An Integrative Intersectional Meta-Analysis of Understandings of Gender in STEM Higher Education Research
By Allison Mattheis, Ph.D.

About the ARC Network

Funded by the National Science Foundation ADVANCE Program, Award HRD-1740860, the ADVANCE Resource and Coordination (ARC) Network seeks to achieve gender equity for faculty in higher education science, technology, engineering, and mathematics (STEM) disciplines. As the STEM equity brain trust, the ARC Network recognizes the achievements made so far while producing new perspectives, methods and interventions with an intersectional, intentional and inclusive lens. The leading advocate for women in STEM the Association for Women in Science (AWIS) serves as the backbone organization of the ARC Network.

About the Virtual Visiting Scholars

The Virtual Visiting Scholars (VVS) program provides a unique opportunity for select scholars across disciplines to pursue research meta-analysis, synthesis, and big data curation on topics crucial to STEM faculty equity. VVS analyze existing research and data, synthesizing different, sometimes competing, perspectives, frameworks, metrics, and outcomes to offer new insights and applications to the broader community.

About the Author

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Executive Summary

Although broad social understandings of gender identity have expanded greatly in the last few decades, the adoption of intersectional, complex definitions in research on the underrepresentation of women in STEM fields has been slower. A specific need exists to expand understandings of gender identity and expression in STEM fields as part of efforts to develop inclusive higher education spaces. In the broad field of research on access and representation in STEM fields, the term "gender" is often used synonymously with "women" and "female." This is a problem in the broader educational research literature (Glasser & Smith, 2008), but particularly pronounced in disciplinary-specific STEM education research. Even less attention has been paid to nuances of gender expression, and how expectations and pressures differ across other categories of identity and professional roles, or to efforts to

disconnect the idea of gender from biological or chromosomal sex. Misunderstandings that conflate gender identity with gender expression and sexual orientation can also marginalize non-heterosexual identified people in their work and study.

Furthermore, many efforts to address gender equity issues in STEM have primarily benefited women with other dominant social identities (e.g. able-bodied, cisgender, heterosexual, white). Being socially categorized as a member of more than one marginalized group compounds experiences of discrimination, demonstrating how privilege and oppression are not equally distributed (Crenshaw, 1991). Women in STEM who are members of other minoritized or marginalized groups often face additional challenges in pursuing productive and successful academic careers. In the last few decades, the application of intersectionality has expanded beyond theories of racial identity construction and formation to address cultural practices that maintain multiple forms of social oppression (Collins, 2015). This project examines the ways that gender is defined as a variable or identity characteristic in research on gender in STEM instruction and mentorship in higher education, how it is considered in combination with other social identities, and what interventions are most commonly proposed to address issues of underrepresentation.

This project used an integrative meta-analysis approach informed by intersectionality and critical feminist perspectives to review higher education-specific research published since 2010 in a set of disciplinary-specific STEM education journals and other journals that address issues of importance to the broader STEM and/or higher education communities. I adopted Whittemore and Knafl's (2005) five stage procedure for such an analysis that draws from Broome's (1993) integrative review strategy that can assess the contributions of both qualitative and quantitative, and empirical and non-empirical research studies. These steps are: (1) problem identification, (2) literature search, (3) data evaluation, (4) data analysis, and (5) presentation of a model. In this report I summarize how I completed the first four steps for this project, and explain how I am engaged in ongoing further work to complete the final step of model-development, with plans for dissemination.

Methods

The overall guiding question for this project is the following: What definitions of gender are presented in the research literature about women's experiences in STEM higher education? I also explored two sub-questions:

1. In what ways does the extant research literature distinguish (or not) between women and femininity, and how is intersectionality addressed?
2. What are the predominant interventions suggested in the extant literature around best practices for addressing and disrupting gender stereotyping and underrepresentation of women in STEM fields?

I began by reviewing the contents of 35 journals, grouped into two primary categories: discipline-specific STEM Education journals, and other journals relevant because of their focus on higher education research, gender in education, or in a few cases, a combination of both. For all of the discipline-specific journals and a selection of the other relevant journals I reviewed all abstracts for all articles published since 2010. Although this is an atypical approach to literature review and synthesis, I wished to immerse myself deeply in the overall corpus of work published in each journal and across STEM fields. This allowed me to get a sense not only of the type of research appearing within and across specific journals, but also to get a sense of "saturation" within each one—that is, how much attention appeared to be paid to issues of gender (and social identity more broadly, as I also looked for research focused on race/ethnicity and dis/ability)

By reviewing the overall corpus of all research published during this time period, rather than just using search algorithms, I was able to not only document the total number of relevant articles identified from each journal, but compare this number the overall number of articles published, and get a sense of the content and focus of those other articles. For the remaining journals I used a set of key terms (e.g. gender, STEM, women, higher education) to search within the assigned time period, and then reviewed abstracts of those articles that were returned. Using this process, I reviewed 8,002 abstracts and selected 798 articles for preliminary review (see Appendix A).

About half of these articles focused on undergraduate experience or instruction, so I chose to separate them for later analysis. Of the approximately remaining 400 articles, I then focused on those from 19 disciplinary specific STEM education journals. I grouped these articles into four categories based on research approach or publication purpose: quantitative (51), qualitative (47), mixed methods (14), and commentary, conceptual essay, or specific program evaluations (106). The first three categories lend themselves to a similar analytic approach, so I then focused on these 112 articles for the next step. Using the software program Dedoose, I first sorted the articles into descriptor sets by relevance (see Appendix B for explanation of relevance), year of publication, and journal source. I then coded each article individually, focusing on those rated as highly relevant. I used a combination of descriptive codes (e.g. those that identified the number of participants in each study, the type of data collection methods used, conceptual or theoretical frameworks employed, and how gender was described or defined) and interpretive codes (e.g. whether proposed interventions were more structural/systemic in approach and used an intersectional lens, or were more individualized, or whether the authors appeared to conflate gender identity and expression or express biological or social understandings of gender).

Preliminary Findings

Appendix C presents a list of the 35 empirical research articles that employ quantitative, qualitative, or mixed methods research designs and were categorized as highly relevant. Analysis of this set of articles in the context of the larger data set revealed two emerging themes: the nature of scholarship on gender in STEM higher education, and where this scholarship is concentrated.

What Scholarly Conversations about Gender are Present in the Literature?

The overall set of articles reviewed for this project reveal that there is still a lack of shared understanding of what "gender" means in much of the STEM higher education research. Very few articles explain what "gender" means from a conceptual standpoint, or how gender was understood in relation to other aspects of identity. Sex-based terminology (e.g. "female" as noun) was often used interchangeably with gender-based terminology (e.g. "woman") and masculinity and femininity were frequently conflated with both sex and gender. Although many researchers are clearly concerned about continued disparities in their fields, the lack of nuance in defining variables or describing study participants limits the impact of their work.

Many of the articles included in the list in Appendix C serve as encouraging exemplars, however. Particularly in the qualitative studies, many researchers adopted feminist and other critical social theories that define gender as a socially constructed category that is fluid and significant in context; many scholars applied Butler's concept of gender as performative to investigate particular experiences in STEM fields (e.g. Solomon et al., 2016; Gonsalves, 2018). These researchers were careful to use terminology that avoided essentialization of gender as part of individual identity (e.g. Gonsalves et al., 2016) and sought to complicate the of assumptions of masculinity associated with many STEM disciplines, such as in engineering (e.g. Blosser, 2017; Cech & Waidzunas, 2011). Notable examples of work that invited participants to identify themselves as cisgender or transgender include Barthelemy et al., 2016 and Stokes et al., 2015. Even in this set of articles, however, it was difficult or impossible to determine whether participants self-identified by gender, or if their identities were assumed by researchers.

This meta-analysis focuses not so much on "what" is known about gender in STEM higher education research, but rather *how* do we know, based on how gender is defined or understood. Findings from this study emphasize the need for continued epistemological conversations among researchers and participants in studies.

Where and When do these Conversations Occur?

Of the ten journals represented in the list of articles in Appendix C, half of the articles were published in two: *CBE-Life Sciences Education* and *Physical Review—Physics Education Research*. 9 articles from each of these journals appear in the list, and of these, 4 articles were published as part of a special issue (both, perhaps coincidentally, released in 2016—a special issue on "Broadening Participation in the Life Sciences: Current Landscapes and Future Directions" and a "Focused Collection on Gender in Physics"). The remaining 5 articles from each journal were relatively distributed across years of publication, matching the identification of 5 relevant articles from the *Journal of Chemical Education*. Most of the remaining articles on this list were published in various engineering specific journals, but none of these appeared more prominent than any other.

The distribution of articles across journals and years of publication reflects the influence of specific publication outlets and editorial boards. *CBE-Life Sciences Education* had the highest number of articles selected for preliminary review, and the most articles categorized as "moderate," in addition to the large percentage of most highly relevant articles. This likely reflects an ongoing commitment of this journal to regularly publish research that highlights the influence of identity on disciplinary learning. When prominent outlets in a specific subdiscipline make such choices, they can impact fields more broadly by promoting the value of such research and encouraging its proliferation.

Next Steps and Plans for Dissemination

The different epistemological assumptions that inform research in the field have produced potentially divergent bodies of knowledge—studies that inform a broader sociocultural understanding of norms and socialization processes in STEM fields, and studies that address specific programs aimed at increasing the representation of women in particular areas of research or study. In Collins' (2015) words, "intersectionality can be conceptualized as an overarching knowledge project whose changing contours grow from and respond to social formations of complex social inequalities" (p. 5). This project aims to contribute to important broader effort of expanding the participation of women in STEM fields by expanding the perspectives of gender utilized in research on STEM in higher education.

The next steps for this research include analysis of articles from the other set of journals, and then synthesis with the findings from the disciplinary specific STEM publications. Based on this cross-comparison across all journals included in the review, I will identify the most common ways that gender (and related concepts) have been conceptualized, and highlight exemplars that can serve as a model for future research. I also plan to compare publication guidelines for the 22 discipline specific journals to identify opportunities for clarification and to promote definitions that are best aligned with goals of intersectional gender equity in STEM higher education.

Appendix A: Journal Saturation Chart

Journal Title	Total Abstracts Reviewed (* indicates total articles published from 2010-2019)	Articles Selected for Preliminary Review	Focus on Graduate Education and Further Study or Professional Work
Advances in Engineering Education	182*	13	5
Bioscience Education	53*	6	3
CBE Life Sciences Education	498*	140	74
Computer Science Education	142*	27	6
Education for Chemical Engineers	180*	6	2
Educational Studies in Mathematics	568*	13	7
Engineering Education	59*	5	1
Engineering Studies	125*	22	18
IEEE Transactions on Education	488*	19	6
Innovation in Teaching and Learning in Information and Computer Sciences	62*	2	0
International Journal of Electrical Engineering Education	264*	1	0
International Journal of Mechanical Engineering Education	244*	2	0
Journal of Biological Education	271*	2	1
Journal for Research in Mathematics Education	189*	24	15
Journal of Chemical Education	583*	55	23
Journal of Engineering Education	236*	40	11
Journal of Geoscience Education	334*	36	31
Physical Review Physics Education Research	595*	71	24
Planet	59*	2	1
Higher Education Pedagogies	91*	2	0
Gender and Education	240	23	15
International Journal of Innovation in Science and Mathematics Education	42	4	1
International Journal of Science Education	463	11	1
International Journal of Science and Mathematics Education	329	8	0

International Journal of Gender, Science and Technology	161*	76	62
Journal of Diversity in Higher Education	90	31	24
Journal of Research in Science Teaching	333	17	7
Journal of Science Education and Technology	400	11	2
Journal of Women and Gender in Higher Education	81	17	9
Journal of Women and Minorities in Science and Engineering	180*	98	57
Research in Science Education	159	2	1
Research in Science & Technological Education	48	2	0
Science Education	213	8	2
Studies in Science Education	25	1	1
Teaching in Higher Education	15	1	0

Appendix B: Relevance Sorting Categories

High: article focuses on women and/or gender in STEM higher education at graduate level or beyond.

Moderate: topic may not be specific to higher education but is still relevant (e.g. women in STEM industry workforce) or influence of identity is a key focus of the research even if identity category is different (e.g. race, ethnicity, or dis/ability) or focused on industry / workforce rather than higher education

Low: social identity is not a focus of the article but gender was used as an identity category in data collection and/or analysis

Appendix C: Empirical Research Articles Categorized as Highly Relevant from Disciplinary-specific STEM Education Journals

Barthelemy, R. S., McCormick, M., & Henderson, C. (2016). Gender discrimination in physics and astronomy: Graduate student experiences of sexism and gender microaggressions. *Physical Review Physics Education Research*, *12*(2), 020119.

Barthelemy, R. S., Van Dusen, B., & Henderson, C. (2015). Physics education research: A research subfield of physics with gender parity. *Physical Review Special Topics - Physics Education Research*, *11*(2), 020107. https://doi.org/10.1103/PhysRevSTPER.11.020107

Bekki, J. M. (2014). Efficacy of an online resource for teaching interpersonal problem solving skills to women graduate students in engineering. *Advances in Engineering Education*
1-27.

Blair, E. E., Miller, R. B., Ong, M., & Zastavker, Y. V. (2017). Undergraduate STEM Instructors' Teacher Identities and Discourses on Student Gender Expression and Equity: Stem Instructors' Discourses on Student Gender. *Journal of Engineering Education*, *106*(1), 14–43. https://doi.org/10.1002/jee.20157

Blosser, E. (2017). Gender Segregation Across Engineering Majors: How Engineering Professors Understand Women's Underrepresentation in Undergraduate Engineering. *Engineering Studies*, *9*(1), 24–44. https://doi.org/10.1080/19378629.2017.1311902

Canetto, S. S., Trott, C. D., Thomas, J. J., & Wynstra, C. A. (2012). Making Sense of the Atmospheric Science Gender Gap: Do Female and Male Graduate Students Have Different Career Motives, Goals, and Challenges? *Journal of Geoscience Education*, *60*(4), 408–416. https://doi.org/10.5408/12-296.1

Cech, E. A., & Waidzunas, T. J. (2011). Navigating the heteronormativity of engineering: The experiences of lesbian, gay, and bisexual students. *Engineering Studies*, *3*(1), 1–24. https://doi.org/10.1080/19378629.2010.545065

Chapman, S., Dixon, F. F., Foster, N., Kuck, V. J., McCarthy, D. A., Tooney, N. M., Buckner, J. P., Nolan, S. A., & Marzabadi, C. H. (2011). Female Faculty Members in University Chemistry Departments: Observations and Conclusions Based on Site Visits. *Journal of Chemical Education*, *88*(6), 716–720. https://doi.org/10.1021/ed100098q

Clark, S. L., Dyar, C., Maung, N., & London, B. (2016). Psychosocial Pathways to STEM Engagement among Graduate Students in the Life Sciences. *CBE—Life Sciences Education*, *15*(3), ar45. https://doi.org/10.1187/cbe.16-01-0036

Connolly, M. R., Lee, Y.-G., & Savoy, J. N. (2018). The Effects of Doctoral Teaching Development on Early-Career STEM Scholars' College Teaching Self-efficacy. *CBE—Life Sciences Education*, *17*(1), ar14. https://doi.org/10.1187/cbe.17-02-0039

Dabney, K. P., & Tai, R. H. (2014a). Comparative analysis of female physicists in the physical sciences: Motivation and background variables. *Physical Review Special Topics - Physics Education Research*, *10*(1), 010104. https://doi.org/10.1103/PhysRevSTPER.10.010104

Dabney, K. P., & Tai, R. H. (2014b). Factors Associated with Female Chemist Doctoral Career Choice within the Physical Sciences. *Journal of Chemical Education*, *91*(11), 1777–1786. https://doi.org/10.1021/ed4008815

Dabney, K. P., & Tai, R. H. (2013). Female physicist doctoral experiences. *Physical Review Special Topics - Physics Education Research*, *9*(1), 010115. https://doi.org/10.1103/PhysRevSTPER.9.010115

Dutta, D. (2015). Sustaining the Pipeline: Experiences of International Female Engineers in U.S. Graduate Programs. *Journal of Engineering Education*, *104*(3), 326–344. https://doi.org/10.1002/jee.20077

Feldon, D. F., Peugh, J., Maher, M. A., Roksa, J., & Tofel-Grehl, C. (2017). Time-to-Credit Gender Inequities of First-Year PhD Students in the Biological Sciences. *CBE—Life Sciences Education*, *16*(1), ar4. https://doi.org/10.1187/cbe.16-08-0237

Gibbs, K. D., & Griffin, K. A. (2013). What Do I Want to Be with My PhD? The Roles of Personal Values and Structural Dynamics in Shaping the Career Interests of Recent Biomedical Science PhD Graduates. *CBE—Life Sciences Education*, *12*(4), 711–723. https://doi.org/10.1187/cbe.13-02-0021

Gibbs, K. D., McGready, J., & Griffin, K. (2015). Career Development among American Biomedical Postdocs. *CBE—Life Sciences Education*, *14*(4), ar44. https://doi.org/10.1187/cbe.15-03-0075

Gonsalves, A. J. (2018). Exploring how gender figures the identity trajectories of two doctoral students in observational astrophysics. *Physical Review Physics Education Research*, *14*(1), 010146. https://doi.org/10.1103/PhysRevPhysEducRes.14.010146

Gonsalves, A. J., Danielsson, A., & Pettersson, H. (2016). Masculinities and experimental practices in physics: The view from three case studies. *Physical Review Physics Education Research*, *12*(2), 020120. https://doi.org/10.1103/PhysRevPhysEducRes.12.020120

Hatmaker, D. M. (2012). Practicing engineers: Professional identity construction through role configuration. *Engineering Studies*, *4*(2), 121–144. https://doi.org/10.1080/19378629.2012.683793

Isaac, C., Kaatz, A., Lee, B., & Carnes, M. (2012). An Educational Intervention Designed to Increase Women's Leadership Self-Efficacy. *CBE—Life Sciences Education*, *11*(3), 307–322. https://doi.org/10.1187/cbe.12-02-0022

Ivie, R., White, S., & Chu, R. Y. (2016). Women's and men's career choices in astronomy and astrophysics. *Physical Review Physics Education Research*, *12*(2), 020109. https://doi.org/10.1103/PhysRevPhysEducRes.12.020109

Laursen, S. L., & Weston, T. J. (2014). Trends in Ph.D. Productivity and Diversity in Top-50 U.S. Chemistry Departments: An Institutional Analysis. *Journal of Chemical Education*, *91*(11), 1762–1776. https://doi.org/10.1021/ed4006997

Layton, R. L., Brandt, P. D., Freeman, A. M., Harrell, J. R., Hall, J. D., & Sinche, M. (2016). Diversity Exiting the Academy: Influential Factors for the Career Choice of Well-Represented and Underrepresented Minority Scientists. *CBE—Life Sciences Education*, *15*(3), ar41. https://doi.org/10.1187/cbe.16-01-0066

Lord, S. M., Layton, R. A., & Ohland, M. W. (2011). Trajectories of Electrical Engineering and Computer Engineering Students by Race and Gender. *IEEE Transactions on Education*, *54*(4), 610–618. https://doi.org/10.1109/TE.2010.2100398

Moss-Racusin, C. A., van der Toorn, J., Dovidio, J. F., Brescoll, V. L., Graham, M. J., & Handelsman, J. (2016). A "Scientific Diversity" Intervention to Reduce Gender Bias in a Sample of Life Scientists. *CBE—Life Sciences Education*, *15*(3), ar29. https://doi.org/10.1187/cbe.15-09-0187

Potvin, G., Chari, D., & Hodapp, T. (2017). Investigating approaches to diversity in a national survey of physics doctoral degree programs: The graduate admissions landscape. *Physical Review Physics Education Research*, *13*(2), 020142. https://doi.org/10.1103/PhysRevPhysEducRes.13.020142

Potvin, G., & Tai, R. H. (2012). Examining the Relationships among Doctoral Completion Time, Gender, and Future Salary Prospects for Physical Scientists. *Journal of Chemical Education*, *89*(1), 21–28. https://doi.org/10.1021/ed100555j

Rosa, K., & Mensah, F. M. (2016). Educational pathways of Black women physicists: Stories of experiencing and overcoming obstacles in life. *Physical Review Physics Education Research*, *12*(2), 020113. https://doi.org/10.1103/PhysRevPhysEducRes.12.020113

Rybarczyk, B. J., Lerea, L., Whittington, D., & Dykstra, L. (2016). Analysis of Postdoctoral Training Outcomes That Broaden Participation in Science Careers. *CBE—Life Sciences Education*, *15*(3), ar33. https://doi.org/10.1187/cbe.16-01-0032

Scase, M. M., & Turnbull, B. (2013). Role Models in Gender-Skewed Disciplines. *Engineering Education*, *8*(1), 98–110. https://doi.org/10.11120/ened.2013.00010

Solomon, Y., Radovic, D., & Black, L. (2016). "I can actually be very feminine here": Contradiction and hybridity in becoming a female mathematician. *Educational Studies in Mathematics*, *91*(1), 55–71. https://doi.org/10.1007/s10649-015-9649-4

Stockard, J., Greene, J., Richmond, G., & Lewis, P. (2018). Is the Gender Climate in Chemistry Still Chilly? Changes in the Last Decade and the Long-Term Impact of COACh-Sponsored Workshops. *Journal of Chemical Education*, *95*(9), 1492–1499. https://doi.org/10.1021/acs.jchemed.8b00221

Stokes, P. J., Levine, R., & Flessa, K. W. (2015). Choosing the Geoscience Major: Important Factors, Race/Ethnicity, and Gender. *Journal of Geoscience Education*, *63*(3), 250–263. https://doi.org/10.5408/14-038.1

Young, K., Lovedee-Turner, M., Brereton, J., & Daffern, H. (2018). The Impact of Gender on Conference Authorship in Audio Engineering: Analysis Using a New Data Collection Method. *IEEE Transactions on Education*, *61*(4), 328–335. https://doi.org/10.1109/TE.2018.2814613