruitment mailings, advertisements, emails, etc., should be assessed. Campus tours, admissions processes and other aspects of recruiting should be studied to understand biases. Instituting common metrics across all programs can aid in developing an understanding of differences. Further studies should investigate how the use of outcome measurements could be used to change institutional policies.

Longitudinal studies are recommended for all students, both women and men, in undergraduate and graduate programs to understand retention leading to graduation. At this time, it is not well understood when and if specific classes, projects, team projects, student groups, faculty interactions, etc., impact persistence. The studies should focus on those specific programs, experiences, networks, methodologies, and other opportunities that influence women's persistence in academia. Additionally, research should address understanding the factors within undergraduate and graduate programs that are linked to continued achievement in the engineering and computing workplace. Understanding how these experiences and influences are the same or different from their male classmates is important to influence the under-representation of women.

It has been shown that having more women as professors helps women persist (Klawe, 2014) but we need to better understand how all professors can differentially develop skills to enable persistence for all students. Supporting relationships have been shown to allow all undergraduates to persist, understanding how these relationships could be leveraged to achieve better outcomes for women is an important research opportunity. These relationships should include professional women or other role models, mentors and sponsors.

Self-efficacy (Betz and Hackett, 1986) and professional role confidence (Cech et al., 2011) have been shown to impact career choice and persistence in undergraduate programs. Researchers should focus on how women develop these individual characteristics during the undergraduate experience. An important aspect of this research is to understand the impact of other factors, including race, ethnicity, sexual orientation, income, etc., on these individual characteristics.

A suggestion was made to begin a large-scale randomized controlled study across universities, for example in all of the Big 10 schools and in selected smaller schools. Universities would be willing to participate as this type of study will improve the student's experience which may eventually increase alumni donations. This large-scale study would focus on persistence across different educational experiences—large universities, private, and community colleges. The study can incorporate geographical differences, campus differences (for example those that have an athletic focus vs. those that do not), tuition aid, traditional vs. non-traditional students, etc. Ideas for further development include rewarding women and minorities for taking engineering and computing programs. The reward could be an internship, promise of a job post-graduation, money, grants or other tangibles.

THE WORKPLACE

Because researchers have limited access to engineering and computing workplaces, studies on professionals working in engineering and computing careers are limited. The one exception is in the academic workplace where the ADVANCE program (National Science Foundation, 2015) has successfully increased the participation and advancement of women in academic science and engineering careers. Future research studies are suggested that focus on women in professional engineering and computing careers so as to understand what interventions are needed to recruit, retain and advance women in these professions. Having an oversight group of practitioners and scholars would facilitate the research within workplaces.

Prior work shows why women leave the engineering and computing professions (Singh et al., 2013; Fouad et al., 2015) and identifies factors related to women persisting in these careers (Buse et al., 2013; Buse and Bilimoria, 2014). Moving forward, the researchers recommend that studies focus on how to make workplaces free from bias, stereotypes, and micro-aggressions. Men and women should be trained to understand how bias, barriers, and micro-aggressions manifest themselves within workplaces. Research is needed on how to minimize and/or eliminate the bias, barriers, and micro-aggressions. For example, some companies are using "blind" recruitment processes, where names are taken off applications and resumes. Studies are needed to understand how longer term biases can be overcome. An understanding of backlash is needed where the backlash is an adverse response to bias training and/or promotional opportunities provided to women.

Sponsors and mentors have been shown to be effective in the retention and advancement of women in leadership (Singh et al., 2006). Researchers should understand the optimal types of sponsors and mentors for women in engineering and computing. Studies show that women are more likely to persist in engineering when they are engaged with their work and find meaningfulness with their career (Buse and Bilimoria, 2014). These factors can be used to attract and retain women to engineering and computing. Specific studies are suggested to understand if workforce diversity is increased when workplaces recruit based on a "change the world" strategy and if the work actually impacts the world positively. There is an opportunity by workplaces to ensure that the job itself is linked to a higher purpose, and researchers can aid practitioners in crafting a higher purpose within organizations.

Researchers should examine women's work and men's work within engineering and computing to determine how work is distributed and enacted so as to overcome recent studies that show women are more likely to work in supporting and less challenging roles and do the office housework (Williams and Dempsey, 2014). Some disciplines like biomedical engineering attract and retain more women than other disciplines like electrical engineering. Researchers are encouraged to explore the nuances involved in the professions to better understand these phenomena. Different disciplines within engineering and computing need to be studied and compared. Within engineering and computing there is much diversity, in the type of work, in the workplace itself (e.g., oil rigs vs. offices) in the specific industries (e.g., academia vs. industry vs. government), in organization size (e.g., Google vs. start-up) etc. Researchers are encouraged to understand these sub-fields and gender distribution within the subfields. The exploration of these differences is recommended so as to discover if there is a socio-technical divide. Work is recommended to show society how and when engineering and computing professions serve the higher good. The identification of organizations, industries, and sub-fields that serve the public can help engage more individuals within the professions.

The researchers suggest studies on the language of engineering and computing as some disciplines have a clear male-female dynamic within the language. For example, in the chemical industry hose fittings are described as male or female. The impact of language within professions and industries and how it impacts the retention and advancement of women in various engineering disciplines, and various computing disciplines should be studied.

Comparative studies are recommended between other professions such as medicine and law where women have greater representations. More studies are needed to understand the differences that men and women experience within the engineering and computing workplace. These studies should focus on the specific changes that organizations can implement to integrate women into the existing workplace while implementing longer term strategies to obtain gender equity.

Researchers should determine the types and frequency of educational initiatives for organizational leaders on bias, barriers, and stereotypes. Organizational leaders should work with experts in implementing structural changes to increase women's representation in engineering and computing. Institutional and governmental policies should be identified that can be used to impact women's achievement in the engineering and computing professions.

A comparative study is recommended where researchers identify two groups of organizations: ones that have had success in retaining and advancing women in engineering and computing and other organizations that are unable to retain women. Identify the type of work, the organizational policies and practices and other factors that differentiate the two. This may include the type of professional and leadership development for the managers, team structures, and work opportunities for the women, and differences between those in powerful positions.

Researchers should determine how work location, work hours, work schedules, and virtual work impacts the achievement of professional women. Longitudinal studies are necessary, especially those that include the work and home interface (e.g., the role of the husband in doing housework, childcare, etc.).

Work is needed to bring together firms employing engineers with undergrad programs to identify what is needed in the curriculum to achieve as an engineer or in computing. Time and effort should be expended to review and update courses and curriculum to reflect today's work environment. This can only be done with teams of men and women from practice working with those in academia.

Organizations can create survival guides for women in engineering and computing. Another suggestion from the researchers is to create a ranking system for good places for women engineers and computer professions. This would be similar to the US News and World Report rankings of the best colleges. And the last recommendation is to understand how counter-spaces or work groups of the same races or ethnicity impact women's achievement in professional engineering and computing.

LIMITATIONS

While the conference organizers attempted to include a range of disciplines studying the under-representation of women in engineering and computing, it is clear that several fields were missed. Not included were any feminist scholars or researchers from economics.

Another limitation of this report is that it only includes "what to do" not the "how to do" needed to enact the research agenda. The work of the conference organizers and the researchers moving forward is to find the opportunities to establish how to implement the many suggestions identified and documented here.

CONCLUSION

Researchers had a unique opportunity to gather and discuss their efforts to understand the factors impacting the under-representation of women in the engineering and computing professions. The researchers agreed that a new collaborative research approach is necessary to accelerate the rate of change in women's representation in these important professions. Recommendations for moving forward include the creation of an oversight committee comprised of researchers, practitioners and other stakeholders, developing a network including additional disciplines applying new technologies and multiple methods to leverage data and data analytics, and to provide continuing opportunities for collaboration among multi-sector and multi-discipline stakeholders to implement effective interventions.

Additionally, the researchers suggested a future research agenda focusing on socio-cultural influences, measurement and intervention strategies related to girls and women at all stages of the career choice process. The under-representation of women in engineering and computing should be viewed as a complex problem that can be overcome with a collaborative strategy, appropriate resources including funding and stakeholders working together to implement effective solutions.

AUTHOR CONTRIBUTIONS

KBu is main author. CH and KBe wrote several sections.

FUNDING

Funding for this project has been provided by the National Science Foundation, Research on Gender in Science and Engineering award 1420214.

REFERENCES

Banaji, M. R. (2001). "Implicit attitudes can be measured," in *The Nature of Remembering: Essays in Honor of Robert G. Crowder*, eds H. L. Roediger, J. S. Nairne, I. Neath, and A. Surprenant (Washington, DC: American Psychological Association), 117–150.

Banaji, M. R., and Greenwald, A. G. (2013). *Blindspot: The Hidden Biases of Good People*. New York, NY: Random House.

Barry, D. (2012). *Abby Sciuto Has Inspired a Whole Generation of Women to Dominate Forensic Science. Jezebel.* Available at: http://jezebel.com/5932049/abby-sciuto-has-inspired-a-whole-generation-of-women-to-dominate-forensic-science

Betz, N. E., and Hackett, G. (1986). Applications of self-efficacy theory to understanding career choice behavior. *J. Soc. Clin. Psychol.* 4, 279–289. doi: 10.1521/jscp.1986.4.3.279

Buse, K., and Bilimoria, D. (2014). Personal vision: enhancing work engagement and the retention of women in the engineering profession. *Front. Psychol.* 5:1400. doi: 10.3389/fpsyg.2014.01400

Buse, K. R., Bilimoria, D., and Perelli, S. (2013). Why they stay: women persisting in the US Engineering Careers. *Career Dev. Int.* 18, 139–154. doi: 10.1108/CDI-11-2012-0108

Cech, E., Rubineau, B., and Seron, C. (2011). Professional role confidence and gendered persistence in engineering. *Am. Sociol. Rev.* 76, 641–666. doi: 10.1177/0003122411420815

Corbett, C., and Hill, C. (2015). *Solving the Equation: The Variables for Women's Success in Engineering and Computing*. Washington DC: AAUW.

Correll, S. J. (2001). Gender and the career choice process: the role of biased self-assessments. *Am. J. Sociol.* 106, 1691–1730. doi: 10.1086/321299

Driscoll, D. L., Appiah-Yeboah, A., Salib, P., and Rupert, D. J. (2007). Merging qualitative and quantitative data in mixed methods research: how to and why not. *Ecol. Environ. Anthropol.* 3, 19–28.

Facebook (2014). *Introducing Safety Check*. Available at: http://newsroom.fb.com/news/2014/10/introducing-safety-check/

Forbes, C. E., and Schmader, T. (2010). Retraining attitudes and stereotypes to affect motivation and cognitive capacity under stereotype threat. *J. Pers. Soc. Psychol.* 99, 740–754. doi: 10.1037/a0020971

Fouad, N. A., Singh, R., Cappaert, K., Chang, W., and Wan, M. (2015). Comparison of women engineers who persist in or depart from engineering. *J. Vocat. Behav.* 92, 79–93. doi: 10.1016/j.jvb.2015.11.002

Frieze, C., Quesenberry, J., Kemp, E., and Velaquez, A. (2012). Diversity or difference? new research supports the case for a cultural perspective on women in computing. *J. Sci. Educ. Technol.* 21, 423–439. doi: 10.1007/s10956-011-9335-y

Geena Davis Institute on Gender in Media (2014). *Gender Bias without Borders*. Available at: http://seejane.org/symposiums-on-gender-in-media/gender-bias-without-borders/

Greenwald, A. G., and Banaji, M. (1995). Implicit social cognition: attitudes, self-esteem and stereotypes. *Psychol. Rev.* 102, 4–27. doi: 10.1037/0033-295X.102.1.4

Greenwald, A. G., McGhee, A. G., and Schwartz, J. (1998). Measuring individual differences in implicit cognition. *J. Pers. Soc. Psychol.* 74, 1464–1480. doi: 10.1037/0022-3514.74.6.1464

Grunspan, D. A., Eddy, S. L., Brownell, S. E., Wiggins, B. L., Crowe, A. J., and Goodreau, S. J. (2016). Males under-estimate academic performance of their female peers in undergraduate biology classrooms. *PLoS ONE* 11:e0148405. doi: 10.1371/journal.pone.0148405

Hill, C., Corbett, C., and St. Rose, A. (2010). *Why So Few? Women in Science, Technology, Engineering and Math*. Washington, DC: AAUW.

Holloway, B., Reed, T., Imbrie, P. K., and Reid, K. (2014). Research-informed policy change: a retrospective on engineering admissions. *J. Eng. Educ.* 103, 274–301. doi: 10.1002/jee.20046

Joshi, A., Neely, B., Emrich, C., Griffith, D., and George, G. (2015). Gender research in AMJ: an overview of five decades of empirical research and calls to action, thematic issue on gender in management research. *Acad. Manag. J.* 58, 1459–1475. doi: 10.5465/amj.2015.4011

Kanney, A. M., Sax, L. J., and Riggers-Piehl, T. A. (2014). Investigating forty years of STEM research: how explanations for the gender gap have evolved over time. *J. Women Minor. Sci. Eng.* 20, 127–148. doi: 10.1615/JWomenMinorScienEng.2014007246

Klawe, M. (2014). *The Science behind Graduating a Class with Majority Female Engineers. Forbes*. Available at: http://www.forbes.com/sites/mariaklawe/2014/07/10/the-science-behind-graduating-a-class-with-majority-women-engineers/#366de2bb2fe2

Koenig, A. M., Eagly, A. H., Mitchell, A. A., and Ristikari, T. (2011). Are leader stereotypes masculine? A meta-analysis of three research paradigms. *Psychol. Bull.* 137, 616–642. doi: 10.1037/a0023557

Laughlin, C., Zastavker, Y. V., and Ong, M. (2007). "Is integration really there? Students' perceptions of integration in their project-based curriculum," in *Proceedings of the ASEE/IEEE Frontiers in Education Conference* (Milwaukee, WI: IEEE), F4C19–F4C25.

Lent, R. W. (2005). "A social cognitive view of career development and counseling," in *Career Development and Counseling*, eds S. D. Brown and R. W. Lent (Hoboken, NJ: John Wiley & Sons), 101–127.

Lent, R. W., Brown, S. D., and Hackett, G. (1994). Toward a unifying social cognitive theory of career and academic interest, choice, and performance. *J. Vocat. Behav.* 45, 79–122. doi: 10.1006/jvbe.1994.1027

Logel, C. R., Walton, G. M., Spencer, S. J., Peach, J., and Mark, Z. P. (2012). Unleashing latent ability: implications of stereotype threat for college admissions. *Educ. Psychol.* 47, 42–50. doi: 10.1080/00461520.2011.611368

MacNell, L., Driscoll, A., and Hunt, A. N. (2015). What's in a name: exposing gender bias in student ratings of teaching. *Innov. Higher Educ.* 40, 291–303. doi: 10.1007/s10755-014-9313-4

Marra, R. M., Rodgers, K. A., Shen, D., and Bogue, B. (2009). Women engineering students and self-efficacy: a multi-year, multi-institution study of women engineering student self-efficacy. *J. Eng. Educ.* 98, 27–38. doi: 10.1002/j.2168-9830.2009.tb01003.x

Moss-Racusin, C. A., Dovidio, J. F., Brescoll, V. L., Graham, M. J., and Handelsman, J. (2012). Science faculty's subtle gender biases favor male students. *Proc. Natl. Acad. Sci. U.S.A.* 109, 16474–16479. doi: 10.1073/pnas.1211286109

National Academy of Engineering (2016a). *14 Grand Challenges for Engineering in the 21st Century*. Available at: http://www.engineeringchallenges.org/challenges.aspx

National Academy of Engineering (2016b). *Advanced Health Informatics*. Available at: http://www.engineeringchallenges.org/challenges/informatics.aspx

National Center for Women and Information Technology (2016). *NCWIT*. Available at: https://www.ncwit.org/

National Research Council (2007). *Beyond Bias and Barriers: Fulfilling the Potential of Women in Academic Science and Engineering*. Washington, DC: National Academies Press.

National Science Foundation (2015). *ADVANCE Portal*. Available at: http://www.portal.advance.vt.edu/index.php

Schmader, T. (2002). Gender identification moderates stereotype threat effects on women's math performance. *J. Exp. Soc. Psychol.* 38, 194–201. doi: 10.1177/0146167208318404

Singh, R., Fouad, N. A., Fitzpatrick, M. E., Liu, J. P., Cappaert, K. J., and Figuereido, C. (2013). Stemming the tide: predicting women engineers' intentions to leave. *J. Vocat. Behav.* 83, 281–294. doi: 10.1016/j.jvb.2013.05.007

Singh, V., Vinnicombe, S., and Kumra, S. (2006). Women in formal corporate networks: an organisational citizenship perspective. *Women Manag. Rev.* 21, 458–482. doi: 10.1108/09649420610683462

The Next MacGyver (2015). *Searching for the Next Great Story about Women. Engineers. Heroes*. Available at: https://www.thenextmacgyver.com/about.html

US Bureau of Labor Statistics (2015). *Women in the Labor Force: A Databook. Retrieved from BLS Reports*. Available at: https://www.bls.gov/opub/reports/womens-databook/archive/women-in-the-labor-force-a-databook-2015.pdf

Williams, J. C., and Dempsey, R. (2014). *What Works for Women at Work*. New York, NY: New York University Press.

Women in Engineering ProActive Network (2016). *Women in STEM Knowledge Center*. Available at: http://www.wskc.org/

Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Psychology

REVIEW
published: 31 May 2017
doi: 10.3389/fpsyg.2017.00901

Check for updates

Can I Work with and Help Others in This Field? How Communal Goals Influence Interest and Participation in STEM Fields

Kathryn L. Boucher[1], Melissa A. Fuesting[2], Amanda B. Diekman[2] and Mary C. Murphy[3]*

[1] School of Psychological Sciences, University of Indianapolis, Indianapolis, IN, United States, [2] Department of Psychology, Miami University, Oxford, OH, United States, [3] Department of Psychological and Brain Sciences, Indiana University, Bloomington, IN, United States

Although science, technology, engineering, and mathematics (STEM) disciplines as a whole have made advances in gender parity and greater inclusion for women, these increases have been smaller or nonexistent in computing and engineering compared to other fields. In this focused review, we discuss how stereotypic perceptions of computing and engineering influence who enters, stays, and excels in these fields. We focus on *communal goal incongruity*–the idea that some STEM disciplines like engineering and computing are perceived as less aligned with people's communal goals of collaboration and helping others. In Part 1, we review the empirical literature that demonstrates how perceptions that these disciplines are incongruent with communal goals can especially deter women and girls, who highly endorse communal goals. In Part 2, we extend this perspective by reviewing accumulating evidence that perceived communal goal incongruity can deter *any* individual who values communal goals. Communal opportunities within computing and engineering have the potential to benefit first generation college students, underrepresented minority students, and communally-oriented men (as well as communally-oriented women). We describe the implications of this body of literature: describing how opting out of STEM in order to pursue fields perceived to encourage the pursuit of communal goals leave the stereotypic (mis)perceptions of computing and engineering unchanged and exacerbate female underrepresentation. In Part 3, we close with recommendations for how communal opportunities in computing and engineering can be highlighted to increase interest and motivation. By better integrating and publically acknowledging communal opportunities, the stereotypic perceptions of these fields could gradually change, making computing and engineering more inclusive and welcoming to all.

Keywords: communal goals, communal goal incongruity, STEM, gender, underrepresentation

OPEN ACCESS

Edited by:
Romila Singh,
University of Wisconsin–Milwaukee, United States

Reviewed by:
Daniel Spurk,
University of Bern, Switzerland
Massimo Miglioretti,
University of Milano-Bicocca, Italy

***Correspondence:**
Kathryn L. Boucher
boucherk@uindy.edu

Specialty section:
This article was submitted to Organizational Psychology, a section of the journal Frontiers in Psychology

Received: *30 October 2016*
Accepted: *16 May 2017*
Published: *31 May 2017*

Citation:
Boucher KL, Fuesting MA, Diekman AB and Murphy MC (2017) Can I Work with and Help Others in This Field? How Communal Goals Influence Interest and Participation in STEM Fields. Front. Psychol. 8:901. doi: 10.3389/fpsyg.2017.00901

INTRODUCTION

Sofia Tomov is a 12 year old computer programmer who developed an algorithm that helps doctors and their patients avoid adverse reactions to medication (Leins, 2016). She is just one of many young scientists who enter prestigious science competitions (e.g., Discovery Education 3M Young Scientist Challenge, Science Olympiad) each year with projects that showcase how science, technology, engineering, and mathematics (STEM) can be used to improve and save lives. Yet, when the lay public is asked to consider a typical engineer or a computer scientist or imagine engineering work, we are unlikely to think of exemplars like her.

Indeed, Sofia Tomov does not fit people's descriptions of computer scientists and engineers that include nerdy, socially awkward men who love science fiction and video games (e.g., Schott and Selwyn, 2000; Cheryan et al., 2009, 2013). Moreover, the applicability and relevance of contributions to people's lives are seldom emphasized in presentations and publications. In fact, STEM fields are rarely viewed as providing opportunities to improve lives or work with others, and, thus, the altruistic purposes that underlie so much of STEM work remain hidden (e.g., Diekman and Steinberg, 2013; Diekman et al., 2017). The hours of coding by computer scientists, the laboratory and teamwork required to develop a breakthrough method, and multiple fixes applied by engineers are not often linked to people's goals and motivations in an explicit way that makes those goals and motivations widely known. The result of these representations is that knowledge about what STEM is good for is underdeveloped. These representations lack the collaborative, real-world problem-solving that actually characterizes much of STEM work.

In the United States, shifting people's representations of STEM work to include scientists who emphasize collaboration in addition to innovation may be a key strategy to addressing a growing national concern. STEM fields are growing in numbers and are critical to the U.S. economy (e.g., U.S. Department of Education, 2006; National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, Rising above the Gathering Storm Committee, 2010; Lennon, 2014). The need for more STEM professionals, particularly engineers and computer scientists, is acute. Developing strategies to recruit groups that are currently underrepresented in STEM, including female students, as well as Black, Hispanic, and Native American students, will play an important role not only in diversifying the STEM workforce, but in growing it to the size necessary to compete in the global economy.

Stereotypic perceptions of STEM fields are one of several important factors that explain patterns of group underrepresentation in STEM fields (e.g., American Association of University Women, 2010, 2015; Cheryan et al., 2017). Indeed, research shows that by showcasing how STEM fields can fulfill people's communal goals of collaboration and helping others, women's STEM interest and participation can increase, and these education efforts may lead to revisions in the stereotypes of who excels and belongs in STEM fields (e.g., Diekman et al., 2011). An underexplored implication of this research is that we may be losing many people–both women *and men*–who wish to be engaged in STEM but who *also* wish to be engaged in careers that make a difference to people's lives.

These communally-oriented individuals are likely to be essential in changing STEM stereotypes and STEM environments to be more welcoming and inclusive to all. When more communally-oriented men leave STEM fields (or decide not to pursue these fields because they do not see opportunities to fulfill their communal goals through STEM), the stereotypes of these fields as predominantly masculine and less communal are maintained and will become harder to change even if greater numbers of women are recruited and retained in STEM. In order to change perceptions of STEM and increase the STEM workforce, we will need more women *and* men whose work and stated purpose relate to communal motives. In this review, we discuss the research that supports this possibility.

FOCUS OF THE CURRENT REVIEW

Our review proceeds in three parts. In Part 1, we first provide an overview of the communal goal perspective, with particular attention to *communal goal incongruity*—the idea that some STEM disciplines like engineering and computing are perceived as less likely to offer opportunities to meet communal goals. That is, when it comes to the "doing" of STEM work, these fields are seen as less collaborative and less centered on helping others. We focus on communal goals because communion and its counterpart agency are posited as the core human motivations necessary for optimal functioning (Bakan, 1966). Communal motivation involves a drive to connect, care, and share with others, whereas agentic motivation involves concerns of the self in terms of one's status, achievement, and independence. Communion and agency are key dimensions for judgments of the self and others (e.g., Judd et al., 2005; Abele and Wojciszke, 2007; Fiske et al., 2007).

Moreover, these goals serve as a lens for how people view and choose different environments like STEM fields (e.g., Diekman and Eagly, 2008; Diekman et al., 2017). When making the decision to enter, stay, or leave a setting, people draw upon beliefs about whether a role will allow them to pursue goals (i.e., *goal affordances*) to determine which of their valued goals can be accomplished (or might be impeded) within the setting. When there is a match between the environment and our goals, we experience *goal congruity*. Goal congruity prompts a state of "motivational readiness" and a pleasant sense of fit (e.g., Kruglanski et al., 2014), whereas goal incongruity can inspire questions about how to achieve congruity, and this search often leads us to change or leave the environment. Thus, communal goal incongruity has been posited as an explanation for differences in STEM interest and success, and this evidence will be reviewed in this part.

When available, we include evidence of communal goal incongruity for individuals in computer science and engineering, as women remain especially underrepresented in these STEM disciplines (e.g., National Science Foundation, 2015; National Science Board, 2016). Next, we extend this perspective to understand how communal goal endorsement and beliefs about communal opportunities in STEM might deter other groups from pursuing STEM (e.g., underrepresented minority students, communally-oriented men, and first generation college students; Part 2). Finally, our review closes with recommendations for offering and highlighting communal opportunities in computing and engineering (Part 3).

This review builds upon existing and emerging syntheses of the empirical literature. Two recent systematic reviews of gender differences in STEM have focused on the role of stereotypic perceptions in shaping gendered STEM participation. Cheryan et al. (2017) provide a model of the contributing factors to gender participation gaps in varying STEM fields, noting stereotypes of the fields as one key contributor. Diekman et al. (2017) review the existing evidence for this particular factor in relation to how STEM fields are stereotyped as less communal than other fields. Building from these syntheses, we conducted a more focused review to further elaborate the communal goal incongruity perspective. Specifically, we extend this perspective to focus beyond gender differences.

Past goal incongruity research has highlighted relative gender differences in the endorsement of communal goals and the impact of this endorsement on women's participation in STEM (e.g., Diekman et al., 2011). However, as with other psychological variables, a focus on gender difference can obscure the gender similarities that exist as well (Hyde, 2005). In this review, we thus examine how similar communal goal processes can explain the STEM decisions of a wide range of people from many different social groups. For example, accumulating evidence suggests that communal goals are highly valued for other group memberships besides women, yet there has not been an attempt to integrate these findings with those examining communal goal incongruity for women in STEM. Thus, our focused review has these two aims. We review new and accumulating evidence that suggests that perceived communal goal incongruity can deter *any* individual who values communal goals. This extension, thus, leads to the final novel contribution of our review, which is to focus on implications of communal goal incongruity for stereotype change and for interventions targeted to multiple groups. Making known the communal opportunities within STEM has the potential to benefit all communally-oriented people, including first generation college students, underrepresented racial and ethnic minority students, and communally-oriented men—as well as communally-oriented women.

To conduct this focused review, we obtained research through computerized literature searches via psychology (PsycINFO) and education (ERIC) databases. We restricted our search to published empirical papers that included the measurement of goals or motivation for both an underrepresented group in STEM (e.g., women, racial minorities) and a represented group in STEM (e.g., men, Whites). To examine similarities and differences for men and women in terms of communal goal endorsement, the following search terms were used: "gender differences" or "men AND women" with combinations of "goals," "motivation," "commun*," "STEM," "science," and "math*." Search results were similar when using "STEM," "science," or "math*." To examine similarities and differences for different racial and ethnic groups in terms of communal goal incongruity, the following search terms were used: "racial differences," "ethnic differences," "race," or "ethnicity" with combinations of "goals," "motivation," "commun*," "STEM," "science," and "math*." Again, search results were similar when using "STEM," "science," or "math*." Lastly, since papers examining first generation college student status came up in multiple searches, we used similar keyword searches for this group.

With the resulting citations from our literature searches, we first examined the titles for relevance and redundancy. If papers explored group differences in goals or motivations in academic contexts, we then reviewed the abstracts and main text to see if the paper's method and results fit the aim of our focused review: reviewing empirical evidence of differences in goals or motivation for underrepresented and better represented groups in STEM fields. Published papers that examined possible group differences in goals or motivation, particularly those relating to communion, are included in this focused review (see **Table 1** for included papers with a focus on gender and **Table 2** for included papers with a focus on race/ethnicity and first generation status).

PART 1. OVERVIEW OF EVIDENCE FOR COMMUNAL GOAL INCONGRUITY PROCESSES AS A DETERRENT IN STEM

Individuals can have multiple motivations for pursuing or not pursuing STEM fields, and these fields can be seen as affording multiple goals as well. Decisions can be based upon the perceived value and earning potential of and mobility within STEM occupations. Work-life balance may also be a goal that is considered in occupational choice (Ceci et al., 2009; Weisgram and Diekman, 2015). Although these goals are important, goals of communion and agency within the work itself may be critical for STEM occupational choices because STEM fields are often perceived as unbalanced in their ability to afford both communal and agentic goals. Goals of communion and agency, although sometimes viewed as opposing motivations, can co-exist; however, as we review below, STEM fields are perceived as affording greater opportunities for agency than communion.

Out of the various goals that people can pursue (e.g., work-life balance, financial security, mobility, status), communal goals are central to this review for several reasons. First, communal goals are beneficial for the individuals pursuing them and those who may benefit from their work. Pursuing communal goals helps fulfill needs for belonging (e.g., Baumeister and Leary, 1995; Fiske, 2004), connection (e.g., Deci and Ryan, 2000), and affiliation (e.g., Hill, 1987). Moreover, communal goals and activities are related to positive outcomes, such as greater social support, feeling more positive emotions, and less stress (e.g., Crocker and Canevello, 2008; Poulin et al., 2013; Poulin, 2014). These benefits extend to the workplace as collaboration with colleagues predicts scientific productivity (e.g., Landry et al., 1996; Lee and Bozeman, 2005) and having closer contact with people one helps at work relates to greater motivation and persistence in the workplace (e.g., Grant, 2007; Grant et al., 2007).

Secondly, stereotypes of communal goal affordances vary by occupational field. Regardless of whether it reflects the reality of these careers, people tend to perceive some careers as fulfilling more communal goals than other careers. STEM fields, and computing and engineering in particular, are viewed as fulfilling fewer communal goals than a wide range of other fields but are viewed as fulfilling similar agentic goals as other traditionally male-dominated fields (Diekman et al., 2011). Agentic motives are naturally important to achievement and success in STEM

TABLE 1 | Included studies in the focused review with a focus on gender.

Citations	Study characteristics	Relevant findings
Morgan et al., 2001	College students Cross-sectional Work goals for careers including STEM	Women were more likely to report that they planned to pursue a career because it was people oriented. Physical and mathematical sciences were seen as involving others to a lesser extent that careers in medicine or education.
Evans and Diekman, 2009	College students Cross-sectional Goal affordances and gender representation in fields including STEM	Male stereotypical fields were seen as deficient in caregiving affordances but high in status affordances, while female stereotypical fields were seen as the opposite. Women were more likely to endorse caregiving goals, and men were more likely to endorse status goals. Gender differences in goal endorsement mediated gender differences in interest in these careers.
Diekman et al., 2010	College students Cross-sectional Communal goal endorsement in STEM	STEM was seen as uniquely impeding communal goal pursuit, and communal goal endorsement negatively predicted STEM interest and mediated gender differences in STEM interest.
Diekman et al., 2011	College students Cross-sectional and experimental Communal stereotypes and goal activation in STEM	STEM is explicitly and implicitly stereotyped as lacking in communion. Activating communal goals resulted in lower interest in STEM careers, but not lower interest in non-STEM careers. Highlighting how science affords communal goals particularly increased women's positivity toward science careers.
Klotz et al., 2014	College-aged women and men Cross-sectional Communal goals in engineering	Students who weren't in engineering in comparison to engineering students were significantly less likely to believe that sustainability was associated with engineering. Believing that engineering could help save lives or improve quality of life significantly predicted intention to pursue an engineering career above and beyond gender and grades in math.
Brown et al., 2015a	College students Cross-sectional and experimental Goal affordances in biomedical science	Increasing science communal affordances increased research positivity and science career motivation; highlighting agentic affordances did not increase these outcomes.
Brown et al., 2015b	College students Cross-sectional and longitudinal Communal affordances in STEM	Controlling for STEM major status, communal goal affordances predicted STEM career interest, research task positivity, and career motivation. Beliefs that STEM afforded communal goals predicted science motivation 10–12 weeks later.
Clark et al., 2016	College students Cross-sectional and experimental Highlighting communal affordances in science	Increasing science communal affordances increased science career positivity for men and women with male and female scientists.
Stout et al., 2016	College students Longitudinal Gender roles and STEM stereotypes	Women who perceived physicial sciences as affording more communal goals at Time 1 took similar amounts of pSTEM courses as men 3 years later. Women who viewed pSTEM as deficient in communal affordances took fewer pSTEM courses than men 3 years later.
Fuesting and Diekman, 2017	College students Cross-sectional and experimental Communal role models in STEM	Participants viewed it as more challenging to locate communal STEM role models than communal role models in other fields. Women and men preferred to work with potential STEM advisors that exhibited communal characteristics.

(e.g., Diekman et al., 2017) and may also help individuals persist through the education necessary to pursue STEM careers. However, it is unlikely that highlighting how STEM fulfills self-oriented goals will make these fields more appealing; most individuals are already well aware how STEM can provide opportunities to pursue self-oriented goals, and highlighting STEM agentic affordances will only confirm individuals' beliefs about STEM. Alternatively, highlighting how STEM affords communal goals disrupts prevalent stereotypes about STEM and should, thus, increase interest in these careers.

Finally, as detailed below, there is also variability in communal goal endorsement across individuals, and members of groups underrepresented in STEM fields (i.e., women, racial and ethnic minorities, and first generation college students) tend to value communal goals to a greater extent than members of groups that are better represented (e.g., Evans and Diekman, 2009; Stephens et al., 2012; Smith et al., 2014; Harackiewicz et al., 2016). Taken together, a focus on communal goals can result in a better understanding of patterns of underrepresentation and ways to recruit

TABLE 2 | Included studies in the focused review with a focus on race/ethnicity and first generation status.

Citations	Study characteristics	Relevant findings
Fryberg and Markus, 2007	American Indian, Asian American, and European American college students at mainstream and tribal universities Cross-sectional Endorsement of interdependent selves and views of education	American Indian college students mentioned helping one's communities more and had more negative associations with education. American Indian college students emphasized family and community concerns more than academic concerns. American Indian and Asian American college students endorsed both independent and interdependent self-representations, while European Americans only endorse independent ones.
Stephens et al., 2012	University administrators and first generation and continuing generation college students Cross-sectional, longitudinal, and experimental Assessing university cultural norms of interdependence and independence and their impact on students	Universities have norms that primarily emphasize independence. There is a mismatch between universities' emphasis on independence with first generation students' goals of interdependence, and this mismatch predicts lower grades. Goal mismatch undermined first generation college students' performance relative to goal matching for interdependence.
Fryberg et al., 2013	Native American and European American high school students Cross-sectional Endorsement of independent and interdependent selves and impact on performance and trust	Native American students showed more interdependent self-representations and less trust for teachers, and interdependent self-representations and teacher trust were positively related to their academic performance.
Smith et al., 2014	Native American and White American college freshmen STEM and non-STEM majors Cross-sectional and longitudinal Communal goal incongruence in STEM	Native American STEM freshmen (men and women) more highly endorsed communal work goals. Communal goal endorsement predicted belonging uncertainty, lower motivation, and perceived poor performance in a later semester.
Allen et al., 2015	Generation status (first and continuing) at a minority-serving institution College students and research assistants in science Cross-sectional and longitudinal Work, communion, and agentic goals, and science interest	First generation college students who believe science can afford communal goals are more interested in science. First generation college students want to stay closer to home for graduate education, and higher communal goal orientation predicted this tendency to want to stay closer to home. Race/ethnicity did not explain the patterns for either study for first generation college students.
Covarrubias and Fryberg, 2015	Latino and White college students of first and continuing generations Cross-sectional and experimental Highlighting communal behavior and its impact on family achievement guilt for attending college	First generation college students have greater family achievement guilt, with Latino first generation students reporting the most. First generation college students who reflected on a time they helped their family reported less family achievement guilt.
Thoman et al., 2015	Underrepresented racial minorities in STEM and those from well-represented groups College students working in biomedical labs at universities and tribal colleges Longitudinal Communal values and science research interest	Underrepresented minority student RAs who saw altruistic values in their research felt more involved and interested in science over time.
Harackiewicz et al., 2016	Race/ethnicity (underrepresented minority and not) and generation status (first and continuing) College students in biology course Longitudinal Utility value intervention in biology	The utility value intervention was particularly successful in reducing the achievement gap for first generation, underrepresented racial minorities in the biology course.

and retain more diverse groups of STEM majors and workers.

Perceived Goal Affordances in STEM

In the United States, stereotypes portray STEM fields as agentic occupations in which goals of independence and status can be pursued; however, these stereotypes also portray STEM fields as providing fewer opportunities than non-STEM fields to pursue communal goals. For instance, male and female undergraduates report that the physical sciences and mathematics allow fewer opportunities to work with and help others than careers in education, the social sciences, or medicine (Morgan et al., 2001). A similar pattern emerges when considering how STEM fields like engineering and computer science specifically relate to non-STEM occupations that are viewed as stereotypically male or female. Specifically, young men and women, both in STEM and other majors, view STEM occupations (e.g., engineering, computer science, and environmental science) as fulfilling fewer communal goals than stereotypically male non-STEM occupations (e.g., business) and stereotypically female non-STEM occupations (e.g., nursing; Diekman et al., 2010, 2011).

Looking within the subdisciplines of STEM, there is consistent evidence across multiple studies that computer science and engineering are viewed as even less communally oriented than many other STEM fields, a view reported by men and women. Careers in engineering and computer science (along with those in physical science and mathematics) were more strongly associated with agentic goals like self-direction and self-promotion than with communal goals (Stout et al., 2016). Other science-intensive careers in the biological and social sciences (e.g., anthropology, psychology) that exhibit more gender parity were conversely perceived as fulfilling more communal than agentic goals (Stout et al., 2016).

Due to widespread stereotypes that computing and engineering allow individuals fewer opportunities to pursue communal goals, a communally-oriented person can feel a lack of fit. The mismatch between what these fields afford and what motivates a person can lower people's motivation to pursue these fields. For example, valuing communal goals negatively predicts interest in engineering, environmental science, and computing even for people who feel that they are good at STEM (Diekman et al., 2010). It follows that these STEM fields may be less likely to attract people who highly value communal goals, many of whom belong to groups currently underrepresented in STEM (e.g., women, racial and ethnic minorities; Diekman et al., 2017). Members of these groups may opt out of STEM in favor of more communally-oriented fields in which they excel and that do not involve negative group stereotypes (e.g., Eccles, 1994; Wang et al., 2013).

Communal Goal Incongruity Is a Barrier for Women in STEM

Past research on communal goal incongruity has largely focused on how perceived goal incongruity can deter members of groups who are currently underrepresented in STEM because communal goals are especially valued by these groups. Women, on average, tend to value communal goals more strongly than men (Evans and Diekman, 2009; Diekman et al., 2011). If STEM environments are perceived as not valuing and not capable of fulfilling communal goals, then communal goal incongruity may reduce women's motivation to pursue STEM (see Diekman and Steinberg, 2013; Diekman et al., 2017, for further review). Conversely, fields that are perceived to afford communal goals attract people who are communally-oriented, and the experience of fit due to goal congruity can result in greater interest and motivation in these fields. In this way, communally-oriented women may be pulled into non-STEM fields in addition to being pushed out of STEM fields.

Correlational evidence from Morgan et al. (2001) found that compared to men, women placed greater importance on interpersonal work goals, perceived STEM fields like the physical sciences and mathematics to be less interesting, and were less likely to report plans to work in these fields. Importantly, experimental evidence shows that communicating that STEM fields can fulfill communal goals boosts women's STEM interest. For instance, women who learn that a scientist spends the day working with others (as opposed to working alone) exhibited particularly strong increases in their attitudes toward science careers (Diekman et al., 2011, Experiment 3).

Extending these findings beyond the lab, communal goal (mis)match relates to students' actual course taking behavior (Stout et al., 2016). This research demonstrated that gender differences in STEM college course taking stemmed from individuals who believe that engineering and computing do not fulfill communal goals: women who believed that engineering and computing fulfilled few other-oriented goals took fewer computing and engineering courses than men with similar beliefs. However, among students who believed that engineering and computing fulfilled relatively more communal goals, there was no gender gap in course taking. Men and women who similarly believe that computing and engineering fulfill communal goals demonstrate similar motivation to pursue computing and engineering courses. Therefore, differences in perceived communal opportunities can play a part in who is attracted to and persists in STEM. Promoting communal opportunities in STEM can increase the number of communally-oriented people in STEM. Without the increased representation of these individuals, stereotypes of these fields as less communal are likely maintained.

PART 2. EXTENSIONS OF THE COMMUNAL GOAL INCONGRUITY PERSPECTIVE TO OTHER GROUPS

Communal Goal Incongruity Is a Barrier for Other Underrepresented Groups in STEM

Although research on communal goal incongruity has mainly explored the impact of anticipated goal fit for women in STEM, other research has focused on communal goal processes for members of underrepresented racial/ethnic groups in STEM. Here, we integrate this work into the broader literature on communal goal incongruity in STEM contexts.

Black, Hispanic, and Native American students, both male and female, have less access to advanced STEM courses in high school (e.g., May and Chubin, 2003; Tyson et al., 2007; Perna et al., 2009) and are less likely to enter and receive degrees in STEM fields (e.g., National Science Foundation, 2015). Racial and ethnic minority students in STEM fields, especially in computing and engineering, continue to be underrepresented at all levels of these disciplines (e.g., American Association of University Women, 2010). This underrepresentation extends into the workplace as racial and ethnic minorities make up a small proportion of workers in STEM fields (e.g., U.S. Census Bureau, 2011).

Communal goal incongruity can influence underrepresented racial and ethnic minority students' overall success in college. Perceiving the culture of academia as one that emphasizes and rewards assertiveness and independence over connectedness and interdependence can lead to a perceived mismatch for racial and ethnic minority students; this mismatch can reduce belonging and impair performance in college (e.g., Fryberg and Markus, 2007; Fryberg et al., 2013). Moreover, research shows that this mismatch can lower well-being and impede the academic success of first generation college students—individuals who are the first member of their family to pursue college (e.g., Stephens et al., 2012; Covarrubias and Fryberg, 2015).

Seeing STEM fields in particular as less communal also negatively influences members of these groups who tend to highly value communal goals (e.g., Smith et al., 2014; Harackiewicz et al., 2016). Researchers have, thus, investigated whether communal goal incongruity reduces underrepresented minority students' STEM motivation. Native American STEM students exhibited less motivation to complete their majors and degrees if they valued communal goals (Smith et al., 2014). Moreover, beliefs that science fulfills altruistic goals predict increased science career motivation especially among students from underrepresented ethnic backgrounds (Thoman et al., 2015). Similarly for first generation college students, beliefs that science allows people to help others predict their science course interest, suggesting that perceptions that science does not fulfill communal goals may be particularly demotivating for first generation college students (Allen et al., 2015).

Communal goal congruity has emerged as a possible mechanism to enhance the full participation and success of students from diverse backgrounds in STEM fields. Engaging collaborative and altruistic motivations can yield benefits across different, underrepresented group memberships because these motives are highly valued and these opportunities are perceived as extremely scarce or nonexistent. Future research is needed to delineate these patterns within specific STEM disciplines like computer science and engineering and explore whether the content of communal goals and the interventions to highlight them will work for all underrepresented groups that value these goals.

Communal Goal Incongruity Can Also Push Men Out of STEM

Because members of underrepresented groups are more likely to be negatively affected by communal goal incongruity, most communal goal incongruity research focuses on the implications of noncommunal STEM stereotypes for recruiting and retaining a more diverse STEM student body and workforce. Developing strategies to increase and sustain motivation to pursue STEM careers among underrepresented groups in STEM is increasingly important and essential. However, *all* individuals who value communal goals—not just members of underrepresented groups in STEM—may be negatively influenced by communal goal incongruity.

Focusing on the relative group differences in communal goal endorsement between men and women can obscure that men also value communal goals. Although men exhibit lower averages than women, men still show relatively high levels of communal goal endorsement (e.g., Evans and Diekman, 2009; Diekman et al., 2011), demonstrating that men, too, value communal goals. If communally-oriented men perceive STEM environments as not valuing and not capable of fulfilling communal goals, they—like women—can experience the negative effects of communal goal incongruity (Diekman et al., 2017).

When communal goals are activated, both men and women exhibit reduced STEM interest in comparison to when communal goals are not activated (Diekman et al., 2011, Experiment 2). If people believe that science careers fulfill communal goals, both men and women who value communal goals exhibit more positive attitudes toward science careers (Diekman et al., 2011, Experiment 3). Individual differences in communal goal endorsement—and not group membership in and of itself—thus determines who will be most affected by communal goal incongruity (Diekman et al., 2011, 2017).

Relatedly, fostering congruity between one's personal goals and the environment can increase men and women's favorability toward science careers and their motivation to pursue them. Regardless of gender, beliefs that STEM fulfills communal goals predict undergraduates' increased motivation to pursue a science career (Brown et al., 2015b). In several experiments, both men and women exhibited increased science career motivation when they learned how scientific research fulfills other-oriented goals (Brown et al., 2015a). Moreover, learning that scientists integrate collaboration into their workdays—instead of learning that scientists spend their days working mostly alone—increases both men and women's attitudes toward pursuing a science career (Clark et al., 2016, Experiment 1). Although these studies do not focus specifically on computer science and engineering, they do showcase that men are similarly turned off to STEM fields in general when they personally value communion and do not view these fields as affording opportunity for it.

Consequences of Having Fewer Communally-Oriented Men in STEM

An implication of the communal goal incongruity perspective is that it is not sufficient to focus exclusively on women: in order to change the stereotypes of STEM fields and the people that work within them, we need to understand why more communally-oriented men may not enter STEM fields and why those already in STEM may not express their communal values within these fields. More specifically, stereotypes about computer science and engineering as masculine and less communal can be challenged in several ways. First, one can incorporate the stories and expressed motivations and purposes of women and men in these fields in publicized narratives and views of STEM. Secondly, one can showcase the variability among men and women in the goals and reasons for why they do the work that they do.

Because the United States needs all of the trained and skilled STEM professionals possible to be innovative and competitive, it is important to consider communally-oriented men's decisions to enter STEM, pursue their communal goals in STEM, and leave STEM. These decisions might illuminate how stereotypes of STEM fields are perpetuated and opportunities to view STEM fields as communal are reduced. If communally-oriented men leave or never enter STEM fields, the remaining men in STEM may be less interested and driven by the communal nature of their work and, thus, continue to shape STEM environments in ways that do not afford communal goals for those who are motivated by them. Outsiders looking in might only see individuals driven primarily by agentic goals and infer that STEM does not afford communal goals and work. In this way, the stereotype is reified and perpetuated.

Past research has not directly tested these predictions, but existing evidence is suggestive. First, as highlighted in Cheryan et al.'s (2017) review, the point in the STEM pipeline with the greatest gender gap is at the early recruitment stage. Current data suggest that there are fewer women than men entering STEM college majors, but retention patterns of these male and female students are not markedly different (Miller and Wai, 2015). What can explain these recruitment differences? The communal goal incongruity perspective reviewed here suggests that prevalent noncommunal views of STEM, coupled with women's higher endorsement of communal goals, could result in the gender gaps found in recruitment to STEM disciplines. However, among men and women who value communal goals and have entered STEM, experiencing a noncommunal culture may result in similar rates of departure because they do not feel like they belong in the current climate of these fields, irrespective of their gender. Indeed, research finds that by fostering a more communal view of STEM fields, men overall are not demotivated to pursue these fields (Diekman et al., 2011; Clark et al., 2016), and communally-oriented men may become more motivated and invested in pursuing STEM.

A second related point is that just as cultural norms and stereotypes constrain women's career options, men's interests and decisions are similarly shaped by societal expectations and values. Croft et al.'s (2015) review finds that men are less likely to seek out communal roles because of gender stereotypes about who is and should be communal (e.g., Deaux and Major, 1987; Fiske et al., 2002; Wood and Eagly, 2002), concerns about how manly they will be perceived by others (e.g., Bosson and Vandello, 2011; Vandello and Bosson, 2012), and possible status loss, social sanctions, and discrimination they may face by fulfilling communal roles and goals (e.g., Heilman and Wallen, 2010; Moss-Racusin et al., 2010).

From these findings, it is possible that more communally-oriented men face substantial identity threat by openly discussing their communal goals and staying in STEM due to the discrepancies between personally and societally-valued goals for men. Multiple threats to one's self-image and self-worth exist in STEM fields; however, for communally-oriented men, they could experience the worry and uncertainty tied to social identity threat when they believe that they could be viewed and evaluated negatively due to their non-conformity to the perceived norms and values of STEM fields and their gender (e.g., Murphy and Taylor, 2012; Boucher and Murphy, 2017). Subtle or explicit cues that signal that their communal goals and interests could be limiting to their inclusion and success and are not expected of men can trigger social identity threat, and over time, these experiences can push communally-oriented men to leave for a more "identity safe" career option or shore up more of their agentic motivation and behavior that fits the current climate. One potential example of this progression would be communally-oriented male STEM majors gravitating away from academic science to professions like medicine where they can pursue their communal goals but still can align with societally-valued goals due to medicine's revered and agentic status. By understanding how men are steered away from communal roles or why they feel pressure to pursue more agentic goals, we can better understand how climates in STEM fields became and remain masculinized and illuminate points of intervention to improve the culture for both men and women.

Lastly, speaking specifically to how STEM stereotypes may be maintained or even strengthened by more communally-oriented men leaving STEM fields, we can draw links to classic social psychological research on stereotype change and maintenance. Without exposure to and presence of communally-oriented men in STEM, the distinction between women and men may be sharper, and the exemplars that come to mind for each may be more prototypical and extreme (e.g., Hamilton and Sherman, 1994). When individuals perceive these two groups are less varied, they are more willing to apply group stereotypes to individual members (e.g., Park and Rothbart, 1982; Park and Hastie, 1987; Park et al., 1991) and more likely to subtype individuals who do not fit the gender stereotypes of their group (e.g., Weber and Crocker, 1983; Rothbart and John, 1985). In this way, stereotypes about STEM fields remain unchanged. However, if STEM fields bring to mind men and women who vary in their reasons for pursuing STEM and their communal goals within STEM, stereotypes may change because it is harder to subtype counterstereotypic individuals. Highlighting how individuals across genders value communal goals at differing strengths, instead of perpetuating perceptions that a certain gender alone highly values communal goals, can lead to changes in the stereotypes of STEM fields and who fits within them.

This past work suggests important future research directions for demonstrating how noncommunal STEM stereotypes are perpetuated by the departure or absence of more communally-oriented individuals and how these stereotypes can be changed by efforts to recruit and retain these individuals. By exploring how communal goal incongruity affects men and women in potentially similar or different ways, we can advance our theoretical understanding of women's underrepresentation in STEM fields that have come close to gender parity and those that still have stark differences in women's participation like computing and engineering. Moreover, this research agenda can provide further insights into how lab-based evidence can be extended in the field and applied to efforts to make STEM fields more inclusive and welcoming to all groups.

PART 3. RECOMMENDATIONS FOR REDUCING COMMUNAL GOAL INCONGRUITY

The research literature on communal goal incongruity holds great promise for application and intervention. Balancing the nearly exclusive emphasis on agentic goals over communal goals can encourage and maintain interest and participation in STEM fields, particularly for those who value communion. Although highlighting the communal affordances in STEM has benefits, this perspective does not argue for an exclusive focus on these goals, because underrepresentation in STEM fields is multiply determined (e.g., Cheryan et al., 2017).

Creating and emphasizing the existing communal opportunities in fields like computing and engineering allows us to de-emphasize gender and racial categories while providing a way for majority and minority groups to come together around a shared motivational orientation. When the focus is on underlying motivational orientations, recruitment efforts can focus on shared values that transcend rather than reify categories. De-emphasizing group categories has additional benefits of reducing identity threat (e.g., Steele et al., 2002; Akcinar et al., 2011) and fostering a common ingroup identity that can result in bias reduction (e.g., Gaertner and Dovidio, 2000). As such, we conclude with recommendations for how to integrate this knowledge about communal goal affordances into practice.

A central theme of the following recommendations is that STEM fields *do* afford communal goals (see initiatives like Coders Without Borders and Engineers Without Borders), and people who value communal goals have a place within these fields. Our recommendations involve making these aspects of STEM more widely known and appreciated by (a) helping to change how STEM fields themselves are seen, (b) providing opportunities to act communally, and (c) widening the range of people seen working within these fields. Efforts toward these aims include creative ways of showcasing STEM, hands-on STEM experiences, and role models who share one's goals. Since past research has nicely delineated the efforts we currently know to be helpful for recruiting and retaining women in STEM (e.g., American Association of University Women, 2015; Cheryan et al., 2015), our suggestions stem from the consideration of our argument for how communal goal incongruity affects women and men and, thus, we focus on efforts that can disrupt noncommunal STEM stereotypes for all.

Show Students That STEM Fields Are Communal

One way to increase interest in STEM is to change perceptions of what type of work these fields involve by making communal affordances known. Students do not often see the links to communal goals evident in STEM work (e.g., sustainability, food availability, medical innovations; Cunningham et al., 2005; National Academy of Engineering, 2008; Klotz et al., 2014). Therefore, complementing lessons of STEM concepts and skills with specific ways that these abilities and knowledge can improve the quality of lives or save lives can have great benefits for students (e.g., Freeman et al., 2014). Resources like Public Broadcasting Service's (PBS) STEM Education Resource Center include a wealth of accessible information about the real world applications of STEM work. After lessons that show STEM's communal possibilities, classroom activities that encourage students to make connections between STEM course material and their lives can further increase motivation and learning (e.g., Hulleman and Harackiewicz, 2009).

Provide Opportunities to Act Communally

In addition to conveying that STEM fields like computer science and engineering are communal, opportunities to practice collaboration and apply one's knowledge are needed. Participating in hands-on experiences that involve collaboration like solar car competitions and design challenges are one way to encourage students to act communally. Opportunities to work as a research assistant allows for more in-depth exposure to STEM work: these research opportunities show collaboration in action and familiarize students with the practical purposes of the work of which they are a part. As a successful example of implementing this in higher education, Harvey Mudd College provided research opportunities in computing after students' first year in college. This effort along with changes to curriculum and conference travel have resulted in the percentage of women graduating in computer science from 12% to around 40% in 5 years (Alvarado and Dodds, 2010; Alvarado and Judson, 2014).

Provide Role Models Who Speak to How They Are Able to Fulfill Their Communal Goals through Their Work in STEM

To draw more female students into STEM, past work highlights the benefits of female role models (e.g., Dasgupta, 2011; Stout et al., 2011). Contact with older female students and female professors in STEM classes leads to more positive self-views and attitudes toward STEM and greater motivation to pursue STEM careers. Female role models are also particularly important to retaining women once they enter STEM; seeing the successes of other women in STEM can help prevent the threatening effects of stereotypes that shed doubt on women's competencies in these fields (Drury et al., 2011; Stout et al., 2011).

Alternatively, to recruit more communally-oriented individuals—both women and men—a role model's communal pursuits and traits may be more important than her or his gender. Both men and women who demonstrate how their STEM careers allow them to pursue communal goals can effectively convey that STEM provides valued opportunities to pursue communal goals (Clark et al., 2016). Furthermore, people may be interested in engaging with other-oriented STEM role models, even if they do not share a gender identity with the role model. Regardless of the advisor's gender, both men and women in STEM preferred to work with a hypothetical advisor who collaborated frequently over an advisor who spent much of his or her time working alone. However, these communally-oriented role models were perceived as particularly scarce in STEM relative to other fields, such as education or medicine (Fuesting and Diekman, 2017).

Thus, having people who work in STEM fields communicate the valued communal aspects of their work reduces communal goal incongruity and increases STEM interest and the likelihood of pursuing these fields (e.g., Klotz et al., 2014). For example, people may get interested in STEM because they want to improve the integrity of their community's roads and bridges, develop computer systems that help make aviation safer and more efficient, provide clean drinking water and better sanitation to improve health and safety, or even fight internet-based human trafficking. By encouraging people to share why they got into their STEM field and why they do the work they do, these individuals can validate the communal goals of students considering taking classes or majoring in STEM fields and can make these fields seem more communally oriented to current students and future generations of students. For much younger students, interviewing STEM professionals about what drew them to the field and what they find most fulfilling about their work can challenge stereotypes at even earlier ages.

In this way, it is important to shine more light on those who are pursuing their communal goals through their work in STEM. This can be accomplished by touring nearby labs and attending conferences that attract speakers from diverse backgrounds and with diverse motivations. Calling back to the changes Harvey Mudd College made to their computer science program, first year students were given the opportunity to attend the annual Grace Hopper Celebration of Women in Computing hosted by the Anita Borg Institute for Women and Technology. Events like this offer great opportunities to learn more about the diversity of people in certain STEM fields and what motivates their work. Attending conferences and visiting labs are helpful because they widen the view of who STEM professionals are and what they do, allow for networking with people at all levels of the field, and provide inspiring exemplars.

The existing evidence points to the benefits of varying students' views of who works in STEM and the goals that motivate them. Female and male mentors who demonstrate how they integrate their communal goals into their careers play a crucial role in recruiting and retaining communally-oriented women and men in STEM. This strategy might be especially helpful in fields like computer science and engineering that have the greatest female underrepresentation and strongest perceived incongruity with communal goals.

As this review details, there have been many advances in the understanding of patterns of underrepresentation for women in STEM fields like engineering and computer science. Motivational perspectives provide insight as to why people choose some fields over others, and considering underlying communal processes and noncommunal stereotypes brings together these multiple factors of climate and early experience that sustain gender gaps. By better integrating and publically acknowledging communal opportunities in computing and engineering, the stereotypic perceptions of these fields could gradually change, making computing and engineering more inclusive and welcoming to all.

AUTHOR CONTRIBUTIONS

KB developed the review topic, conducted the literature review, led the writing of the paper, and revised the paper. MF helped develop the review topic, helped conduct the literature review, and contributed substantively to the writing and revising of the paper. AD helped develop the review topic and contributed substantively to the writing and revising of the paper. MM helped develop the review topic and contributed substantively to the writing and revision of the paper.

FUNDING

We want to acknowledge support for this work, provided by a NSF grant (GSE-1232364) awarded to AD and a NSF grant (DRL-1450755) awarded to MM.

REFERENCES

Abele, A. E., and Wojciszke, B. (2007). Agency and communion from the perspective of self versus others. *J. Pers. Soc. Psychol.* 93, 751–763. doi: 10.1037/0022-3514.93.5.751

Akcinar, E. N., Carr, P. B., and Walton, G. M. (2011). Interactions with men and Whites matter too. *Psychol. Inq.* 22, 247–251. doi: 10.1080/1047840X.2011.625606

Allen, J. M., Muragishi, G. A., Smith, J. L., Thoman, D. B., and Brown, E. R. (2015). To grab and to hold: cultivating communal goals to overcome cultural and structural barriers in first-generation college students' science interest. *Transl. Issues Psychol. Sci.* 1, 331–341. doi: 10.1037/tps0000046

Alvarado, C., and Dodds, Z. (2010). "Women in CS: An evaluation of three promising practices," in *Proceedings of the 41st SIGCSE Technical Symposium on Computer Science Education*, New York, NY; Milwaukee, WI: ACM Press. 10–13; 57–61.

Alvarado, C., and Judson, E. (2014). Using targeted conferences to recruit women into computer science. *Commun. ACM* 57, 70–77. doi: 10.1145/2500883

American Association of University Women (2010). *Why So few? Women in Science, Technology, Engineering, and Mathematics*. Washington, DC: American Association of University Women.

American Association of University Women (2015). *Solving the Equation: The Variables for Women's Success in Engineering and Computing*. Washington, DC: American Association of University Women.

Bakan, D. (1966). *The Duality of Human Existence: An Essay on Psychology and Religion*. Chicago, IL: Rand McNally.

Baumeister, R. F., and Leary, M. R. (1995). The need to belong: desire for interpersonal attachments as a fundamental human motivation. *Psychol. Bull.* 117, 497–529. doi: 10.1037/0033-2909.117.3.497

Bosson, J. K., and Vandello, J. A. (2011). Precarious manhood and its links to action and aggression. *Curr. Dir. Psychol. Sci.* 20, 82–86. doi: 10.1177/0963721411402669

Boucher, K. L., and Murphy, M. C. (2017). *Why So few?: The Role of Social Identity and Situational Cues in Understanding the Underrepresentation of Women in* STEM *Fields. Self and Social Identity in Educational Contexts*. New York, NY: Routledge.

Brown, E. R., Smith, J. L., Thoman, D. B., Allen, J. M., and Muragishi, G. (2015a). From bench to bedside: A communal utility value intervention to enhance students' biomedical science motivation. *J. Educ. Psychol.* 107, 1116–1135. doi: 10.1037/edu0000033

Brown, E. R., Thoman, D. B., Smith, J. L., and Diekman, A. B. (2015b). Closing the communal gap: The importance of communal affordances in science career motivation. *J. Appl. Soc. Psychol.* 45, 662–673. doi: 10.1111/jasp.12327

Ceci, S. J., Williams, W. M., and Barnett, S. M. (2009). Women's underrepresentation in science: sociocultural and biological considerations. *Psychol. Bull.* 135, 218–261. doi: 10.1037/a0014412

Cheryan, S., Master, A., and Meltzoff, A. N. (2015). Cultural stereotypes as gatekeepers: increasing girls' interest in computer science and engineering by diversifying stereotypes. *Front. Psychol.* 6:49. doi: 10.3389/fpsyg.2015.00049

Cheryan, S., Plaut, V. C., Davies, P. G., and Steele, C. M. (2009). Ambient belonging: how stereotypical cues impact gender participation in computer science. *J. Pers. Soc. Psychol.* 97, 1045–1060. doi: 10.1037/a0016239

Cheryan, S., Plaut, V. C., Handron, C., and Hudson, L. (2013). The stereotypical computer scientist: gendered media representations as a barrier to inclusion for women. *Sex Roles* 69, 58–71. doi: 10.1007/s11199-013-0296-x

Cheryan, S., Ziegler, S. A., Montoya, A. K., and Jiang, L. (2017). Why are some STEM fields more gender balanced than others? *Psychol. Bull.* 143, 1–35. doi: 10.1037/bul0000052

Clark, E. K., Fuesting, M. A., and Diekman, A. B. (2016). Enhancing interest in science: exemplars as cues to communal affordances of science. *J. Appl. Soc. Psychol.* 46, 641–654. doi: 10.1111/jasp.12392

Covarrubias, R., and Fryberg, S. A. (2015). Movin' on up (to college): first-generation college students' experiences with family achievement guilt. *Cult. Divers. Ethn. Minor. Psychol.* 21, 420–429. doi: 10.1037/a0037844

Crocker, J., and Canevello, A. (2008). Creating and undermining social support in communal relationships: the role of compassionate and self-image goals. *J. Pers. Soc. Psychol.* 95, 555–575. doi: 10.1037/0022-3514.95.3.555

Croft, A., Schmader, T., and Block, K. (2015). An underexamined inequality: cultural and psychological barriers to men's engagement with communal roles. *Pers. Soc. Psychol. Rev.* 19, 343–370. doi: 10.1177/1088868314564789

Cunningham, C. M., Lachapelle, C., and Lindgren-Streicher, A. (2005). "Assessing elementary school students' conceptions of engineering and technology," in *Proceedings of the 2005 American Society of Engineering Education Conference & Exposition*, (Portland, OR).

Dasgupta, N. (2011). Ingroup experts and peers as social vaccines who inoculate the self-concept: the stereotype inoculation model. *Psychol. Inq.* 22, 231–246. doi: 10.1080/1047840X.2011.607313

Deaux, K., and Major, B. (1987). Putting gender into context: an interactive model of gender-related behavior. *Psychol. Rev.* 94, 369–389. doi: 10.1037/0033-295X.94.3.369

Deci, E. L., and Ryan, R. M. (2000). The "what" and "why" of goal pursuits: human needs and the self determination of behavior. *Psychol. Inq.* 11, 227–268. doi: 10.1207/S15327965PLI1104_01

Diekman, A. B., Brown, E. R., Johnston, A. M., and Clark, E. K. (2010). Seeking congruity between goals and roles: a new look at why women opt out of science, technology, engineering, and mathematics careers. *Psychol. Sci.* 21, 1051–1057. doi: 10.1177/0956797610377342

Diekman, A. B., Clark, E. K., Johnston, A. M., Brown, E. R., and Steinberg, M. (2011). Malleability in communal goals and beliefs influences attraction to stem careers: evidence for a goal congruity perspective. *J. Pers. Soc. Psychol.* 101, 902–918. doi: 10.1037/a0025199

Diekman, A. B., and Eagly, A. H. (2008). "Of men, women, and motivation: A role congruity account," in *Handbook of Motivation Science*, eds W. L. Gardner and J. Y. Shah (New York, NY: Guilford Press), 434–447.

Diekman, A. B., and Steinberg, M. (2013). Navigating social roles in pursuit of important goals: a communal goal congruity account of STEM pursuits. *Soc. Personal. Psychol. Compass* 7, 487–501. doi: 10.1111/spc3.12042

Diekman, A. B., Steinberg, M., Brown, E. R., Belanger, A. L., and Clark, E. K. (2017). A goal congruity model of role entry, engagement, and exit: understanding communal goal processes in STEM gender gaps. *Pers. Soc. Psychol. Rev*. 21, 142–175. doi: 10.1177/1088868316642141

Drury, B. J., Siy, J. O., and Cheryan, S. (2011). When do female role models benefit women? The importance of differentiating recruitment from retention in STEM. *Psychol. Inq.* 22, 265–269. doi: 10.1080/1047840X.2011.620935

Eccles, J. S. (1994). Understanding women's educational and occupational choices: applying the Eccles et al. model of achievement-related choices. *Psychol. Women Q.* 18, 585–609. doi: 10.1111/j.1471-6402.1994.tb01049.x

Evans, C. D., and Diekman, A. B. (2009). On motivated role selection: gender beliefs, distant goals, and career interest. *Psychol. Women Q.* 33, 235–249. doi: 10.1111/j.1471-6402.2009.01493.x

Fiske, S. T. (2004). *Social Beings: A Core Motives Approach to Social Psychology*. Hoboken, NJ: Wiley.

Fiske, S. T., Cuddy, A. J., and Glick, P. (2007). Universal dimensions of social cognition: warmth and competence. *Trends Cogn. Sci.* 11, 77–83. doi: 10.1016/j.tics.2006.11.005

Fiske, S. T., Cuddy, A. J., Glick, P., and Xu, J. (2002). A model of (often mixed) stereotype content: competence and warmth respectively follow from perceived status and competition. *J. Pers. Soc. Psychol.* 82, 878–902. doi: 10.1037/0022-3514.82.6.878

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., et al. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proc. Natl. Acad. Sci. U.S.A.* 111, 8410–8415. doi: 10.1073/pnas.1319030111

Fryberg, S. A., Covarrubias, R., and Burack, J. A. (2013). Cultural models of education and academic performance for Native American and European American students. *Sch. Psychol. Int.* 34, 439–452. doi: 10.1177/0143034312446892

Fryberg, S. A., and Markus, H. R. (2007). Cultural models of education in American Indian, Asian American and European American contexts. *Soc. Psychol. Educ.* 10, 213–246. doi: 10.1007/s11218-007-9017-z

Fuesting, M. A., and Diekman, A. B. (2017). Not by success alone: role models provide pathways to communal opportunities in STEM. *Pers. Soc. Psychol. Bull.* 43, 163–176. doi: 10.1177/0146167216678857

Gaertner, S. L., and Dovidio, J. F. (2000). *Reducing Intergroup Bias: The Common Ingroup Identity Model*. New York, NY: Psychology Press.

Grant, A. M. (2007). Relational job design and the motivation to make a prosocial difference. *Acad. Manag. Rev.* 32, 393–417. doi: 10.5465/AMR.2007.243 51328

Grant, A. M., Campbell, E. M., Chen, G., Cottone, K., Lapedis, D., and Lee, K. (2007). Impact and the art of motivation maintenance: the effects of contact with beneficiaries on persistence behavior. *Organ. Behav. Hum. Decis. Process* 103, 53–67. doi: 10.1016/j.obhdp.2006.05.004

Hamilton, D. L., and Sherman, J. W. (1994). "Stereotypes," in *Handbook of Social Cognition*, *Vol. 2, Applications*, eds R. S. Wyer a T. K. Srull (Hillsdale, NJ: Erlbaum), 1–68.

Harackiewicz, J. M., Canning, E. A., Tibbetts, Y., Priniski, S. J., and Hyde, J. S. (2016). Closing achievement gaps with a utility-value intervention: disentangling race and social class. *J. Pers. Soc. Psychol.* 111, 745–765. doi: 10.1037/pspp0000075

Heilman, M. E., and Wallen, A. S. (2010). Wimpy and undeserving of respect: penalties for men's gender-inconsistent success. *J. Exp. Soc. Psychol.* 46, 664–667. doi: 10.1016/j.jesp.2010.01.008

Hill, C. A. (1987). Affiliation motivation: people who need people... but in different ways. *J. Pers. Soc. Psychol.* 52, 1008–1018. doi: 10.1037/0022-3514.52.5.1008

Hulleman, C. S., and Harackiewicz, J. M. (2009). Promoting interest and performance in high school science classes. *Science* 326, 1410–1412. doi: 10.1126/science.1177067

Hyde, J. S. (2005). The gender similarities hypothesis. *Am. Psychol.* 60, 581–592. doi: 10.1037/0003-066X.60.6.581

Judd, C. M., James-Hawkins, L., Yzerbyt, V., and Kashima, Y. (2005). Fundamental dimensions of social judgment: understanding the relations between judgments of competence and warmth. *J. Pers. Soc. Psychol.* 89, 899–913. doi: 10.1037/0022-3514.89.6.899

Klotz, L., Potvin, G., Godwin, A., Cribbs, J., Hazari, Z., and Barclay, N. (2014). Sustainability as a route to broadening participation in engineering. *J. Eng. Educ.* 103, 137–153. doi: 10.1002/jee.20034

Kruglanski, A. W., Chernikova, M., Rosenzweig, E., and Kopetz, C. (2014). On motivational readiness. *Psychol. Rev.* 121, 367–388. doi: 10.1037/a0037013

Landry, R., Traore, N., and Godin, B. (1996). An econometric analysis of the effect of collaboration on academic research productivity. *High. Educ.* 32, 283–301. doi: 10.1007/BF00138868

Lee, S., and Bozeman, B. (2005). The impact of research collaboration on scientific productivity. *Soc. Stud. Sci.* 35, 673–702. doi: 10.1177/0306312705052359

Leins, C. (2016). *Tennessee Girl Creates Algorithm to Stop Adverse Reactions to Prescription Drugs*. U.S. News & World Report. Available online at: http://www.usnews.com

Lennon, C. (2014). *Lack of Skilled Workers Threatens Economic Growth*. U.S. News & World Report. Available online at: http://www.usnews.com

May, G. S., and Chubin, D. E. (2003). A retrospective on undergraduate engineering success for underrepresented minority students. *J. Eng. Educ.* 92, 27–39. doi: 10.1002/j.2168-9830.2003.tb00735.x

Miller, D. I., and Wai, J. (2015). The bachelor's to Ph. D. STEM pipeline no longer leaks more women than men: a 30-year analysis. *Front. Psychol.* 6:37. doi: 10.3389/fpsyg.2015.00037

Morgan, C., Isaac, J. D., and Sansone, C. (2001). The role of interest in understanding the career choices of female and male college students. *Sex Roles* 44, 295–320. doi: 10.1023/A:1010929600004

Moss-Racusin, C. A., Phelan, J. E., and Rudman, L. A. (2010). When men break the gender rules: status incongruity and backlash against modest men. *Psychol. Men Masc.* 11, 140–151. doi: 10.1037/a0018093

Murphy, M. C., and Taylor, V. J. (2012). "The role of situational cues in signaling and maintaining stereotype threat," in *Stereotype Threat: Theory, Process, and Application*, eds M. Inzlicht and T. Schmader (New York, NY: Oxford University Press), 17–33.

National Academy of Engineering (2008). *Changing the Conversation: Messages for Improving Public Understanding of Engineering*. Washington, DC: National Academies Press.

National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, Rising above the Gathering Storm Committee (2010). *Rising Above the Gathering Storm, Revisited: Rapidly Approaching Category 5*. Washington, DC: National Academies Press.

National Science Board (2016). *Science and Engineering Indicators 2016 (NSB-2016-1)*. Arlington, VA: Author.

National Science Foundation (2015). *National Center for Science and Engineering Statistics. Women, Minorities, and Persons with Disabilities in Science and Engineering: 2015. NSF 15-311*. Arlington, VA: National Science Foundation.

Park, B., and Hastie, R. (1987). Perception of variability in category development: instance-versus abstraction-based stereotypes. *J. Pers. Soc. Psychol.* 53, 621–635. doi: 10.1037/0022-3514.53.4.621

Park, B., Judd, C. M., and Ryan, C. S. (1991). Social categorization and the representation of variability information. *Eur. Rev. Soc. Psychol.* 2, 211–245. doi: 10.1080/14792779143000079

Park, B., and Rothbart, M. (1982). Perception of out-group homogeneity and levels of social categorization: memory for the subordinate attributes of in-group and out-group members. *J. Pers. Soc. Psychol.* 42, 1051–1068. doi: 10.1037/0022-3514.42.6.1051

Perna, L., Lundy-Wagner, V., Drezner, N. D., Gasman, M., Yoon, S., Bose, E., et al. (2009). The contribution of HBCUs to the preparation of African American women for STEM careers: a case study. *Res. High. Educ.* 50, 1–23. doi: 10.1007/s11162-008-9110-y

Poulin, M. J. (2014). Volunteering predicts health among those who value others: two national studies. *Health Psychol.* 33, 120–129. doi: 10.1037/a0031620

Poulin, M. J., Brown, S. L., Dillard, A. J., and Smith, D. M. (2013). Giving to others and the association between stress and mortality. *Am. J. Public Health* 103, 1649–1655. doi: 10.2105/AJPH.2012.300876

Rothbart, M., and John, O. P. (1985). Social categorization and behavioral episodes: a cognitive analysis of the effects of intergroup contact. *J. Soc. Issues* 41, 81–104. doi: 10.1111/j.1540-4560.1985.tb01130.x

Schott, G., and Selwyn, N. (2000). Examining the "male, antisocial" stereotype of high computer users. *J. Educ. Comput. Res.* 23, 291–303. doi: 10.2190/V98R-5ETX-W9LY-WD3J

Smith, J. L., Cech, E., Metz, A., Huntoon, M., and Moyer, C. (2014). Giving back or giving up: native American student experiences in science and engineering. *Cult. Divers. Ethn. Minor. Psychol.* 20, 413–429. doi: 10.1037/a0036945

Steele, C. M., Spencer, S. J., and Aronson, J. (2002). Contending with group image: the psychology of stereotype and social identity threat. *Adv. Exp. Soc. Psychol.* 34, 379–440. doi: 10.1016/S0065-2601(02)80009-0

Stephens, N. M., Fryberg, S. A., Markus, H. R., Johnson, C. S., and Covarrubias, R. (2012). Unseen disadvantage: how American universities' focus on independence undermines the academic performance of first-generation college students. *J. Pers. Soc. Psychol.* 102, 1178–1197. doi: 10.1037/a0027143

Stout, J. G., Dasgupta, N., Hunsinger, M., and McManus, M. A. (2011). STEMing the tide: using ingroup experts to inoculate women's self-concept in science, technology, engineering, and mathematics (STEM). *J. Pers. Soc. Psychol.* 100, 255–270. doi: 10.1037/a0021385

Stout, J. G., Grunberg, V. A., and Ito, T. A. (2016). Gender roles and stereotypes about science careers help explain women and men's science pursuits. *Sex Roles* 75, 490–499. doi: 10.1007/s11199-016-0647-5

Thoman, D. B., Brown, E. R., Mason, A. Z., Harmsen, A. G., and Smith, J. L. (2015). The role of altruistic values in motivating underrepresented minority students for biomedicine. *Bioscience* 65, 183–188. doi: 10.1093/biosci/biu199

Tyson, W., Lee, R., Borman, K. M., and Hanson, M. A. (2007). Science, technology, engineering, and mathematics (STEM) pathways: high school science and math coursework and postsecondary degree attainment. *J. Educ. Stud. Placed Risk* 12, 243–270. doi: 10.1080/10824660701601266

U.S. Census Bureau (2011). *2006-2010 American Community Survey: EEO 1w; Detailed Census Occupation by Sex and Race/Ethnicity for Worksite Geography; Civilians Employed at Work 16 Years and Over*. Generated by the authors with American Fact Finder at factfinder2.census.gov.

U.S. Department of Education (2006). *A Test of Leadership: Charting the Future of U.S.* higher education. Washington, DC: U.S. Department of Education.

Vandello, J. A., and Bosson, J. K. (2012). Hard won and easily lost: a review and synthesis of theory and research on precarious manhood. *Psychol. Men Masc.* 14, 101–113. doi: 10.1037/a0029826

Wang, M. T., Eccles, J. S., and Kenny, S. (2013). Not lack of ability but more choice: individual and gender differences in choice of careers in science, technology, engineering, and mathematics. *Psychol. Sci.* 24, 770–775. doi: 10.1177/0956797612458937

Weber, R., and Crocker, J. (1983). Cognitive processes in the revision of stereotypic beliefs. *J. Pers. Soc. Psychol.* 45, 961–977. doi: 10.1037/0022-3514.45.5.961

Weisgram, E., and Diekman, A. (2015). Family friendly STEM: perspectives on recruiting and retaining women in STEM fields. *Int. J. Gender Sci. Technol.* 8, 38–45. Available online at: http://genderandset.open.ac.uk/index.php/genderandset/index

Wood, W., and Eagly, A. H. (2002). A cross-cultural analysis of the behavior of women and men:Implications for the origins of sex differences. *Psychol. Bull.* 128, 699–727. doi: 10.1037/0033-2909.128.5.699

Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Psychology

PERSPECTIVE
published: 15 December 2017
doi: 10.3389/fpsyg.2017.02138

Check for updates

The Leadership Lab for Women: Advancing and Retaining Women in STEM through Professional Development

Ellen B. Van Oosten, Kathleen Buse and Diana Bilimoria*

Weatherhead School of Management, Case Western Reserve University, Cleveland, OH, United States

Innovative professional development approaches are needed to address the ongoing lack of women leaders in science, technology, engineering, and math (STEM) careers. Developed from the research on women who persist in engineering and computing professions and essential elements of women's leadership development, the Leadership Lab for Women in STEM Program was launched in 2014. The Leadership Lab was created as a research-based leadership development program, offering 360-degree feedback, coaching, and practical strategies aimed at increasing the advancement and retention of women in the STEM professions. The goal is to provide women with knowledge, tools and a supportive learning environment to help them navigate, achieve, flourish, and catalyze organizational change in male-dominated and technology-driven organizations. This article describes the importance of creating unique development experiences for women in STEM fields, the genesis of the Leadership Lab, the design and content of the program, and the outcomes for the participants.

Keywords: women's leadership development, women in STEM, gender bias, individual change, coaching

OPEN ACCESS

Edited by:
Radha R. Sharma, Management Development Institute, India

Reviewed by:
Robert Jason Emmerling, ESADE Business School, Spain
Chunyu Zhang, Shaanxi Normal University, China
Karen C. Eboch, Bowling Green State University, United States

***Correspondence:**
Ellen B. Van Oosten
ellen.vanoosten@case.edu

Specialty section:
This article was submitted to Organizational Psychology, a section of the journal Frontiers in Psychology

Received: *15 January 2017*
Accepted: *23 November 2017*
Published: *15 December 2017*

Citation:
Van Oosten EB, Buse K and Bilimoria D (2017) The Leadership Lab for Women: Advancing and Retaining Women in STEM through Professional Development. Front. Psychol. 8:2138. doi: 10.3389/fpsyg.2017.02138

RETAINING THE BEST AND BRIGHTEST

Carrie Jenkins felt the presentation to senior management went really well. As a program manager for a mid-sized manufacturing company, she oversaw the largest engineering project the company had ever had. Senior management recognized her and her team for effectively completing the project on time and under budget and promoted her to senior project manager shortly thereafter. What the management team did not know was that 1 year earlier, she was actively engaged in an external job search.

The vignette above is a true story about Carrie Jenkins[1], a 44-year-old engineering manager with 20 years of experience. After graduating with undergraduate and graduate degrees in biomedical engineering, she worked as a design engineer for a consumer products company. Outside of work, she was married with three children and struggled to juggle the constant demands of work and family. While she loved her work, her relationship with her manager, Jerry, was a source of constant stress. Jerry had a command-and-control leadership style and preferred to give orders rather than ask for input or engage in dialog. The advice he often gave Carrie was to adopt a more assertive style when presenting to management. He encouraged her to be dominating, such as pounding her fist to emphatically convey important points. Carrie followed his advice and became more authoritative in her style and highly directive with her associates. However, she never felt comfortable, and it wasn't working well. Her team operated in

[1]Names of individuals in this article have been disguised to protect participant identity.

silos and seemed to wait for her to make all the decisions, which was a constant source of frustration. After years of trying to motivate the team, she concluded that she was not a good fit for the company and began to look elsewhere.

In the midst of her job search, her organization learned of a professional development program specifically for women in STEM fields and invited Carrie to attend. Through the experience, Carrie discovered that her preferred leadership style, which was collaborative and democratic, could work effectively. She developed a personal vision and discovered that her values and strengths overlapped well with the organization's culture. She gained the confidence to be authentic in her approach. Great things began to happen. Her team trusted her more, became more unified, and performed at a higher level. Carrie became re-engaged and re-energized in her work and suspended her job search. A promotion to Program Manager came a few months after her graduation from the program. Carrie reflected upon her experience in this way: "The biggest eye-opener was that I needed to be true to myself and that I can be effective as myself, but I will never be effective trying to be someone else".

The Leadership Lab is a professional and leadership development program specifically for women in the science, technology, engineering, and math fields (STEM) just like Carrie Jenkins. In this article, we describe the origin and design of the program and discuss why this type of professional development is needed to advance and retain women in STEM professions. Finally, we highlight initial outcomes of the program.

BARRIERS TO ADVANCEMENT

Women's participation in the United States. labor force has grown exponentially over the past seven decades to the point where women comprised 47% of the workforce and 52% of professional and management occupations in US Bureau of Labor Statistics (2015). However, women continue to be under-represented at the highest levels of leadership with only 5% of Fortune 500 CEOs and 20% of corporate board positions held by women (Catalyst, 2016). In the STEM professions, women represent 46% of scientists, with higher representation in social, biological, and medical sciences, 25% of those in computer and mathematical professions and 12% of those in the engineering professions (US Bureau of Labor Statistics, 2015).

Previous studies have identified obstacles that women must overcome to be successful in the STEM workplace. These barriers and biases have been summarized into the following categories: structural barriers within the educational system; individual and psychological factors; family influences and expectations; and perceptions of the STEM educational and the workplace experiences (Kanny et al., 2014). Despite these barriers to women's professional achievement, many institutions are focused on increasing the representation and advancement of women in the engineering and computing professions. These include educational institutions (Klawe, 2014; Anderson, 2016), government agencies (National Academies, 2016; National Institutes of Health, 2016), non-profits (Corbett and Hill, 2015; National Center for Women in Technology, 2016; Society of Women Engineers, 2016) and corporations (Google, 2014; Loosvelt, 2016). The primary impetus for this is because an inclusive culture provides tangible benefits for organizations (Manjdo, 2014; Post and Byron, 2015), societies (Katrin Elborgh-Woytek, 2013), as well as for individual women (David Beede, 2011). Despite these benefits, women leave certain STEM professions such as engineering at double the rate of men (Frehill, 2008), creating a brain drain of talent and a persistent challenge for organizations.

Previous organizational efforts to create gender balance in leadership have primarily focused on reducing gender discrimination and increasing attention on diversity and inclusion through company-wide policies and programs, yet such initiatives have failed to create more gender-diverse workforce participation and leadership (Ely et al., 2011). Female STEM professionals continue to experience real barriers to advancement, retention, and leadership. Organizational studies investigating female under-representation, particularly in leadership, have shifted from examining more visible efforts to exclude women (e.g., overt acts of sex-based discrimination such as banning women from the shop floor) to more subtle forces, also known as *implicit bias* or second-generation bias (Ely et al., 2011). Implicit bias consists of stereotypical beliefs about gender that pose invisible barriers to women's advancement, as well as workplace structures and everyday practices that inadvertently favor men. For example, women often lack access to the informal networks necessary for advancement, potentially disadvantaging them when promotion decisions are being made. Because science and technology professions and industries like science, engineering, and manufacturing are stereotypically viewed as male-dominated, women may experience difficulties in the form of second-generation biases while working in these fields (Heilman et al., 2004).

DEVELOPING WOMEN WHO PERSIST AND SUCCEED

In research examining women who persist in engineering careers, individual factors and contextual experiences separated those who remained from those who opted out (Buse et al., 2013; Buse and Bilimoria, 2014). The individual factors included self-efficacy, having a career identity and the ability to see a better future, adaptability, and being engaged at work. Contextual experiences related to a woman's choice of engineering, work experiences as an engineer, and her family situation. Career commitment was found to be influenced by work engagement, a personal vision, and an interaction between the age and number of children (Buse and Bilimoria, 2014). In other work, researchers examined the organizational conditions under which women are more likely to succeed in STEM workplaces to include supportive managers, policies and practices that encourage work-life integration, and an equitable gender climate (Bilimoria and Lord, 2014). Overall, women who persist understand themselves and what they want from life, nurture supportive relationships personally and professionally, recognize the impact of socio-cultural factors on their ability to achieve, and take initiative to overcome bias and barriers.

Given the barriers, advancing and retaining women in traditionally male-dominated professions requires organizations to implement strategies for professional development tailored to address the gendered context of women's careers and lives. Research in women's leadership development suggests a number of factors promote an ascent to leadership, including self-awareness (Taylor et al., 2016), a holistic self-concept and identity (Ely et al., 2011; Debebe et al., 2016; Sugiyama et al., 2016) and a personal vision (Buse and Bilimoria, 2014). Having an understanding of implicit bias including workplace practices is also essential. Women are urged to understand and overcome gender bias (Lanaj and Hollenbeck, 2015); however, many women are not even aware when bias is occurring (Crosby, 1984, 1986).

STEM female professionals benefit from mentors and coaches who provide support and inspiration. Developmental relationships, such as those with mentors and coaches, provide psychosocial support and career development advice (Kram, 1985). Since women learn well through others' stories of success and struggle (Debebe, 2011), women-only leadership development programs have been recommended (Debebe et al., 2016), especially for populations lacking critical mass such as women in leadership and women in STEM disciplines. Furthermore, peer coaching provides a safe environment for developmental feedback to be exchanged and mutual learning to occur (Parker et al., 2014). In the next section, we explain the participant profile and share program objectives, content, and other design elements of the Leadership Lab.

LEADERSHIP LAB PROGRAM PARTICIPANTS AND DESIGN

The Leadership Lab Program was developed to address the unique context of women's experience in technical roles and organizations and to provide participants the knowledge, skills, connections, and support to succeed and catalyze change in their organizations. Research from several streams shaped the design for the program including: why women persist in STEM roles (Buse and Bilimoria, 2014), self-awareness and self-efficacy in women's leadership development (O'Neil et al., 2015; Sugiyama et al., 2016), emotional intelligence in leadership effectiveness (Goleman et al., 2002), the catalytic power of a personal vision (Smith et al., 2009; Buse and Bilimoria, 2014; Passarelli, 2015) and the positive impact of coaching relationships (Smith et al., 2009). Intentional Change Theory (ICT) provided a framework for participants to engage in professional development. ICT describes a process that facilitates learning, growth, and change through five phases of discovery including the ideal self, the real self, learning agenda, experimentation and practice, and supportive, trusting relationships (Boyatzis and Akrivou, 2006; Boyatzis, 2008).

In the Leadership Lab, five themes characterized participants' hopes and expectations for their development experience: influencing others in a male-dominated environment, becoming re-energized in their choice of a STEM career, developing "soft" skills including how to communicate with and manage diverse others, and navigating a balance between career and personal life. The Leadership Lab design was purposeful in addressing these components, which are critical for women's advancement.

Led by female instructors with experience with STEM professions, the program learning objectives included helping participants to (a) understand the complex factors impacting women in male-dominated professions, (b) recognize the value women bring to the STEM workplace, (c) explore factors for leadership effectiveness, and (d) develop strategies and skills to flourish professionally and personally. Individual, relational, organizational, and socio-cultural factors impacting women's effectiveness and success were explored throughout the program as illustrated in **Figure 1**. An emphasis was placed on helping women to develop self-awareness, self-efficacy, emotional intelligence and coaching capability.

The program design included seven days of experiential learning, scheduled in three modules over three months. The first module focused on the bias, barriers, and opportunities facing women in STEM and the power of a personal vision. The second module addressed skill development in the areas of leadership and emotional intelligence. The third module focused on skills and strategies for leading the way forward. Topics covered during these modules included gender diversity in organizations, implicit bias, resonant leadership, emotional intelligence, self-efficacy, negotiations, leadership presence, and coaching. Participants completed assessments to encourage self-awareness, including a 360-degree report on emotional

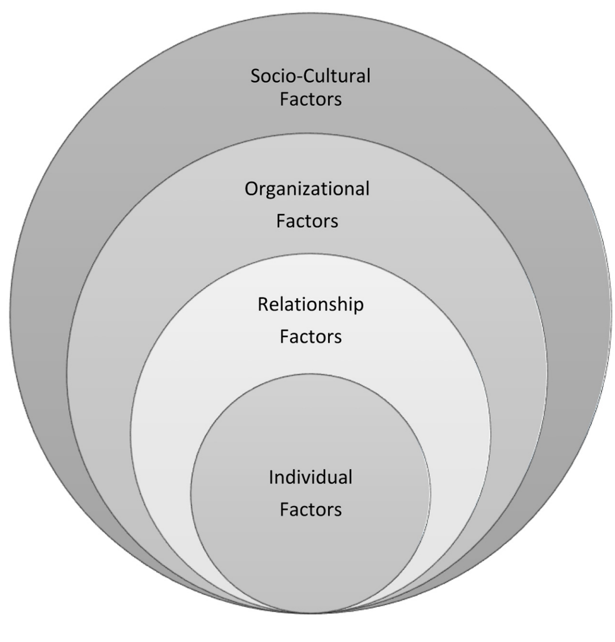

FIGURE 1 | Levels of learning addressed in the Leadership Lab.

intelligence. They were paired with an executive coach and met three times over the course of the program. Coaches worked between residencies to help participants explore their passion, values, career aspirations, emotional triggers and developmental focus. Participants also practiced peer coaching in triads which served as a source of ideas, feedback and psychosocial support for team members. Peer coaching triads met three times during the program. On the final day of the program, the manager of each participant was invited to attend a graduation luncheon, where s/he hear a program summary and insights gleaned by the participants.

To date, the program has been offered five times, with three cohort groups representing women in STEM generally and two cohorts representing women in manufacturing. Women participants were nominated and supported by their organizations. Participant work experience ranged from 5 to 25 years. The women represented a variety of positions such as Senior Quality Engineer, Engineering Program Manager and Project Manager for the STEM cohort and Global Environment and Sustainability Manager for the manufacturing cohorts.

ENCOURAGING OUTCOMES

Over 50 women have completed the Leadership Lab in the past three years, and the feedback has been overwhelmingly positive. In participant feedback collected post-program through surveys and interviews, four themes were mentioned most by the participants: (a) job promotions, (b) heightened awareness of unconscious bias and how to mitigate it, (c) stories of personal transformation around self-efficacy and breaking counter-productive thinking and behavior, and (d) benefits received from coaching relationships.

Participants have continued to stay connected with their cohort and with the faculty. Each cohort has created a medium to stay connected; several use Facebook groups, one uses a LinkedIn group, and another meets quarterly by video conference. From these connections, we know that the attendees have been retained in their professions, although a long-term study is needed to validate the impact of the program on retention. Based on participant testimonials, it was estimated that about 40% of the women had sought and received a promotion within 12 months of completing the program.

Beyond positioning women for advancement, the program helps women to understand and address the barriers often characteristic of male-dominated workplaces and to know ways to better navigate the environment. Take Andrea, for example. She was a research engineer working for an aerospace organization. After 5 years, she felt stuck and did not feel as if she was going to advance. She applied to the Leadership Lab in hopes it would re-energize her and boost her career prospects. While in the program, Andrea applied for a project manager position, which had been a long-time career ambition and was offered the job. Prior to starting, she was contacted by two male managers at another division who invited her to meet. Andrea looked forward to it, thinking it would be good to get to know her new colleagues before working together. The managers had a different idea. Andrea recalled the experience:

> *"Their message was, 'we don't think you're the right person for this job. We think our candidate is better and she should have gotten the job.' They kept pounding me telling me I shouldn't have been chosen to be project manager. I sat there stunned at first. Then I stopped them and said, "Hold on. I haven't even started in the role and you are saying that I'm not a good fit for it? I have a PhD in chemistry and am qualified. Before you say that I cannot do this job, let me do it but don't complain before I even get started. One of them apologized to me a year later."*

Participants report personal transformation especially in terms of deeper self -awareness, social awareness and self-efficacy. In Andrea's case, she offered:

> *"The program was an eye opener for me because I felt as if a veil was lifted and I finally saw how under-represented women are in my organization. We have 30 project managers and only 1 woman – me. When I give a presentation, they drill me with more questions. At first, I thought it was me, but my co-workers noticed it too. In meetings, men would take the seats at the table and women would sit behind them. I remember thinking this can't happen anymore, so at the next meeting, I started sitting at the table. The program gave me courage and tools to manage those difficult situations.*
>
> *Before the Leadership Lab, I would not have had the guts to tell the two men what I thought as they criticized me for no reason. I would have listened, and then gone to my supervisor and let him deal with it. But I'm different now. I reflect on the situation and first have the difficult conversations before asking others for help. In the past, I would have waited for someone else to tell me about an open position and now I look for them."*

[Research engineer, Aerospace]

An element of the program that participants highly valued was the executive and peer coaching each one experienced. One participant, Trisha, commented:

> "*For me, this [coaching] was one of the most fulfilling aspects of the course. I learned that I haven't had much coaching in my career. Receiving feedback from my peers, and a professional coach was awesome! From my peers, I loved having someone listen to me, repeat back what they heard so that I could hear how my words were interpreted, and give me honest feedback. From my coach, I received the greatest gift: someone who helped me articulate my dreams and goals, and bolstered my confidence in being able to achieve them by giving me tools and feedback that helped me realize that what I want is realistic and achievable."*

[Credit and Collections Manager, Manufacturing]

CONCLUDING REMARKS

Innovative professional development approaches are needed to address the ongoing lack of women leaders in science and technology-related fields. This article spotlights a new program designed as a research-based professional development immersion for women. The program aim is to equip women with the capability to navigate the complexities in non-traditional professions. While plans are in place to do more thorough long-term studies, early analysis of the program's outcomes show increases in participant's self-awareness, self-efficacy, and ability to persist and excel in their chosen profession. These provide encouraging signs of the intervention's success in advancing and retaining women in STEM and in the manufacturing professions.

AUTHOR CONTRIBUTIONS

EVO was the lead author. KB and DB also made significant contributions to this manuscript.

REFERENCES

Anderson, N. (2016). Carnegie mellon pushes for more women in engineering and computer science. *Washington Post*. Available at: https://www.washingtonpost.com/news/grade-point/wp/2016/09/16/carnegie-mellon-pushes-for-more-women-in-engineering-and-computer-science/

Bilimoria, D., and Lord, L. (2014). *Women in Stem Careers: International Perspectives in Increasing Workforce Participation, Advancement and Leadership*. London: Edward Elgar.

Boyatzis, R. E. (2008). Leadership development from a complexity perspective. *Consult. Psychol. J. Pract. Res.* 60, 298–313. doi: 10.1037/1065-9293.60.4.298

Boyatzis, R. E., and Akrivou, K. (2006). The ideal self as the driver of intentional change. *J. Manag. Dev.* 25, 624–642. doi: 10.1108/02621710610678454

Buse, K. R., Bilimoria, D., and Perelli, S. (2013). Why they stay: women persisting in the US engineering careers. *Career Dev. Int.* 18, 139–154. doi: 10.1108/CDI-11-2012-0108

Buse, K., and Bilimoria, D. (2014). Personal vision: enhancing work engagement and the retention of women in the engineering profession. *Front. Psychol.* 5:1400. doi: 10.3389/fpsyg.2014.01400

Catalyst (2016). *Women in S&P 500 Corporations*. Available at: http://www.catalyst.org/knowledge/women-sp-500-companies

Corbett, C., and Hill, C. (2015). *Solving the Equation: The Variables for Women's Success in Engineering and Computing*. Washington, DC: AAUW.

Crosby, F. (1984). The denial of personal discrimination. *Am. Behav. Sci.* 27, 371–386. doi: 10.1177/000276484027003008

Crosby, F. C. (1986). Cognitive biases in the perception of discrimination: the importance of format. *Sex Roles* 14, 11–12. doi: 10.1007/BF00287694

David Beede, T. J. (2011). *Women in STEM: A Gender Gap to Innovation*. Available at: http://www.esa.doc.gov/sites/default/files/womeninstemagaptoinnovation8311.pdf

Debebe, G. (2011). Creating a safe environment for women's leadership transformation. *J. Manag. Educ.* 35, 679–712. doi: 10.1177/1052562910397501

Debebe, G., Anderson, D., Bilimoria, D., and Vinnicombe, S. (2016). Women's leadership development programs: lessons learned and new frontiers. *J. Manag. Educ*. 40, 231–252. doi: 10.1177/1052562916639079

Ely, R., Ibarra, H., and Kolb, D. (2011). Taking gender into account: theory and design for women's leadership development programs. *Acad. Manag. Learn. Educ.* 10, 474–493. doi: 10.5465/amle.2010.0046

Frehill, L. M. (2008). Why do women leave the engineering work force? *SWE Mag. Soc. Women Eng*. 54, 24–26.

Goleman, D., Boyatzis, R., and McKee, A. (2002). *Primal Leadership Realizing the Power of Emotional Intelligence*. Boston, MA: Harvard Business School Press.

Google. (2014). *Google Official Blog*. Available at: http://googleblog.blogspot.com/2014/05/getting-to-work-on-diversity-at-google.html

Heilman, M. E., Wallen, A. S., Fuchs, D., and Tamkins, M. M. (2004). Penalties for success: reactions to women who succeed at male gender-typed tasks. *J. Appl. Psychol.* 89, 416–427. doi: 10.1037/0021-9010.89.3.416

Kanny, A. M., Sax, L. J., and Riggers-Piehl, T. A. (2014). Investigating forty years of STEM research: how explanations for the gener gap have evolved over time. *J. Women Minor. Sci. Eng.* 20, 127–148. doi: 10.1615/JWomenMinorScienEng.2014007246

Katrin Elborgh-Woytek, M. N. (2013). *Women, Work and the Economy: Macro Economic Gains from Gender Equity*. Available at: https://www.imf.org/external/pubs/ft/sdn/2013/sdn1310.pdf

Klawe, M. (2014). *The Science Behind Graduating a Class with Majority Female Engineers Forbes*. Available at: http://www.forbes.com/sites/mariaklawe/2014/07/10/the-science-behind-graduating-a-class-with-majority-women-engineers/#366de2bb2fe2

Kram, K. E. (1985). *Mentoring at Work: Developmental Relationships in Organizational Life*. Glenview, IL: Scott Foresman.

Lanaj, K., and Hollenbeck, J. (2015). Leadership overemergence in self managing teams: the role of gender and countervailing biases. *Acad. Manag. J.* 58, 1476–1494. doi: 10.5465/amj.2013.0303

Loosvelt, D. (2016). *What Facebook and Pinterest are doing to Hire More Women the Vault*. Available at: http://www.vault.com/blog/workplace-issues/what-facebook-and-pinterest-are-doing-to-hire-more-women/

Manjdo, F. (2014). *The Business Case for Diversity in the Tech Industry*. NewYork, NY: New York Times

National Academies (2016). *Committee on Women in Science, Engineering, and Medicine*. Washington, DC: The National Academies of Science, Engineering and Medicine.

National Center for Women in Technology (2016). Available at: https://www.ncwit.org/

National Institutes of Health (2016). *Women in Biomedical Careers*. Maryland, MD: National Institutes of Health.

O'Neil, D. A., Hopkins, M. M., and Bilimoria, D. (2015). A framework for developing women leaders: applications to executive coaching. *J. Appl. Behav. Sci*. 51, 253–276. doi: 10.1177/0021886315575550

Parker, P., Kram, K., and Hall, D. (2014). Peer coaching: an untapped resource for development. *Organ. Dyn.* 43, 122–129. doi: 10.1016/j.orgdyn.2014.03.006

Passarelli, A. (2015). Vision-based coaching: optimizing resources for leader development. *Front. Psychol.* 6:412. doi: 10.3389/fpsyg.2015.00412

Post, C., and Byron, K. (2015). Women on boards and firm financial performance: a meta-analysis. *Acad. Manag. J.* 58, 1546–1571. doi: 10.5465/amj.2013.0319

Society of Women Engineers (2016). Available at: http://societyofwomenengineers.swe.org/

Smith, M., Van Oosten, E. B., and Boyatzis, R. E. (2009). "Coaching for sustained desired change," in *Research in Organization Development and Change*, Vol. 17, eds R. Woodman, W. Pasmore, and R. Shani (Bingley: Emerald), 145–174. doi: 10.1108/S0897-3016(2009)0000017006

Sugiyama, K., Cavanagh, K., Van Esch, C., Bilimoria, D., and Brown, C. (2016). Constructing leadership development: pedagogies of women's and general leadership development programs. *J. Manag. Educ.* 40, 253–292. doi: 10.1177/1052562916632553

Taylor, S., Sturm, R. Atwater, and Braddy, P. (2016). Underestimating one's leadership impact: are women leaders more susceptible? *Organ. Dyn*. 45, 132–138. doi: 10.1016/j.orgdyn.2016.02.007

US Bureau of Labor Statistics (2015). *Women in the Labor Force: A Databook*. Washington, DC: BLS Reports.

Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Psychology

ORIGINAL RESEARCH
published: 19 May 2017
doi: 10.3389/fpsyg.2017.00816

Ten Years toward Equity: Preliminary Results from a Follow-Up Case Study of Academic Computing Culture

Tanya L. Crenshaw[1], Erin W. Chambers[2], Cinda Heeren[3] and Heather E. Metcalf[4]*

[1] Cascade Energy, Portland, OR, United States, [2] Computer Science, St. Louis University, St. Louis, MO, United States, [3] Computer Science, Thomas Siebel Center for Computer Science, University of Illinois at Urbana-Champaign, Urbana, IL, United States, [4] Association for Women in Science, Washington, DC, United States

Just over 10 years ago, we conducted a culture study of the Computer Science Department at the flagship University of Illinois at Urbana-Champaign, one of the top five computing departments in the country. The study found that while the department placed an emphasis on research, it did so in a way that, in conjunction with a lack of communication and transparency, devalued teaching and mentoring, and negatively impacted the professional development, education, and sense of belonging of the students. As one part of a multi-phase case study spanning over a decade, this manuscript presents preliminary findings from our latest work at the university. We detail early comparisons between data gathered at the Department of Computer Science at the University of Illinois at Urbana-Champaign in 2005 and our most recent pilot case study, a follow-up research project completed in 2016. Though we have not yet completed the full data collection, we find it worthwhile to reflect on the pilot case study data we have collected thus far. Our data reveals improvements in the perceptions of undergraduate teaching quality and undergraduate peer mentoring networks. However, we also found evidence of continuing feelings of isolation, incidents of bias, policy opacity, and uneven policy implementation that are areas of concern, particularly with respect to historically underrepresented groups. We discuss these preliminary follow-up findings, offer research and methodological reflections, and share next steps for applied research that aims to create positive cultural change in computing.

Keywords: academia, computing, cultural change, gender, policy design, recruitment, retention, STEM

OPEN ACCESS

Edited by:
Catherine Alison Hill, American Association of University Women, United States

Reviewed by:
Joseph M. Goodman, Illinois State University, United States
Kelly Mack, Association of American Colleges and Universities, United States

****Correspondence:***
Tanya L. Crenshaw
tanya.crenshaw@cascadeenergy.com

Specialty section:
This article was submitted to Organizational Psychology, a section of the journal Frontiers in Psychology

Received: *12 January 2017*
Accepted: *04 May 2017*
Published: *19 May 2017*

Citation:
Crenshaw TL, Chambers EW, Heeren C and Metcalf HE (2017) Ten Years toward Equity: Preliminary Results from a Follow-Up Case Study of Academic Computing Culture. Front. Psychol. 8:816. doi: 10.3389/fpsyg.2017.00816

1. INTRODUCTION

Over the past 50 years, researchers, policy makers, educators, and employers have invested much toward the recruitment and retention of women and people from historically underrepresented minority backgrounds in computing. While some scientific fields, such as the life sciences, have seen great improvement in degree participation by women, computer science and engineering have experienced declining occupational and degree participation by women and people of color, with enrollment and employment trends by these groups in 2013 nearing where they were in the 1960s (Hill et al., 2010).

This gap is particularly problematic with respect to the shift in the college-going population in the past 50 years (Barr, 2014). The number of bachelor's degrees awarded annually has more than tripled since the 1960s. The proportion of women earning bachelor's degrees has grown from 43 to 57% in 2013; in 2013, 50.3% women earned 50.3% of science and engineering bachelor's degrees (National Science Board, 2016). Yet, that same year, women earned only 18% of bachelor's in Computer Science. In looking at all of the bachelor's degrees earned by gender, in the 1960s men were earning Computer Science degrees at three times the rate of women, while by 2012, men were earning Computer Science degrees at six times the rate of women.

Looking beyond undergraduate degree attainment, other work shows gaps in the workforce. Proportions vary broadly by field, but the computer and information science, and engineering workforces see the smallest proportions of women at 24 and 15%, respectively (National Science Board, 2016). In 2014, Google publicly disclosed that 17% of its tech workers were women, 3% were Hispanic and 2% were black (Huddleston, 2014). That same year, Facebook, LinkedIn, and Yahoo also publicly released employee diversity reports, with similar demographics. On the academic side, in 2010, only 4% of full-time Computer Science faculty were members of underrepresented minority groups (National Science Board, 2014). In 2013, their numbers had risen to 6% (National Science Board, 2016).

Much research explains such gaps by pointing to cultural barriers and biases faced by women and people from underrepresented minority backgrounds. These barriers and biases influence sense of scientific identity, self-efficacy, and fit (Rosser, 2004; Moss-Racusin et al., 2012; Corbett and Hill, 2015). They are also largely responsible for the stratification and inequities related to a complex landscape of professional experiences: Hiring, space and resource allocation, salary and compensation package composition, evaluation, recognition and awards, research grant funding, promotion, tenure, access to key professional networks and mentors, movement into leadership roles, access to funding and knowledge resources necessary for scientific commercialization, and more (Heilman and Okimoto, 2007; Bilimoria et al., 2008; Isaac et al., 2009; Ely and Rhode, 2010; Hill et al., 2010; Ely et al., 2011; Metcalf, 2011; Moss-Racusin et al., 2012; Lincoln et al., 2012; Blume-Kohout, 2014).

Research and practice have focused primarily on the recruitment side of the picture, aiming to draw more women and people of color into STEM by "fixing" their interests, self-confidence, and self-efficacy and providing them with tools they can use to survive within the existing culture (Metcalf, 2011, 2014; Fouad et al., 2012; Knipfer et al., 2017). While this approach can be immensely useful as a support system, it does not address root systemic causes necessitating survival mechanisms in the first place. Survival mechanisms alone cannot and have not resolved the structural and systemic issues pervasive within STEM educational and work spaces. This study joins in the research efforts dedicated to understanding and addressing the cultural and experiential issues impacting the retention of women and people of color in STEM, particularly in computing disciplines where retention issues are growing.

This year, universities around the country, including the University of Illinois at Urbana-Champaign, are reporting record-breaking numbers of freshman women entering Computer Science programs (Hustad, 2016; RHIT, 2016; Williams, 2016). We are excited to see this influx of women due to recruiting and outreach efforts. But we and the department at Illinois want to make sure that the underlying cultural barriers and biases are addressed in ways that facilitate the success of the students and faculty within the department rather than seeing a mass exodus down the road. Even if these women choose to stay in their programs and complete their degrees, there is still much work to do in improving the educational and professional opportunities and experiences of underrepresented groups.

To that end, we report on our Spring 2016 pilot results from a follow-up case study of the Computer Science culture at the University of Illinois at Urbana-Champaign, a research-intensive Computer Science department. Though we have not yet completed our full data collection and cannot generalize our results, we find it worthwhile to reflect on the pilot data we have collected thus far. Pilot data reveal improvements in the perceptions of undergraduate teaching quality and undergraduate peer mentoring networks. However, we also found evidence of continuing feelings of isolation, incidents of bias, policy opacity, and uneven policy implementation that are areas of concern, particularly with respect to historically underrepresented groups.

2. STUDY HISTORY

To provide some background on the history of our study, we discuss our original study and the events that led up to our Spring 2016 pilot study.

Altogether, we have spent a total of 42 years at the University of Illinois' Department of Computer Science at multiple levels: undergraduate, graduate, and faculty. As summarized in **Figure 1**, we met in 2003, the start of a brief 2-year window during which we were all students in the Department of Computer Science.

In 2005, Heather Metcalf graduated from Illinois and began pursuing her master's degree in Gender and Women's Studies at the University of Arizona. In part, her motivations for seeking the degree was to better and more systematically understand and address a number of problematic gendered and cultural experiences she had had and witnessed while obtaining her first master's in Computer Science at Illinois.

At the time, Computer Science was experiencing a downward trend in enrollment at the national and university levels (Vegso, 2005). Cinda Heeren, working on completing her Ph.D. in Computer Science, was piecing together funding from a variety of positions such as *Visiting Assistant Director of Diversity Programs* and *Visiting Lecturer*. Third-year Ph.D. students Erin Wolf Chambers and Tanya L. Crenshaw were experiencing a sense of unease in the department that aligned with many of the Metcalf's own experiences at Illinois. The department held a disciplined focus on research excellence, but the focus had evolved into a culture of exclusivity that seemed to be having a particularly detrimental effect on women and students of color in the department. Talented students were not feeling successful and were leaving their programs of study.

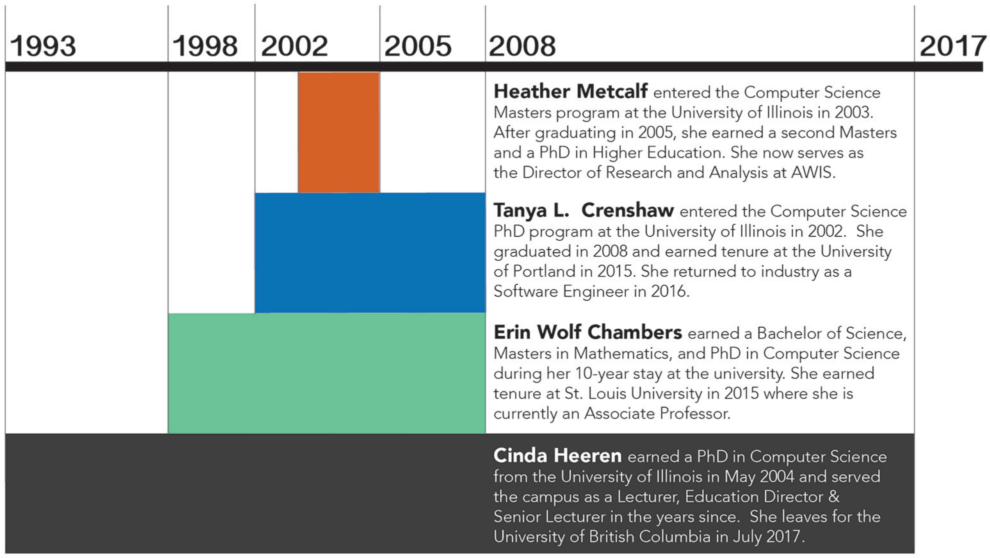

FIGURE 1 | Altogether, the co-authors have spent 42 years at the University of Illinois at all levels of inquiry: undergraduate, graduate, and faculty.

Compounding this sense of unease was the demographic landscape of the department. As shown in **Figures 2–4**. in Fall 2005, the department's undergraduate population comprised 650 undergraduates and 414 graduates. Men comprised close to 90% of both the undergraduate and graduate populations.

After seeing many brilliant friends and colleagues leave the department and the field, we felt action was necessary. Across two time zones, we self-organized into a research team and sought to understand the departmental culture beyond our own individual experiences. From January to July 2006, we conducted a two-phase study to evaluate undergraduate and graduate student attitudes on areas contributing to enrollment and persistence: recruitment, retention, and preparation. We began the study by interviewing eleven participants, deliberately picked for their collective breadth of experience and demographic characteristics. These hour-long interviews uncovered qualitative trends and helped to refine the survey questionnaire. In the second phase, we utilized online questionnaires that collected quantitative and qualitative data to survey a total of 119 students comprising 61 undergraduate students, and 58 graduate students. Overall, the survey participants were 17% women and 83% men, at a time when the department itself was 14% women and 86% men.

In our 2006 study, we found that while the department placed an emphasis on research, it did so in a way that devalued teaching and mentoring, and negatively impacted the professional development, education, and sense of belonging of the students. We found a lack of communication and transparency throughout the department fueled these frustrations. While these negative impacts were expressed to a slightly greater degree by women in the department, they were pervasive across all demographic categories.

By the end of our work, we presented the department with a collection of policy and practical recommendations. Published in a white paper to the department (Crenshaw et al., 2007), a 2008 article (Crenshaw et al., 2008) and in Metcalf's second master's thesis (Metcalf, 2007), these recommendations encouraged more interactions among community members, greater flexibility in programs of study, and more opportunities for quality outreach, teaching, and mentoring that can also assist in the department's research orientation and goals. The eight recommendations were:

1. Provide more comprehensive information to prospective graduate students.
2. Facilitate more opportunities for outreach.
3. Facilitate more interaction between students and faculty.
4. Improve quality of teaching.
5. Provide more flexibility in core requirements.
6. Increase early research opportunities.
7. Create multiple and diverse mentoring opportunities.
8. Provide an adequate family leave policy.

In the years since the original 2006 study, through the bold involvement and advocacy from several key faculty members, the department has revised its curricula, advising policies and practices, and outreach efforts. Quoting a letter of support from the Computer Science Department Head (Rutenbar, unpublished), the specific changes informed by our study included:

1. A smaller and more flexible undergraduate core curriculum.
2. A more flexible graduate core curriculum, which again attracts students with more diverse backgrounds and interests, and which allows Ph.D. students to start research more quickly.
3. Annual progress reviews for all Ph.D. students, which have improved communication between students, advisors, and other faculty mentors.
4. Changes in graduate admissions procedures which broaden the set of potential advisors for all incoming students.

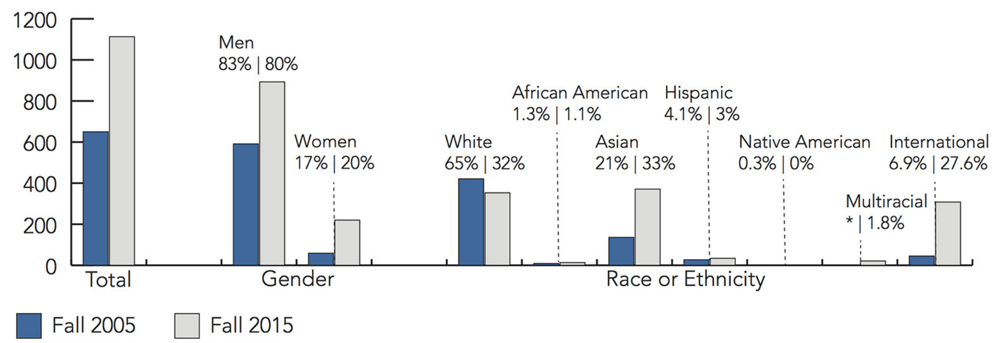

FIGURE 2 | A comparison of the undergraduate student demographics in Fall 2005 and Fall 2015. In 2005, there were 650 undergraduate students. The population almost doubled by 2015, with 1113 students. Note that "Multiracial" was not a racial category measured by the department in 2005.

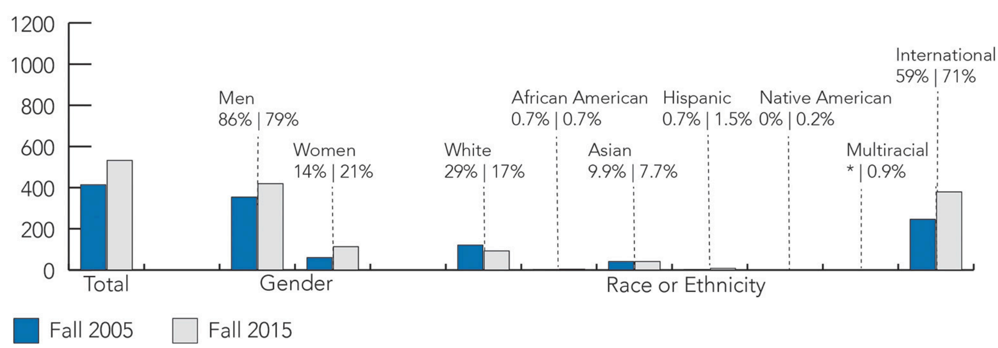

FIGURE 3 | A comparison of the graduate student demographics in Fall 2005 and Fall 2015. In 2005, there were 414 undergraduate students. By 2015, the population was 532 students, with 21% women and over 70% international students. Note that "Multiracial" was not a racial category measured by the department in 2005.

5. A formal teaching requirement for all Ph.D. students.
6. Significant improvements in undergraduate advising policies, including an assigned Faculty Mentor to every undergraduate as well as two full time student-facing academic professionals.

While the department instituted a number of changes, many were met with resistance. During a presentation of the findings, several faculty members expressed disbelief even in the face of statistically significant evidence. We experienced a particularly poignant moment during one presentation to the faculty. While discussing a participant's quote on a lack of mentors, one faculty member said, *"Your work is very interesting, but this kind of thing doesn't happen in my research group."* We had interviewed two of his students, one of whom said the exact quote to which he objected. We knew that *"kind of thing"* happened in his group, and that his own students were lamenting a lack of research mentors. We report only one of our own experiences here, but this pattern of resistance despite empirical evidence is seen in the research on bias. Both men and women have relative reluctance, particularly those who are faculty in STEM departments, to accept evidence of gender biases in their field (Uhlmann and Cohen, 2005, 2007; Castilla and Benard, 2010; Handley et al., 2015).

In the changes that have been made, it is unclear how deeply or how meaningfully the culture has improved as a result. In addition, new challenges have arisen; the CS department has grown considerably in size. In response, in 2015, the department's Associate Department Head reached out to our team to conduct a follow-up study to gain a renewed sense of the current state of the departmental culture. Cinda Heeren, now one of the first official teaching faculty in the department and one of the first to be subject to the professionalization of the instructional track, joined our original team to contribute her longitudinal, pedagogical, and advocacy expertise to the design and implementation of this study.

Over 10 years later, the demographics nationally and departmentally have shifted. As shown in **Figure 5**, Computer Science is seeing increasing enrollments. Universities around the country, including Illinois, are reporting record-breaking numbers of freshman women entering Computer Science programs (Hustad, 2016; RHIT, 2016; Williams, 2016). Between Fall 2005 and Fall 2015, the Department of Computer Science undergraduate population almost doubled at 1113 students (893 men, 220 women, 353 white, 13 African American, 371 Asian, 34 Hispanic, 21 Multiracial, 308 international, 13 "unknown," and 474 state residents). There were 532 graduate students (119 MCS students, 103 MS students, 310 doctoral students) with demographic descriptives summarized in **Figures 3**, **4**. This time, women comprised roughly 20% of the student population which is similar to national student trends seen in **Figure 5**. Students from under-represented minority backgrounds represented 6.2%

of the undergraduate population (8.6% among U.S. citizens) and 3.4% of the graduate population (11.8% among U.S. citizens), which is about one quarter of the level of representation in the national trends.

3. METHODOLOGY

In our current iteration of this work, we are taking a critical mixed-methods approach to a case study of the computer science departmental culture (Creswell, 2008) at the University of Illinois at Urbana-Champaign. Our approach pairs survey data with in-depth, semi-structured follow-up interviews of current undergraduate students, graduate students, and faculty about their experiences with various aspects of the department's culture. To develop the survey instrument and interview protocols for this inquiry, we began with the original 2005 instruments, updating them to reflect any revised or new university programs and policies. Updates to the instruments also incorporated findings from the research on recruitment, retention, and persistence into the workforce that have been released since 2005. In addition, we created new survey and interview protocols for use with departmental faculty to incorporate their perspectives and experiences for a more holistic view of the culture. This was impossible while we were all graduate students in the department, but we believe it is a piece of the picture that was missing in 2006.

Before distributing the surveys and conducting their subsequent follow-up interviews throughout the department, in Spring 2016, we piloted our revised instruments with a deliberate sub-sample of undergraduate students, graduate students, and faculty from the department[1].

In our participant solicitation for the pilot study, we selected participants to reflect a breadth of experiences, from first-year undergraduates to tenured faculty, and demographic characteristics. We made clear our own connections to the university. Moreover, due to Heeren's extensive student network and pre-existing relationships with the students and faculty, our recruitment and consent documents made it clear that she would not be present during the interviews, nor would she have access to the resulting transcripts or identifying data.

Eleven participants (four undergraduate students, five graduate students, and two faculty) were sampled, using an e-mail solicitation sent by Heeren to 18 members of the department. Participants were given a short background of the study, including a message that participation in the study was entirely voluntary. Individuals agreed to participate in the study by scheduling an appointment with the three interviewers: Chambers, Crenshaw and Metcalf. We spent 1

	Undergraduate		Graduate	
	Fall 2005	Fall 2015	Fall 2005	Fall 2015
Total	650	1113	414	532
Men	591	893	354	419
Women	59	220	60	113
White	421	353	118	93
African American	9	13	3	4
Asian	136	371	41	41
Hispanic	27	34	3	8
Native American	0	0	0	1
Multiracial	n/a	21	n/a	5
International	45	308	246	379

FIGURE 4 | A tabular summary of the column data visualized in Figures 2, 3. From 2005 to 2015, the undergraduate population almost doubled while the graduate population saw an increase of 28%. Note that "Multiracial" was not a racial category measured by the department in 2005.

[1]Our materials have received IRB approval from the University of Illinois at Urbana-Champaign, IRB No. 16507. St. Louis University had an Institutional Authorization agreement—or IAA/Reliance Agreement—filed with the University of Illinois, stating they would honor Illinois' IRB decision.

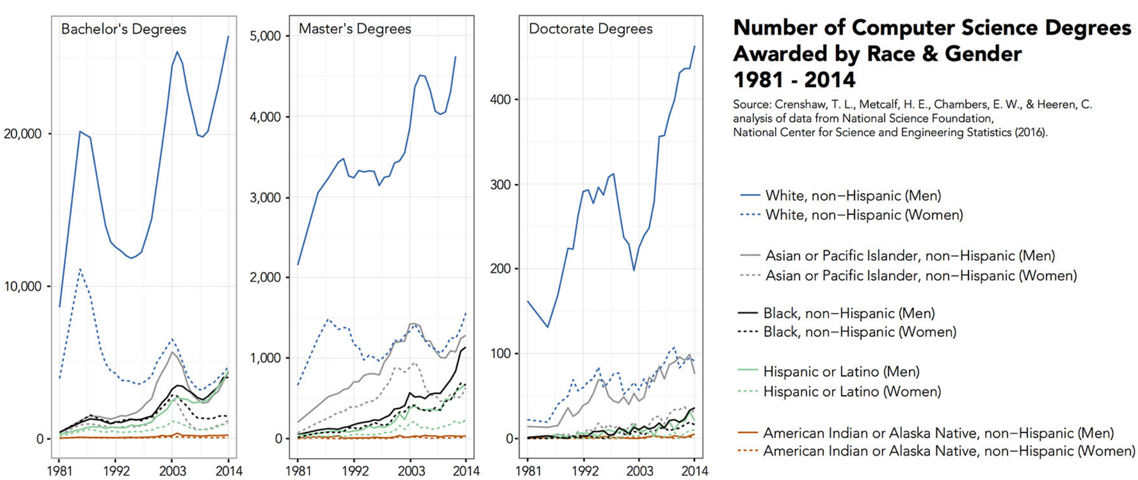

FIGURE 5 | Nationally, the number of Computer Science degrees awarded by race and gender from 1981 to 2014. Data source: National Science Foundation, National Center for Science and Engineering Statistics (2016).

h to 90 min with each participant; we administered a paper version of our pilot survey instrument and conducted semi-structured follow-up interviews based on the participant's survey answers.

This paper reports on the pilot study results, focusing on preliminary qualitative findings from the undergraduate and graduate student populations. While we have developed our survey and conducted pilot interviews with two faculty, here we focus on our qualitative student data for the purposes of preliminary comparison between the 2005 study and the current departmental patterns. We will continue to pilot the faculty instruments and will report on these findings in future work.

For the undergraduates, the survey instrument covered topics related to their pathway to the department, their courses, the quality of teaching they experienced, their academic advising needs and experiences, their mentoring needs and experiences, sources of support, policy awareness, their sense of fitting in and feeling successful in the department, extracurricular activities, departmental values, future career goals, and demographic information. Survey questions included open-ended response options for demographic questions and at the end of each topic area so that participants could share more freely about their experiences with that topic in the department. For the graduate students, the survey instrument covered the same topics in addition to graduate program requirements, choosing an area of research, and, for doctoral students, the Ph.D. qualification exam.

For the analysis of our qualitative data, we conducted inductive thematic content coding (Braun and Clarke, 2006) and critical discourse analysis (CDA) (Ayers, 2005; Fairclough et al., 2011) of over 94,000 words of interview transcripts. As has been done in past qualitative work utilizing inductive thematic content analysis (McClelland and Holland, 2015; Moss-Racusin et al., 2015), the expansive body of research on culture in computer science, particularly related to academia, has been used to guide the analysis such that specific thematic categories arose organically from the data. Using the cloud-based software app Dedoose, two members of the research team were responsible for independently coding the data, beginning with a pilot test on a sub-sample of the data. Coding categories and themes were iteratively cross-checked for inter-coder reliability and to resolve coding discrepancies. Our analysis has helped us to refine the survey we will administer to the department in the Spring 2017 semester.

The critical approach that we take is one that emphasizes the importance of taking ownership of our own subjectivities and how these influence our research inquiry. Critical researchers, qualitative and quantitative alike, advocate that scientific research include a "systematic examination of powerful background beliefs" (Harding, 1991) that shape the work. These scholars charge researchers to engage in critical self-reflexivity, claiming responsibility for their positionalities by acknowledging them throughout their work (Haraway, 1991; Harding, 2006; Baez, 2007). To that end, our methodological approach also includes Section 5 of this paper, a reflection on our positionalities relative to the study and the experiences shared by our participants.

4. 2016 PILOT STUDY RESULTS

This paper details the preliminary comparisons based on our longitudinal work. Though we have not yet completed our data collection and cannot generalize our results, we find it worthwhile to reflect on the pilot data we have collected thus far as they illustrate compelling qualitative patterns thus far. Our analysis revealed three major themes:

- Improvements in the perceptions of undergraduate teaching quality.
- Improvements in undergraduate peer mentoring networks coupled with continuing feelings of isolation at both the undergraduate and the graduate level.
- Incidents of bias exacerbated by policy opacity and uneven policy implementation, all areas of concern, particularly with respect to historically underrepresented groups.

We discuss these themes juxtaposed with the recommendations we made in 2006. Though our preliminary results do not align with all eight recommendations, these three are the most relevant:

- **Facilitate more interaction between students and faculty.** Multiple student participants described an absence of meaningful interactions with faculty. They expressed interest in increased interactions in advising and mentoring, in graduate classes, and with respect to activities, like the qualification exam. This section covers the qualification exam, where positive faculty interactions should occur and have great impacts on retention and success. Some participants reported direct mentorship during their qualification exam. Yet, others expressed a lack or complete absence of feedback on performance and described uneven implementation of recent changes in the qualification exam format.
- **Improve quality of teaching.** Additions of teaching staff and teaching assistant training have lead to positive perceptions of teaching in the 100- and 200-level courses for undergraduates among our participants. Still, our participants described remaining gaps in graduate-level teaching quality and in teaching assistant preparation.
- **Create multiple and diverse mentoring opportunities.** Each of our student participants described challenges in finding effective tenure-track faculty mentoring relationships and sought creative means to develop career and psychosocial support networks for themselves. For our undergraduate participants, departmental and university student organizations remained places where they find mentoring relationships with their peers. However, graduate student participants, as in the original study, expressed feelings of isolation.

We discuss these recommendations and their underlying themes in greater detail in the subsequent sections.

4.1. Facilitate More Interaction between Students and Faculty

In 2006, the final question of the survey asked simply, "What do you think could be done to improve the department?" Of graduate participants, 31% cited increasing student-professor interactions. In a department whose student population has grown as much as Illinois', and without new hires keeping pace, it is increasingly difficult for faculty to balance their existing workloads, let alone to make time for additional student engagement. That said, there are moments already in the rhythm of the academic year where greater interactions may be more purposefully had.

One such moment is the Ph.D. qualification exam.

4.1.1. The Ph.D. Qualification Exam

The Ph.D. qualification exam is the first major milestone for doctoral graduate work in the Computer Science department. According to the department's public website,

"The purpose of the Ph.D. Qualifying Exam is for students to convince the faculty that they should be considered a Ph.D. candidate. Faculty evaluate whether the student has the knowledge, experience, perspective, and determination to complete the Ph.D. program. In addition, faculty will evaluate the student's presentation and communication skills to ensure a mastery of English sufficient to teach in a U.S. institution can be achieved by the end of the Program[2]."

Publicly, the department offers that implementation of the exam may vary across research groups. It certainly varies. Comprehensive written tests, oral presentation of assigned research papers, submission of an original manuscript, and unstructured interviews are all examples of how the exam is implemented across groups. For some students, the exam format selected by their research group was effective, efficient, and contributed to their professional development.

An international second-year Ph.D. student described the recently revised format of her qualification exam, *"We need to just write a paper...about our own research."* She presented her work in a Q&A format to four professors in a committee. She said of the format, *"And I really liked it that it was to write a paper, rather than spending time doing course work that doesn't really help with the research. So I was really happy with the new style."*

She also described the kind of feedback she received after the exam, *"I got the paper reviews for each of the professors with all of the comments and I have to rewrite my paper. They were expecting things to be there that I didn't explain well. But it's rewriting a paper that I would potentially publish and I got reviews before actually publishing it."*

For this student, the exam format was an opportunity to receive feedback on her research, writing, and scientific communication skills and helped her strengthen her work. She was being asked to complete a task she would need to do well to complete her Ph.D.: Write research papers. In the process, she interacted with four professors, discussing her own research, 2 years into her degree. Moreover, she received high-quality written feedback in the same form that she'll receive on her future scholarly works, even after graduation. She said, *"The best part was it was about my research so whenever I go back to [the committee's] questions, I feel like there was an improvement or new ideas about my own work, which is the most important thing about research."*

Other students, however, did not experience quality interactions with faculty through their qualification exams. For example, a white third-year doctoral student described his format as a written exam based on a reading list. He said, *"'You passed' was my feedback. Never got to see my exam. Never got any detailed opinion of what things I was good at, what things I should improve on. Which papers I did better at, which ones I didn't do as good at."* This student expressed a strong desire to have the opportunity to reflect on his strengths and weaknesses and felt that the lack of feedback served as a barrier to being as successful as possible. From his perspective, even though he passed, the exam did not contribute to his professional development nor did it allow for meaningful engagement with his research group advisor or faculty committee members.

An underrepresented doctoral student of color in her third year, who also took a written exam, received a conditional pass. She said, *"The thing is, like they don't tell us how we passed. I just got [word] that I passed on the condition that I have a research paper submitted by the end of next semester. But there's nothing that says you did well on the written part, but you didn't do well on this part. Or you did well on this part on part but you didn't do well on this specific question."* Like the previous student, she sought a deeper understanding of skills so that she could work to improve upon them and expected that the qualification exam would present her with that opportunity from faculty feedback.

Given that this is the first of only three milestones in the Computer Science Ph.D., it is concerning that students are not receiving quality feedback. It is a missed opportunity for greater interactions between students and faculty in the department that have a direct impact on the students' success. The qualification exam is a moment that can provide students with quality professional feedback and direct mentoring that would aid in their development.

An area of even greater concern is how implementation of the exam can differ for students from different demographics even within the same research group. We interviewed two graduate students from the same research group comprised of about 10 tenure-track faculty members. From a policy transparency, implementation, and equity perspective, interviews with these two students stood out.

In both cases, the students were offered a two-part exam. In the first part, the group's faculty offered a standard reading list 3 months before a closed-book written exam was administered. The purpose of the written exam was to assess student knowledge of the research area's fundamental topics.

The second part of the exam was described in this way by a white doctoral student,

"There was a verbal part, but basically, my understanding of what that was for was purely just to evaluate your English speaking skills. It was like, meet with a faculty member and talk about your research for like 10 min."

When asked how many meetings, the student replied, that he was supposed to have three independent meetings, and that, *"I think I ended up having two instead of three. Because one person was just not available.*

[2]Source: http://cs.illinois.edu/academics/graduate/phd-program/qualifying-exam

The same exam was described by an underrepresented woman of color,

"Part of my qualifying exam is taking the written exam and then basically going to each and every one of the [group's] faculty and having a 10–15 min interview which covers absolutely nothing."

This student also described bias and assumptions in her day-to-day interactions with faculty and students, particularly around language:

"I'm American and I'm also [race]. I know how to speak English very, very well. It's my first language. I also know how to speak [another language] very, very well. I'm a bilingual. But they never dare to ask. And I feel like its ok. Don't be too afraid to ask, you know. As long as like, you're asking honestly and not trying to, you know ... I don't know. There is an honest way of asking a question. And then there is a way where you're like just looking for a fight."

Both students in this research group separately described unwritten evaluation criteria for the verbal part of the exam that made them both feel uncomfortable because of the ways these criteria target international students. Both also expressed the sense that this portion of the exam was providing no feedback and serving no larger purpose in the evaluation of their research skills.

4.2. Improve Quality of Teaching

With respect to teaching, great changes have taken place as a result of the policy changes in the past 10 years. In our original study, 45% of undergraduates did not feel the department valued teaching, and 66% did not attend class because they felt that lectures did not help them learn the material. Ten years ago, over half of the suggestions from undergraduates were related to teaching improvements.

Since 2006, two notable changes have been put in place. First, the department has introduced a professional teaching track position; teaching faculty hired into this track handle the bulk of introductory undergraduate level courses. Second, Ph.D. students are now required to fill a teaching assistant role for one semester. With that, there is now a "Teaching Assistant Preparation" seminar required for beginning Ph.D. students who run labs or teach discussion sections. We discuss these changes in turn.

4.2.1. Professional Teaching Track

In 2006, a substantive number of student comments on the department were related to teaching. One participant, whose sentiment reflected much of what our sample population reported, said,

> *"I would like the university to help teach professors who are great minds/researchers how to teach and interact with students better. I understand that UIUC is a great research school, and I know the importance of this, but sometimes the people who are best at research are terrible teachers."*

At the time, we offered that one solution could be to adopt the "Assistant Professor of the Practice" position (Fogg, 2004) that were seen at universities like Duke and Carnegie Mellon University. Today, the university offers a variety of teaching faculty positions. As described on a recent job opening at the department's website,

> *"Teaching faculty positions are renewable, career-oriented, non-tenure-track positions. Initial appointments are typically at the rank of Instructor, Lecturer, or Teaching Assistant Professor, with the possibility of promotion to the ranks of Senior Instructor, Senior Lecturer, or Teaching Associate Professor and Teaching Professor[3]."*

Within the department, these kinds of teaching faculty are responsible for the CS1 and CS2 introductory programming sequence taken by all undergraduates. Almost all students interviewed in 2016 felt that the department valued teaching, although many noted that it valued teaching only at lower levels, where non-tenure track faculty emphasized teaching as the main part of their job. An underrepresented graduate student of color who works as a teaching assistant for one these courses describes them in this way, *"CS 125 and CS 225, they're kind of like low level, freshman, sophomore, kind of level courses. And these are excellent courses. They're envisioned excellently. They have the best professors, the best lecturers in the whole department. But once you, climb up into 400 and 500 levels just goes (whew sound). You know? And its more of...sometimes I feel like if we're—especially for the 500 level classes. It's not about the teaching, it's more about the showing."*

Another graduate student, a white man, echoed this sentiment, *"I think the Computer Science department has a split brain. And one half of that brain really values excellent teaching. And the other half of that brain couldn't care less."* An international graduate student was more precise. When describing the teaching quality in the upper division courses, she said, *"It depends on the faculty. Because I've taken another 500 level course and that professor was excellent."*

Thus, it seems that the department's investment in undergraduate teaching, particularly at the lower-levels, has helped to shift the perception of undergraduate teaching quality and investment. These investments were not matched at the graduate level, where our 2016 participants continue to express high levels of dissatisfaction in the quality and level of investment in teaching. In addition, this investment does not pay adequate attention to equity issues in terms of who is taking on these roles and how the roles are valued financially, as many of the teaching staff positions at the university seem to offer less job security and lower pay; retention of high-quality teaching faculty may be a challenge on campus.

4.2.2. Teaching Assistant Preparation

In the original study, the quality of teaching was a much-discussed topic among participants. Only 65% of participants felt that the department valued excellent teaching. Among the undergraduates, more than half of the recommendations on how to improve the department were related to teaching. At the time, one participant said,

"I would like to see T.A.s with more instruction on how to teach a class. The first course a student takes in Computer Science is the

[3]Source: https://cs.illinois.edu/about-us/faculty-positions.

most critical, because it is that course that will make a student decide whether to stay in the department."

Teaching assistants are assigned to a variety of courses with many different demands; some positions require administrative work, grading or assisting students during office hours. Other courses require leading a laboratory or discussion section. In 2006, teaching assistants for the department participated in a campus-wide 2-day training course. International teaching assistants received an additional 2 days of training. At the time, we pointed out that the University of California at Berkeley offered its own course, CS301, called *Teaching Techniques for Computer Science* which discusses techniques for effective teaching specific to computer science.

Today, all Ph.D. students in the department are required to fulfill a teaching assistant role for at least one semester. In response to our recommendation, to better prepare their teaching assistants, the department offers a seminar course, CS591 TA, or "*Teaching Assistant Training*," to prepare its teaching assistants for their service. Student interviews enumerated some of the course's topics, including lesson planning, encouraging student participation, protecting student privacy, cultural sensitivity and Title IX compliance.

Among the three graduate students interviewed who took the course, two perceived it as useful. One student, a white man, was not as engaged. He felt it was a mix of "*common sense,*" topics he did not care about, and some topics of interest unrelated to teaching. He ended his description of his experience with, "*Maybe I'm not the perfect candidate for that class. Or maybe I just didn't receive the instruction well.*"

While there is unevenness in terms of how the students are engaging in the course, there are also discrepancies in how the seminar requirement is enforced. Of the five graduate students interviewed, two, both men, reported they did not participate in the seminar before accepting a teaching role in the department. One international student offered, "*I actually skipped it and I was allowed to skip it because it's offered only in fall and I wasn't a TA in Fall '14 when I joined, I was an audit in Fall '14. But then I chose to be a TA in spring and then that...seminar wasn't offered in spring.*"

The student went on to explain that his course evaluations offered positive student feedback and so he was not made to take the seminar in Fall 2015. He further offered that he might have taken it in Fall 2015, "*but it clashed with one of my courses. And then I couldn't ... I mean I thought I shouldn't be dropping the course for TA training.*"

Those students who had taken the course also identified gaps in their preparation for teaching roles. One white third-year Ph.D. student described his career goal as "*tenure-track faculty member*" was frustrated by the lack of teaching preparation and opportunity he had found in the department. He offered, "*Because I don't think you can just grade your advisor's exams and then say "I'm a teacher now.*" An underrepresented student of color and second-year Ph.D. student described "*heartbreaking*" stories she heard from students during her office hours. She wanted to help, "*but I have no idea where to refer them for example, for mental health or counseling. I don't have that information except like if I actually go and search on the internet.*" She felt very unprepared to handle emergency or crisis situations presented by her students and described a lack of awareness of the departmental or campus resources to which she could direct her students in these moments.

Undergraduate experiences echoed such gaps in teaching assistant training for crisis situations. A senior undergraduate student, a white woman, described one such experience. Led by a teaching assistant, the students were instructed to work in groups on an in-class assignment. She said she got behind on the problem, and started working on it independent of her group. As the teaching assistant circled the room, she saw the student's work and said, "'*good job, you figured this one out, don't tell these guys because they need to work it out for themselves too.*"' The student went on to say, "*And this kid in my group got so mad that I figured out this problem, he literally stood up, threw his chair back and was like, "you're just a freaking girl, you must have cheated on this thing, there's no way...*"

Nobody did a thing. Met with a roomful of silent bystanders to the violence, the yelling, the insults, the chair-throwing, she said, "*I just left the class crying.*"

Many of the students in our pilot interviews described situations in their courses, online discussion groups, student organizations, and research groups where they witnessed or directly experienced hostile behavior, harassment, and bias and felt unsure about how to handle the situations as teachers, students, or peers.

For example when asked about whether she had witnessed inappropriate behavior on campus, an international graduate student spoke generically about seeing such behavior from both students and faculty in the context of coursework and social interactions. We asked her, "*How do you handle that when it happens?*" She offered that sometimes it can be useful to call out the behavior, and that she had once seen a person do so effectively. She said, "*but that person wasn't from computer science. That was funny to see...they were from physics.*"

More often than not, participants explained that these situations are met with awkward silence. Several of our participants described how the culmination of such experiences, particularly when they have been the target of these words and behaviors, has had a deflating effect. For example, one white undergraduate student explained that she has had to learn to tolerate these behaviors:

"*I don't feel a sense of...of hope that like, oh you know, just push through and it's going to get better, once you get into industry — no. It's just how it is and you have to get used to it or get out of it. It's not really something that's going to be fixed within the next few years.*"

She went on to explain that these experiences profoundly changed her formerly exuberant approach to outreach:

"*Obviously if young women have aspirations to be in this field I want them to succeed and I want to help them achieve their goals. But for the young women who are not sure, I'm not going to push them to do something that they're not sure about...you have to be 150 percent sure that this is what you want or you're not going to succeed and then you've just wasted time...I came into this department putting in a lot of effort into...getting women excited about this and we're going to make a change by just showing them* *how exciting this all is. And to some degree I think that can work. But, on the other hand...[being here is] not a healthy thing."*

4.3. Create multiple and diverse mentoring opportunities

Our 2006 study uncovered a student appetite for multiple kinds of mentoring relationships, but a lack of opportunity to find mentors. At the time, 18% of undergraduate and 53% of graduate students reported having a mentor, with many participants wishing for some kind of mentor but feeling unsure as to how to find one.

There are multiple ways that a department may offer mentoring relationships to its students. One is through undergraduate advising. However, in 2006, only 2 undergraduate participants, or 3%, said that their advisor also served as a mentor to them. At the graduate level, thesis advisors may also serve a mentoring role, but of the 51 graduate participants who reported having an advisor in 2006, roughly half reported that their advisor was their mentor.

In a university context, tenure-track faculty are often counted upon to serve in a mentoring capacity. To that end, the department has instituted a new role, *"Faculty Mentor,"* to support undergraduate advising. Yet, in a department as large as Computer Science at Illinois, we have great empathy for how spread-thin faculty can feel. The undergraduate population has doubled in 10 years, with few new positions added due to state budget constraints.

With such challenges, it becomes even more important to provide multiple and diverse mentoring opportunities. The student population at any department can serve as a rich network of peer mentoring; senior undergraduates can mentor first-year students and Ph.D. students can mentor those in the Master's program. Students of all levels can learn from each other. Our preliminary results provide evidence of how students do mentor each other as well as the challenges that students feel in reaching out.

We discuss our preliminary results regarding Faculty Mentors and peer mentoring in turn.

4.3.1. Faculty Mentors

Since the original 2006 study, the department has instituted a new role, Faculty Mentor. The departmental website on undergraduate advising offers that,

The Computer Science Department has a three-tiered approach to advising: the Office of Undergraduate Programs, faculty mentors, and peer advisors[4] *....All students are assigned a faculty mentor, with whom they must meet at least once each academic year, typically before April. The department enforces this requirement with a registration hold*[5].

In the survey for undergraduate students, we asked, *"Why do you meet with your Faculty Mentor?"* Focused on the required nature of the relationship, all four undergraduates wrote similar responses. One wrote, *"Because it's required."* Another wrote, *"I seldom do; I only do when required. [The faculty mentor is] more focused on checkboxes than individualized advice + connections."*

In undergraduate interviews, there were multiple kinds of Faculty Mentor experiences, from helpful to contractual to discouraging. A junior undergraduate who identified as Asian American said, *"I actually just visited my faculty mentor a few days ago. And it was actually a little more helpful than I thought."* He described that the Faculty Mentor was meeting with multiple students in a group setting. He said, *"I was like 'yea, which courses should I take?' and then in addition to that, he explained what they were about. And...other students were there and they also gave me some feedback... And a lot of them were seniors and upper classmen so, they were pretty good."*

A junior international undergraduate student said her Faculty Mentor was *"really helpful."* She recalled a time that she expressed anxiety about her career opportunities and that *"My mentor talked about...that I don't need to feel so pressured to do everything technical. She says 'Just do what you want. During the summer, you don't have to do an internship.' She like calmed me down a bit and assured me."*

She lamented that her friends did not seem to have the same kind of helpfulness in their Faculty Mentors. *"[Their] Faculty Mentors don't email them until the very end and then like now time's running out. So they just do like a quick 10 min thing and it"s something to get over with. I know a lot of people where it's like that."* Another undergraduate, who identified as white, echoed the "checkbox nature" of his Faculty Mentor relationship. *"It was a little bit of advice and a lot of more or less review, to kind of say "you"re doing fine."*

A senior undergraduate student, who identified as white, said that her Faculty Mentor told her that she was *"not cut out for this department."* In response to an average grade in a course, the Faculty Mentor encouraged her to stop any extra curricular activities. The student said the the meeting was, *"Completely unhelpful."* She reflected that if she hadn't had her other chosen mentors, if she had been a less resilient student, she may have dropped out of the program because of the interaction.

When asked if she looked into getting a different mentor assigned, she reported that she did not. Furthermore, *"I never knew if I could or not."*

4.3.2. Peer Mentoring

In 2006, there were a handful of departmental organizations providing academic, research, social support and outreach opportunities for students. The organizations that still exist today are:

- CSGSO: The Computer Science Graduate Student Organization. Its main offering is a Friday social hour for graduate students.
- ACM: Association for Computing Machinery student chapter. It is open to both undergraduate and graduate students, though its membership is largely undergraduates. A large physical space in the computer science building is reserved for this student club and is often open as a student lounge and homework space. In addition, the ACM students organize an

[4]While the website says there are peer advisors, we found no evidence of a formal peer mentoring system for undergraduate advising.
[5]Source: http://www.cs.uiuc.edu/academics/undergraduate/undergraduate-advising.

annual tech conference, *Reflections Projections*. The October 2016 conference had 1,800 registrants.

- WCS: Women in Computer Science. This organization works for recruitment and retention of women at all levels of computer science. WCS hosts meetings and social events for both undergraduate and graduate students. Their largest offering is the ChicTech program designed to inspire girls to consider careers in computing. The November 2016 ChicTech retreat saw 75 high schoolers staying overnight on campus to get a feel for the different opportunities in computer science.

While not created for the purpose of peer mentoring, we find that these departmental organizations provide students with opportunities to meet other students in the department; such interactions allow students to create social networks that can be leveraged for both psychosocial support and professional development.

In 2006, though graduate students seemed largely unhappy with the activities organized by CSGSO, undergraduates enjoyed the organizations in which they participated. Ten years later, the graduate students still wished for more interactions. Undergraduates have a greater number of organizations in which they participate and flourish, but some had not yet found a group with which they *"clicked."*

In the 2016 interviews, a white senior undergraduate listed the student clubs in which she was involved, *"Hack Illinois, Women in Computer Science, ACM."* She had even started a new student club specializing in a certain kind of software development. She attributed her club with being, *"a major part, if not the only reason I stayed in this field."* With all her extra curricular activities, she found that, *"I have friends who are kind of coming to me with career questions and want like, recommendations on those kinds of things."*

A multiracial senior undergraduate who had transferred into the department from another on campus really liked how many side projects the ACM students had. He said, *"People are really enthusiastic and really into the projects and I love that kind of a culture because it drives me."*

Of the five graduate students interviewed in 2016, only one mentioned CSGSO. An international Master's student said, *"I mean, I have really limited number of interactions with graduate students which is something that should be happening. So CSGSO tries to keep its happy hour...I try my best to be there, but there's only like five or six people there. Generally it's like the pizza comes at 4:45, people come in at 4:40, maybe 4:42 or something. They grab the pizza and they just leave."*

This same student lamented his lack of opportunities to interact with other students given that he was in the Master's program. He offered, *"As far as the department is considered, I think there's more social events for Ph.D.'s students than Master's students. Because my roommate is a Ph.D. student...and he has a lot of social events at the department which are hosted by the department."* He imagined a gathering in which he had the opportunity to meet other kinds of graduate students. *"Let's say I'm a second year Master's and I know someone who's doing a Ph.D., who's in their fourth year, I can look up to them as a mentor or something."*

Other graduate students echoed this sentiment of *"a limited number of interactions."* An international graduate student who had spent some time in the Math Department before coming the Computer Science compared how the two department provided "shared spaces to graduate students." As a smaller department, she said of math, *"The first year, the department puts all the TA's in the same place."*

This sentiment was captured even within research groups. A white third-year Ph.D. student said that his group, *"tends to have everybody kind of off doing their own thing. And while that's fine, it means that if you look at our groups papers there's not a lot of cross pollination."* Similarly, a Ph.D. student and underrepresented woman of color said that her research group was *"a friendly one"* but that, *"even within in my group, people keep their work separate from each other. We have like separated work that is the same project, but not really collaborating with the same – on the same topic. It's hard to get that collaboration going."*

The graduate students who did enjoy some kind camaraderie within the department did so in a teaching assistant role. One underrepresented woman of color said that her peer mentor network was, *"The TA's for CS 225[6] for now. They range from like, civil engineering, industrial engineering, also computer science TA's. But it's more like a group of friends, you know?"* An international Master's student said, *"That was one reason why I chose to be a TA. Because, I mean, I figured out that I didn't know a lot of many people in the department after a semester. And then when you're a TA you know a lot of students."*

When he was seeking a thesis advisor, the same Master's student found mentorship through a teaching assistant, *"I had a TA for one of my courses...and she was in the same area as me. She knew my advisor and she helped me connect with him."*

4.3.3. Creative Sources of Mentors

In the written survey, 3 out of 4 undergraduates answered "No" when asked, "Do you have a mentor?" Yet, in addition to the departmental organizations, we found many students seeking creative sources of career and psychosocial support than in 2006. They found support in their peers, family members, friends, and teaching staff.

One Asian undergraduate felt a sense of unease when it came to doing homework with undergraduate men. She said, *"I've had moments where I feel like some male students will ask to work with me. Not because they think I'll be academically like equally successful, or like I'll be very helpful. But just because they want to like...they want to like say that "oh, yea, I worked with her" and like, because I'm a female student."* She went on to say, *"It feels really weird...do you see me like a peer?"*

We asked whether she had looked into any of the departmental organizations. She said, *"I just feel like I don't really fit in with the people there...I just feel like I don't really connect with them."* Instead, she had cultivated her own small homework and support network, which included her teaching assistants, engineering learning assistant as well as peers, *"a group of people*

[6] An introductory, CS2 course.

who will be supportive in that way and not try to boast and like look down on me, you know for not knowing something."

In the written survey, a multiracial senior checked the statement, *"I do not need a mentor."* He elaborated in the interview, *"Not so much that I don't need a mentor, that I think it's more of a student collaboration mentorship. I find a student who has gone through a similar thing and I had talked to them about it. So I have many mentors, kind of one on one, but they're more friends giving friends advice."*

We asked if he ever followed up with his Faculty Mentor on any of the topics he wanted to discuss. He replied, *"I will always default to another student before I will default to an advisor..."* though he included much of the professional teaching staff and academic office staff in his own mentoring network.

Other sources of mentors were diverse and were often leveraged in times of personal crisis. An white graduate student talked about a family friend, a professional psychologist, that he was able to call in times of struggle. A white undergraduate had a parent and a family friend who both worked on campus; she mentioned them, contrasting these *"fantastic"* sources of mentorship with her discouraging Faculty Mentor interactions.

We are glad that students have support networks, but mentoring should not just be sought as a coping mechanism to deal with the struggles had in the department. Mentoring should also serve as a personal and professional development network that helps all members of the community be engaged in ways that catalyze their successes. Our student participants have expressed wide-ranging negative and harmful mentoring experiences with their tenure-track Faculty Mentors to the degree that they often do not even consider these faculty as part of their mentoring networks and often feel as if their advisors and Faculty Mentors see them as burdens and administrative checkboxes.

One international graduate student pointed out her thesis advisor's mentoring qualities, *he really knows what he's doing. And it's really important to have a mentor that they know their field well. And I couldn't really find a ... a good mentor that's like they had a passion about like the next 10 years of their field.*

Aside from graduate students with thesis advisors, we didn't find substantive evidence of research mentorship. One student, a white man, even hesitated talking to his own advisor about career matters. He said, *"Like I, mean I wouldn't bother my advisor whether I should put this on my CV or not."*

5. POSITIONALITY

In qualitative research, the stories of both the researcher and the research participants are reflected in the themes that emerge (Kovach, 2009). As such, a statement of our positionality is warranted, given our educational experiences at the university and our professional experiences in the tech industry and the Computer Science Academy. While other human subjects research methodologies may wonder whether our deep connection to the university of inquiry is a too-great source of subjectivity, we view our experiences as an asset. However, with this asset comes a responsibility to set aside time for reflection on our own subjectivity.

Taking inventory of our team, we represent 42 years of experience at the university. From Illinois, we have collectively earned one bachelor's degree, two Master's degrees, and three doctoral degrees. The joys, sleights, and traumas that we experienced on the campus influenced our subsequent professional trajectories. We became senior lecturers, tenured professors, software engineers, and research directors. All the while, we invested energy into the kinds of service that would make the field a better one for underrepresented groups. And, by July 2017, we will all have left the campus.

With these experiences, during the course of our pilot study, we interviewed participants to gather data, but we also saw an opportunity for connection, collegiality and mentorship. As participants shared their own stories, we found moments of celebration in positive shared experiences. For example, when reviewing the variety of student clubs in the department, one student mentioned the Women in Computer Science as a valuable resource. Our own Chambers said, *"I helped found that group...when I was a sophomore. I was one of the first presidents."* The participant offered up a high-five to celebrate as well as an invitation to rejoin the club's current officers for dinner that evening.

In another moment of celebration, Crenshaw noticed a participant was wearing a particularly unique top. She asked, *"Are you wearing an Apple sweater because you're going to go work there?"* The participant replied, *"I am."* The participant had already signed an offer letter with the company. The audio erupts into laughter and lots of *"Congratulations!."*

Not all was celebration. One participant was particularly frustrated with the amount of cheating he was seeing. We commiserated over similar instances and experiences while we were in the department; this allowed us to gather further comments on this culture from the student, including his thoughts on how it began in the department, *"I think there's a lot of students who have been programming for years and consider themselves programmers, but find difficulty doing the assignments and then they think, "well I'm a programmer, one, I could do other important things, and two I don't need this."*

Another participant who was hungry for more interactions on campus shyly described how he stood out from his peers because he *"played a lot of sports."* Metcalf told him her own story, *"When I was here, a friend of mine created a Tuesday night volleyball group...And it wasn't just students within this department, but there were engineering students who would join us too. So, connected departments. And then I started a softball group on Sundays. We would all get together and play softball together."* In a way, sharing her story was a small moment of mentorship for the participant, helping him to see how he might create more opportunities for interaction himself.

Having our own stories to offer in exchange also helped participants feel less alone. We could say with kindness and integrity, *"Yes, we know. We saw it too. That happened to us, too."* This ability becomes particularly important with sensitive topics like gender discrimination. One participant described a situation where she didn't do anything in response to bad behavior from a student. She said that, *"every time it happens it's so shocking, that I don't feel like " did that even just happen?"*

Metcalf weighed in, *"Because you are shocked at the inappropriateness and you are left speechless about it, right? It's normal for you to feel taken aback and to not really have words in that moment to express a thing."* She also offered, *"And that is why it's so important to have people who aren't just silent bystanders but who can be allies in those situations. And who are trained to see them and to call people out on those kinds of behaviors. So it's not just the person who's the target of the remark..."*

Some quotes from participants felt eerie, as if words had been taken from our own mouths. At one point, an undergraduate summarized her experiences at Illinois this way, *I hesitate to say this, but I don't encourage women to enter the field right now. It's not a healthy environment. I...I'm not sure if I'm happy that I did it, myself.* There have been multiple moments for all of us when we had to take long breaks from recruiting activities. It is difficult to invite people into a field that can, at times, be so narrow and feel so mean.

It was in these eerie similarities that we realized the importance of our own self-care in this inquiry. Immediately after the pilot interviews in April 2016, we took a month-long break from our weekly conference calls. We described this period as *"Feeling the Feels."* Chambers wrote a long journal entry during this time, reflecting on how people call her *"one of the lucky ones"* but that it doesn't particularly feel that way. She expresses anger at the times she's been labeled as *"underperforming"* without concrete reason and enumerates the heartbreaking stories of sexual assault she's heard from colleagues, and her own moments where she has been *"left speechless"* by bad behavior. She also reflects on the ways she tries to make her corner of the field a little better. Such reflections resonate with many of the comments shared in our interviewers, and strengthen our feelings of connection to this group.

6. CONCLUSION

This pilot study is the initial step in our follow-up research to understand whether the departmental culture has changed since our original research over 10 years ago, particularly relative to the experiences of women and other underrepresented groups. Our data and discussion above represents only preliminary results from the latest phase in our case study of the University of Illinois' Department of Computer Science. The information gathered in this pilot study has allowed us to update and strengthen our survey and interview instruments.

Our fully-revised data-collection instruments are planned for the Spring 2017 semester where we will recruit participants from the larger departmental population, including faculty, for surveys and follow-up interviews on a variety of topics related to the departmental culture, including: workload; sense of belonging; departmental values; policy awareness, understanding, and effectiveness; sources of mentoring, information, and support; collegiality and respect; classroom experiences; social experiences; research experiences; advising experiences; career goals and development; performance evaluation; communication; perceptions about equity; scientific identity, and more. We will gather more data and conduct additional statistical and thematic analyses that will inform further improvements within the department and contribute to the larger body of research on computing culture. In addition, this will allow us to more fully analyze how the experiences of faculty and students at University of Illinois compare and relate to the broader culture of computing. We will be able to explore a set of recommendations to improve retention and outcomes at Illinois and beyond.

As in other foundational, in-depth case study research (e.g., Margolis and Fisher, 2003), our case study work allows for deeper understanding of the systemic issues affecting computer science retention not only within the case study location, but at similarly situated environments, however defined, beyond it. Such work also inspires new lines of inquiry for a variety of computing environments.

In the meantime, our preliminary findings indicate both improvements and areas of concern. The concrete improvements in undergraduate teaching and the continued success of peer mentoring in the face of increasing enrollment is laudable; in addition, the increased population of women and underrepresented students of color gives hope for the trajectory and future of the department. However, if the department hopes to retain and see success for its growing population of women and underrepresented students of color, several systemic, policy, and cultural issues will need to be addressed.

Descriptions of bias, including acts of violence and differential policy application, exacerbated by policy and resource opacity are particularly concerning. The existence of any one of these areas is likely to contribute to attrition. The incidents of bias against women, students of color, and international students in the classroom, research groups, and online departmental forums left unaddressed by peers, instructors, and faculty sadly align with the expansive body of research on bias, harassment, and discrimination in STEM fields (Hill et al., 2010; Metcalf, 2011; Lincoln et al., 2012; Clancy et al., 2014; Metcalf, 2014; Corbett and Hill, 2015; Moss-Racusin et al., 2015). These indicate the need for bias and harassment training, bystander education, and more effective federal, institutional, and departmental policy implementation and awareness for students, faculty, teaching assistants, and instructors.

The ongoing disconnect between faculty and students, sense of isolation, reliance on peer mentoring networks to cope with negative experiences in the department, perceived inaccessibility of tenure-track faculty, and marginal and negative mentoring experiences also raise retention concerns. Effective mentoring relationships, especially when structured as mosaics, groups, networks, and multiples, positively influence retention, organizational commitment, educational and career development and progression, skill development, knowledge acquisition, and more. Marginal and negative mentoring relationships, however, contribute to stifled careers, attrition, isolation, negative educational and career experiences, and even harmful long-lasting outcomes (Ragins, 1999; Anderson, 2011; Hamlin and Sage, 2011; Baker et al., 2017; Metcalf and Coggin, 2016). The creation of an assigned Faculty Mentor is a positive first step in providing students with the career and psycho-social support needed to be successful; however, the existence of an assigned Faculty Mentor alone cannot yield these outcomes, particularly if the substance of the mentoring relationship is primarily bureaucratic. The quality and content of mentoring relationship matters.

Over the course of a decade, the department has made some substantial progress toward creating a more inclusive culture. While our initial findings are not entirely positive and have been, at times, painful to reflect upon on a personal level, we remain grateful to a departmental leadership willing to do the difficult work of reflection with us—to learn from its struggles and its successes. While some of what we have found thus far is mirrored in the research elsewhere, this unique 10-year look from a cultural vantage point, rather than an individualistic one, provides the possibility of novel interventions in the systemic root causes of inequity and exclusion. As we continue our data collection, we are hopeful that lessons learned will continue to shape positive change in the department for all of its members. In addition, we hope that this multi-phase case study and our future work to expand it to other computing environments will deepen our collective empirical understanding of how systemic, rather than superficial, change unfolds over time and across departmental and institutional contexts.

ETHICS STATEMENT

This study was carried out in accordance with the recommendations of the University of Illinois at Urbana-Champaign Institutional Review Board, IRB No. 16507, with written informed consent from all subjects. All subjects gave written informed consent in accordance with the Declaration of Helsinki. The protocol was approved by the IRB.

AUTHOR CONTRIBUTIONS

This work is a product of all four co-authors. All co-authors have contributed in various degrees to the study's survey instruments, research concept, and analytical methods used.

FUNDING

The Department of Computer Science at the University of Illinois at Urbana-Champaign supplied partial funding for our study, supplying travel monies, interview space, a $10 remuneration for each participant, transcription services, and an honorarium for HM.

ACKNOWLEDGMENTS

We thank Jeff Erickson, EC' doctoral advisor and the Associate Department Head of Computer Science from 2013 to 2016. He invited us back to campus to take another look at his department, to understand the ways in which it had improved since 2006, and to uncover new ways that it may be better. He provided both logistical support and encouragement throughout this work.

REFERENCES

Anderson, L. (2011). A learning resource for developing effective mentorship in practice. *Nurs. Stand.* 25, 48–56. doi: 10.7748/ns.25.51.48.s49

Ayers, D. F. (2005). Neoliberal ideology in community college mission statements: a critical discourse analysis. *Rev. High. Educ.* 28, 527–549. doi: 10.1353/rhe.2005.0033

Baez, B. (2007). Thinking critically about the "critical:" quantitative research as social critique. *New Direct. Inst. Res.* 133, 17–23. doi: 10.1002/ir.201

Baker, V. L., Lunsford, L. G., and Pifer, M. J. (2017). *Developing Faculty in Liberal Arts Colleges: Aligning Individual Needs and Organizational Goals*. New Brunswick, NJ: Rutgers University Press.

Barr, V. (2014). *Women in Stem, Women in Computer Science: we're Looking at it Incorrectly*. Availbale online at: http://cacm.acm.org/blogs/blog-cacm/180850-women-in-stem- women-in-computer-science-were-looking-at-it-incorrectly/fulltext (accessed January 30, 2016).

Bilimoria, D., Joy, S., and Liang, X. (2008). Breaking barriers and creating inclusiveness: lessons of organizational transformation to advance women faculty in academic science and engineering. *Hum. Resour. Manag.* 47, 423–441. doi: 10.1002/hrm.20225

Blume-Kohout, M. (2014). Understanding the gender gap in stem fields entrepreneurship. *Small Business Assoc. Office Advocacy*. doi: 10.2139/ssrn.2506835

Braun, V., and Clarke, V. (2006). Using thematic analysis in psychology. *Qual. Res. Psychol.* 3, 77–101. doi: 10.1191/1478088706qp063oa

Castilla, E., and Benard, S. (2010). The paradox of meritocracy in organizations. *Admin. Sci. Q.* 55, 543–676. doi: 10.2189/asqu.2010.55.4.543

Clancy, K. B., Nelson, R. G., Rutherford, J. N., and Hinde, K. (2014). Survey of academic field experiences (safe): trainees report harassment and assault. *PLoS ONE* 9:e102172. doi: 10.1371/journal.pone.0102172

Corbett, C., and Hill, C. (2015). Solving the equation: the variables for women's success in engineering and computing. *Am. Assoc. Univ. Women*.

Crenshaw, T., Chambers, E. W., Metcal, H., and Thakkar, U. (2008). "A case study of retention practices at the University of Illinois at Urbana-Champaign," in *Proceedings of the 39th SIGCSE Technical Symposium on Computer Science Education, SIGCSE 2008, March 12-15, 2008* (Portland, OR), 412–416. doi: 10.1145/1352135.1352276

Crenshaw, T. L., Chambers, E. W., Metcalf, H., and Thakkar, U. (2007). Recruitment, preparation, retention: a case study of computing culture at the University of Illinois at Urbana-Champaign. *CoRR* abs/cs/0702141.

Creswell, J. W. (2008). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches, 3rd Edn*. Thousand Oaks, CA: Sage Publications, Inc.

Ely, R. J., Ibarra, H., and Kolb, D. M. (2011). Taking gender into account: theory and design for women's leadership development programs. *Acad. Manage. Learn. Educ.* 10, 474–493. doi: 10.5465/amle.2010.0046

Ely, R. J., and Rhode, D. L. (2010). "Women and leadership: defining the challenges," in *Handbook of Leadership Theory and Practice*, Chapter 14, eds N. Nohria and R. Khurana (Harvard Business Press), 377–410. Available online at: http://www.hbs.edu/faculty/Pages/item.aspx?num=37552

Fairclough, N., Mulderrig, J. and Wodak, R. (2011). "Critical discourse analysis," in *Discourse Studies: A Multidisciplinary Introduction*, ed T. A. Van Dijk (London: SAGE Publications Ltd.), 357–378. doi: 10.4135/9781446289068.n17

Fogg, P. (2004). For these professors, "practice" is perfect. *Chronicle High. Educ.* 50.

Fouad, N., Singh, R., Fitzpatrick, M., and Liu, J. (2012). *Stemming the Tide: Why Women Leave Engineering*. Technical report, Milwaukee, WI.

Hamlin, R. G., and Sage, L. (2011). Behavioural criteria of perceived mentoring effectiveness: an empirical study of effective and ineffective mentor and mentee behaviour within formal mentoring relationships. *J. Eur. Indust. Train.* 35, 752–778. doi: 10.1108/03090591111168311

Handley, I. M., Brown, E., Moss-Racusin, C., and Smith, J. (2015). Quality of evidence revealing subtle gender biases in science is in the eye of the beholder. *Proc. Natl. Acad. Sci. U.S.A.* 112, 13201–13206. doi: 10.1073/pnas.1510649112

Haraway, D. (1991). Situated knowledges: the science question in feminism and the privilege of partial perspective. *Feminist Studies*, 14, 575–599. doi: 10.2307/3178066

Harding, S. (1991). *Whose Science? Whose Knowledge? Thinking from Women's Lives*. New York, NY: Cornell University Press.

Harding, S. (2006). *Science and Social Inequality: Feminist and Postcolonial Issues*. Urbana, IL: University of Illinois Press.

Heilman, M. E., and Okimoto, T. G. (2007). Why are women penalized for success at male tasks? the implied communality deficit. *J. Appl. Psychol.* 92, 81–92. doi: 10.1037/0021-9010.92.1.81

Hill, C., Corbett, C., and St Rose, A. (2010). *Why So Few? Women in Science, Technology, Engineering, and Mathematics.* Washington, DC: ERIC.

Huddleston, T. Jr. (2014). *Google Owns Up to Lack of Diversity*. Fortune.

Hustad, K. (2016). *46% of Incoming Computer Science Majors in UIUC's College of Engineering are Women*. ChicagoInno.

Isaac, C., Lee, B., and Carnes, M. (2009). Interventions that affect gender bias in hiring: a systematic review. *Acad. Med.* 84, 1440–1446. doi: 10.1097/ACM.0b013e3181b6ba00

Knipfer, K., Shaughnessy, B. A., Hentschel, T., and Schmid, E. (2017). Unlocking women's leadership potential: a curricular example for developing female leaders in academia. *J. Manag. Educ.* 41, 272–302. doi: 10.1177/1052562916673863

Kovach, M. (2009). *Indigenous Methodologies: Characteristics, Conversations, and Contexts*. Toronto, ON; Buffalo, NY; London: University of Toronto Press.

Lincoln, A., Pincus, S., Koster, J., and Leboy, P. (2012). The matilda effect in science: awards and prizes in the united states, 1990s and 2000s. *Soc. Stud. Sci.* 42, 307–320. doi: 10.1177/0306312711435830

Margolis, J., and Fisher, A. (2003). *Unlocking the Clubhouse: Women in Computing*. Cambridge, MA; London: MIT Press.

McClelland, S., and Holland, K. (2015). You, me, or her: leaders' perceptions of responsibility for increasing gender diversity in stem departments. *Psychol. Women Q.* 39, 210–225. doi: 10.1177/0361684314537997

Metcalf, H. (2007). *Recruitment, Retention, and Diversity Discourse: problematizing the "problem" of Women and Minorities in Science and Engineering*. Master's thesis, University of Arizona, Tucson, AZ.

Metcalf, H. (2011). *Formation and Representation: Critical Analyses of Identity, Supply, and Demand in Science, Technology, Engineering, and Mathematics*. Ph.D. thesis, University of Arizona.

Metcalf, H., and Coggin, L. P. (2016). "Barriers to effective mentoring practices in academia: challenges to equitable faculty support in movement into senior ranks," in *Paper presented at Closing the Gender Gap: Advancing Leadership and Organizations*. doi: 10.5703/1288284316080

Metcalf, H. E. (2014). Disrupting the pipeline: critical analyses of student pathways through postsecondary stem education. *New Direct. Inst. Res.* 2013, 77–93. doi: 10.1002/ir.20047

Moss-Racusin, C., Molenda, A., and Cramer, C. (2015). Can evidence impact attitudes? public reactions to evidence of gender bias in stem fields. *Psychol. Women Q.* 39, 194–209. doi: 10.1177/0361684314565777

Moss-Racusin, C. A., Dovidio, J. F., Brescoll, V. L., Graham, M. J., and Handelsman, J. (2012). Science faculty's subtle gender biases favor male students. *Proc. Natl. Acad. Sci. U.S.A.* 109, 16474–16479. doi: 10.1073/pnas.1211286109

National Science Board (2014). *Science and Engineering Indicators 2014*. Arlington, VA: National Science Foundation (NSB 14-01).

National Science Board (2016). *Science and Engineering Indicators 2016.* Arlington, VA: National Science Foundation (NSB-2016-1).

Ragins, B. R. (1999). "Gender and mentoring relationships: a review and research agenda for the next decade," in *Handbook of Gender and Work*, ed G. Powell (Thousand Oaks, CA: Sage), 347–370.

RHIT (2016). *Record-Breaking Freshman Class of Female Students Expected for 2016-17*. Available online at: http://www.rose-hulman.edu/news/academics/2016/record-breaking-freshman-class-of-female-students-expected-for-2016-17.aspx

Rosser, S. V. (2004). Using POWRE to ADVANCE: institutional barriers identified by women scientists and engineers. *NWSA J.* 16, 50–78. doi: 10.2979/NWS.2004.16.1.50

Uhlmann, E., and Cohen, G. (2005). Constructed criteria redefining merit to justify discrimination. *Psychol. Sci.* 104, 207–223. doi: 10.1111/j.0956-7976.2005.01559.x

Uhlmann, E., and Cohen, G. (2007). "I think it, therefore it's true": effects of self-perceived objectivity on hiring discrimination. *Organ. Behav. Hum. Decis. Process.* 104, 207–223. doi: 10.1016/j.obhdp.2007.07.001

Vegso, J. (2005). Interest in CS as a major drops among incoming freshmen. *Comput. Res. News*. 17.

Williams, T. (2016). Women total 48.5% of Carnegie Mellon's 2016 computer science class. *Good Call*. Available online at: https://www.goodcall.com/news/women-make-computer-science-gains-09126

Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Advantages of publishing in Frontiers

OPEN ACCESS
Articles are free to read for greatest visibility and readership

FAST PUBLICATION
Around 90 days from submission to decision

HIGH QUALITY PEER-REVIEW
Rigorous, collaborative, and constructive peer-review

TRANSPARENT PEER-REVIEW
Editors and reviewers acknowledged by name on published articles

Frontiers
Avenue du Tribunal-Fédéral 34
1005 Lausanne | Switzerland

Visit us: www.frontiersin.org
Contact us: info@frontiersin.org | +41 21 510 17 00

REPRODUCIBILITY OF RESEARCH
Support open data and methods to enhance research reproducibility

DIGITAL PUBLISHING
Articles designed for optimal readership across devices

FOLLOW US
@frontiersin

IMPACT METRICS
Advanced article metrics track visibility across digital media

EXTENSIVE PROMOTION
Marketing and promotion of impactful research

LOOP RESEARCH NETWORK
Our network increases your article's readership