IDENTITY AS A RESEARCH LENS IN SCIENCE AND PHYSICS EDUCATION

CHRIS GOSLING, McGill University

ABSTRACT. Gender research in physics education has traditionally focused on studying learning differences between males and females, understanding how to present content in a way that is more accessible for females, or uncovering explanations for observed differences in engagement with physics (e.g., Hazari, Sonnert, Sadler, & Shanahan, 2010; Kost, Pollock, & Finkelstein, 2009). Recent work in Physics Education Research (PER) calls for an epistemological shift (Traxler, Cid, Blue, & Barthelemy, 2016) in research concerning gender, one that focuses on the complex and intersectional nature of student learning as gendered identity formation within the culture of school science. This shift is necessary because the traditional approaches to gender research within the Physics Education Research community of practice cannot account for the contextual nature of gender nor its intersection with other factors. The science education community has much to offer in this regard, having developed and applied identity formation as an analytical tool (e.g., Carlone & Johnson, 2007). The aim of this critical literature review is to present a survey of the relevant literature that investigates how identity is employed by researchers and how its use can help move gender research in physics beyond a binary perspective of gender.

RÉSUMÉ. Les recherches sur le genre et l'égalité des sexes en didactique de la physique se sont traditionnellement attardées à l'étude des différences dans les apprentissages entre les garçons et les filles, comprendre comment les enseignants peuvent présenter les contenus de sorte que ces derniers soient plus accessibles chez les filles, ou découvrir des raisons expliquant les différences observées dans l'engagement des femmes en physique (Hazari, Sonnert, Sadler, et Shanahan, 2010; Kost, Pollock, et Finkelstein, 2009). De récentes recherches en didactique de la physique (RDP) suggèrent une transition épistémologique (Traxler, Cid, Blue, et Barthelemy, 2016) dans les études sur sur le genre, une qui met l'accent sur la nature complexe et intersectionnelle sur l'apprentissage des élèves puisque la formation de l'identité genrée et sexuée fait partie de la culture scientifique à l'école. Cette transition est nécessaire étant donné que les approches traditionnelles dans les études sur le genre dans la communauté professionnelle des pratiques enseignantes en didactique de la physique ne peuvent pas tenir pour acquis la nature contextuelle de l'égalité des sexes ni les intersections avec d'autres facteurs. La communauté des chercheurs en didactique des sciences a beaucoup à offrir à cet égard puisqu'ils ont développé et utilisé la formation identitaire comme outil d'analyse (Carlone et Johnson, 2007). Le but de cette recension des écrits critique est de présenter un sondage des écrits pertinents s'intéressant à démontrer comment l'identité est employée par les chercheurs et comment son utilisation peut soutenir d'autres études en physique au-delà de la perspective binaire du genre.

Key words: *Identity, gender, physics, science, education.*

INTRODUCTION

Despite decades of concern about female representation in the physical sciences, physics lags behind the other sciences in both the recruitment and retention of women to postsecondary degree programs in Canada, the United States, and internationally (Francis et al., 2016). The demographics of physicists do not reflect those of the wider population; for example, in the United States, only 20% of bachelor's degrees are currently awarded to women (Statistical Research Center | American Institute of Physics, 2017). This lack of progress is particularly significant given the efforts of scholars whose focus on gender issues within physics education research (PER) has endeavored to uncover ways to bring more women into the field and keep them there (see discussion in Traxler, Cid, Blue, & Barthelemy, 2016).

Gender research in PER has traditionally focused on studying learning differences between male and female students, understanding how to present content in a way that is more accessible for women, or uncovering explanations for observed differences in engagement with physics (e.g., Hazari, Sonnert, Sadler, & Shanahan, 2010; Kost-Smith et al., 2010). These related threads of inquiry have produced a detailed picture of these learning differences, but by their nature cannot capture the nuances of students' experiences in physics and how they relate to the field. Gender research in PER has also traditionally considered "female" students as a uniform category defined in relation to their male counterparts. This approach positions female students as deficient when compared to their male counterparts (Traxler et al., 2016) and also prohibits a deeper exploration of how students, with a spectrum of gender identities, engage with and experience physics.

The limitations outlined above plague the majority of existing gender studies in PER. To address these shortcomings, scholars have called for an epistemological shift (Traxler et al., 2016) in research on gender, one that focuses on the complex and intersectional nature of student learning as gendered identity formation within the culture of school science. In addition, we must carefully consider how gender is categorised to avoid reinforcing gendered inequalities of power (Francis & Paechter, 2015). These shifts are needed because the traditional approaches to gender research within the PER community cannot account for the contextual nature of gender nor its intersection with other factors (May, 2012). Science education researchers have much to offer in this regard, having developed and applied identity formation as an analytical tool (e.g., Carlone & Johnson, 2007).

This critical literature review will first discuss the motivation for using identity as a research lens in PER. I will then compare and contrast how identity has been conceptualized and mobilized in the study of science and physics education in recent studies. Finally, this review will consider the potentially illuminating lessons in the way that these researchers conceive and deploy identity as a theoretical lens in their work.

WHY DO WE NEED IDENTITY?

A Sociocultural Perspective

In his 2001 article, Lemke describes the sociocultural perspective on science education as "viewing science, science education, and research on science education as human social activities conducted within institutional and cultural frameworks" (p. 296). Accordingly, a sociocultural approach to science education research does not consider science learning to be a stand-alone process, but rather an activity which is intricately connected to students' lives outside of school. Lemke notes that, "students' beliefs, attitudes, values, and personal identities" are all critical to their success in learning science (p. 305). How then, could a research approach focused solely on cognitive gains or differences between different groups of learners, hope to capture the complexity of students' experiences? The answer, of course, is that it cannot. The process of learning science as it is currently taught frequently requires students to surrender facets of their personal identity and some of the bonds that they share with their community (Lemke, 2001). This process is most problematic for students who do not fit the dominant paradigm of a physicist—that is to say, anyone who is not white, cisgender (gender identity matching their birth sex), male, able-bodied, and heterosexual. While some non-dominant students reject these concessions and maintain their connections to their cultures and communities, in doing so, they run the risk of failing in science. A cognitive approach to understanding the process of learning science would deem these students as "unsuccessful", but a sociocultural approach might shed light on the disconnect between the cultures of home and school while demonstrating that there are confounding influences that affect student learning. The construct of identity, in particular, is aptly suited to investigating such complex interdependencies between cultures, community, and learning.

What is identity?

Though a literature review of this nature does not require the development of a theoretical framework, it is worth defining what researchers mean when they use the term identity. Brickhouse (2001) described the process of learning as "not merely a matter of acquiring knowledge, it is a matter of deciding what kind of person you are and want to be and engaging in those activities that make one a part of the relevant communities" (p. 286). She refers to this this act of deciding what kind of person you are and want to be as identity formation. Similarly, Gee (2000) defined identity as being recognized as a certain "kind of person" (p. 99) at a given time and place. Taken together, we arrive at a working definition of identity as: the sum of one's beliefs about oneself, one's actions, and how one's behavior is interpreted by others in a given context.

A note on poststructuralist terminology

Before delving into a review of recent research in science and physics education that uses identity as an analytical lens, I will pause to explain two terms that poststructuralist researchers

commonly employ when talking about identity and student learning: positioning and performativity.

Positioning is used to describe the act of putting one's self or someone else into a particular stance, most frequently during a verbal exchange or conversation (Davies & Harré, 1990). With a specific eye toward group work in physics, Berge and Danielsson (2013) wrote that "positioning is always twofold; a positioning of someone else also implies a positioning of oneself, and moreover, people can both position themselves (reflexive positioning) and position others (interactive positioning) in a conversation" (p. 1181). Consider as an example a comment that I might make while working in a small group comparing the approach a fellow group member employed to solve a problem to that I used. By voicing this aloud, I am simultaneously putting myself into a particular role ("thorough checker," for example) and positioning my peer in a certain way ("rapid problem solver," perhaps). It is important to note that the range of positions available during a conversation is not infinite. Though a small group of three to four students working together is itself a form of cultural production (Carlone, Johnson, & Eisenhart, 2014), the function of this group of students and the roles that each one assumes are modulated by larger discourses, such as the classroom culture, the school community, and the larger physics community as a whole.

Performativity is a term that is used to describe how individuals perform a certain role in a given context. In her writings on the nature of gender, Judith Butler (1999) wrote that performativity is "repetition and a ritual, which achieves its effects through its naturalization in the context of a body, understood, in part, as a culturally sustained temporal duration" (p. xv). That is to say, performativity refers to how a person acts in ways that lead others to view them as a certain kind of person. These acts are sustained and ongoing and, for many, unconscious ways of fulfilling expected roles. Therefore, if someone is described as performing a male gender, they think of themselves as male, act in ways that they consider to be compatible with a male gender, and are recognized as having a male gender in that context. Notice that none of these elements are related to a person's sex—a performative perspective of gender rejects the binary female/male definition completely.

It is important to note that the idea of performativity is not limited to gender and can be applied to different facets of our identities. For example, students can perform "good student" identities by acting in ways that meet the expectations that others might have for how good students should act. Finally, performativity can change based on one's situation. For instance, the way that one performs a "good student" identity might change dependent on one's academic course given that different teachers have differing expectations and definitions of what it means to be a good student.

Learning as Identity Formation

Understanding learning as a form of identity construction is a particularly rich approach because "it accounts for the importance of both individual agency as well as societal structures that

constrain individual possibilities" (Brickhouse, 2001, p. 286). As such, the concept of identity enables researchers to determine the cause for a student's difficulty in learning, whether because they are having difficulty grasping the information being presented or because the difficulty stems from a conflict between how a student views themselves and how they are expected to behave in class. Brickhouse (2001) provides a poignant example:

> Thus a girl who is silent in science class may well be acting in this way because she aspires to be a good girl student. . . . It may be the case that a student will decide that she has no desire to be a part of the communities at school that are engaged in school science. Perhaps she finds what they do to be boring and irrelevant to her own concerns. Or perhaps she finds the other members of the community to be simply obnoxious. She chooses disengagement and ignorance in the process of deciding that she does not desire membership into school science communities. (p. 287)

In using identity as a theoretical construct, we are better able to understand student learning; it is not sufficient to say that students are or are not learning; we must aim to understand the reasons why students are learning the way that they are.

Carlone and Johnson (2007) made a compelling case for using identity to study the learning of science. They noted that existing approaches fall flat when attempting to determine why some students do not persist in science despite their qualifications to do so (Carlone & Johnson, 2007). The obvious response is that there is something about these students that is at odds with the way that they are being taught science—perhaps it is something in their backgrounds, the way they experience the courses, or the roles that they must take on in order to be successful within the culture of school science. Carlone and Johnson (2007) also highlighted how traditional approaches to studying the learning of science fail to account for students' agency and are generally static;that is, such approaches consider factors that modulate student learning to be discrete variables, rather than allowing for a wide spectrum of responses. After chronicling the limitations of past studies of science learning, they offered identity as an alternative. This allows for accounts of structure and agency, for a performative view of gender and race, and for flexibility to be applied across large time scales and in variable contexts (Carlone & Johnson, 2007). These scholars developed a model for identity to better understand their data; I discuss this model later in this review.

A more recent call for the use of identity in science education research comes from Traxler, Cid, Blue, and Barthelemy (2016), who highlighted identity as a possible way forward for gender research in physics education given its flexibility. In particular, as a research lens, identity is not limited by a binary definition of gender; rather, it understands gender to be performative and contextual. That is to say, Traxler and her collaborators assumed a Butlerian approach to gender, describing how it is both performed and interpreted, and pointing out that the way that one's gender is performed and interpreted depends on context. Finally, Traxler et al. (2016) noted that identity also has the potential to account for the intersection of gender with additional factors such as race or ethnicity, socioeconomic status, and sexual orientation. Given the dearth of

studies examining the confluence of such factors concerning gender in PER, this appears to be an area where the use of identity as a research lens would enable substantial gains by allowing researchers to produce a more comprehensive and nuanced picture of how students engage with physics.

EXISTING RESEARCH USING IDENTITY

A Model of Science Identity Formation: Competence, Performance, and Recognition

In their research, Carlone and Johnson (2007) created a novel model of science identity formation to understand how the experiences of their participants with science, over time, contributed to different elements of their science identities. Their definition of identity operationalizes the sociocultural definition offered by Gee (2000). Carlone and Johnson's model maintains three facets of identity: competence, performance, and recognition; all must exist for students to fully form science identities. Competence refers to being proficient in practices that are relevant to the one's context (a physics classroom, for example), performance refers to demonstrating this competence, and recognition refers to others perceiving this performance as credible. In the context of a physics class, these facets might look like a student having the ability to solve a particular problem, doing so in a way that their teacher can observe their work, and the teacher then confirming the suitability of their solution.

Carlone and Johnson found that the development of students' science identities was, at times, severely hampered by their interactions with established members of the field, who did not provide the positive recognition critical for the formation of full-fledged science identities. This unconscious behavior may have occurred because the students' performance of their competence did not meet their professor's expectations. This is not to say that the performances were lacking, but rather, that they did not have the expected form. For example, describing a scientific idea accurately, but using different language than that common to the field, might have prevented some faculty members from recognizing their explanation as accurate.

Carlone and Johnson's (2007) study is of critical importance, not only because it successfully utilized identity as a research lens, but also because it illuminated three essential elements that are crucial to students' identity formation. This is particularly meaningful because if students do not form science identities, they are unlikely to be successful in their science courses and will subsequently not pursue careers in the field. Carlone and Johnson's study also highlighted recognition as a crucial component of identity formation, which, in turn, directly impacts student learning given that an incomplete science identity may prevent students from fully engaging with science content as insiders.

Secondary Students' Physics Identity Formation

While previous research suggests that female students are less likely to view themselves as physics people than male students, a recent study determined that students' gendered

perceptions of identity are mutable (Hazari et al., 2013; Hazari, Sonnert, Sadler, & Shanahan, 2010). In their work, Hazari et al. (2010, 2013) found that discussions about the under-representation of women in physics held a particular power to positively affect students' physics' identities.

Lock and Hazari's later research (2016) built on these findings when they focused on a single classroom where discussions about the under-representation of women in physics were being conducted to investigate the impact that these discussions had on student thinking. This study concluded that these discussions offered an opportunity for students to change their views of who can be a physicist and what being a physicist entails. It also revealed that this shift can, in turn, change the way students interpret their science experiences and can also impact their physics identity and career aspirations. It is crucial to note that the shifts in student thinking occurred not only for "female" students but also for "male" students, which indicates the potential for such discussions to gradually transform the culture of physics to be a more accepting space.

Forms of competence

Gonsalves (2014) used identity as a tool to examine how students modify their behaviors or pursue different ways to demonstrate competence within the cultural norms of physics. As viewed through the lens of identity, her data "revealed two predominant ways of being recognized as a physicist: demonstrating one or more of three main types of competence (analytical, technical and academic competence); and by performing stereotypical physicist behaviour" (p. 509). These themes of competence and performance connect directly to Carlone and Johnson's (2007) model of identity formation and further enhance it. In this case, the use of identity as a lens allowed Gonsalves to demonstrate that the competence required for students to form physics identities might assume different modes and still be recognizable by established members of the field. Her work additionally demonstrates how students modified their behavior in response to their experiences of the physics culture.

Recognition: The Role of Teachers in Secondary Students' Science Identity Formation

Hazari, Brewe, Goertzen, and Hodapp's (2017) study focused on factors that affect how high school students form physics identities. The researchers collected quantitative data from a large Likert-scale survey (*n=962*) that asked female undergraduate students to report how they viewed themselves; there were similarly asked to assess how they were positioned by their peers and by their teacher (p. 97). The students' responses showed that recognition by high school teachers was particularly important for the formation of a physics identity for girls in high school (Hazari et al., 2017). This finding is a linchpin in the field because it demonstrates the significant influence these teachers maintain in impacting their students' physics identity development—many teachers are ignorant of the extent to which their recognition (or lack thereof) impacts female students. Hazari et al. (2017) also found that high school is a particularly fruitful time during students' development for them to receive positive recognition. However, Hazari et al.

also noted that further research is needed to determine what counts as meaningful recognition and how the recognition can be transmitted to students. I wondered about this final aspect as I read her work, curious if the recognition must happen verbally, and in person. Or, could the recognition be transmitted using other media, such as comments and feedback on written assignments (e.g., homework or journals) or even responses to students' posts on an electronic discussion board?

Performance: Pedagogical Approaches and Identity Disruption

The role of the teacher in a student's physics identity formation is not limited to recognition alone; pedagogical approaches are also a key component in helping students see themselves as *physics* people. Carlone's (2004) research into reformed teaching methods that endeavored to engage students in their own learning and encouraged them to think about what it means "to 'do science' and 'be a science person'" (p. 393) provided clear insights into why student learning was not as successful as anticipated. Carlone's study used the concept of identity to understand the experiences that students, with similar backgrounds, had in a novel high school physics course. Identity emerged as a construct that determines what sort of behaviors are valued within a learning environment and what kinds of roles are available for particular students to assume (pp. 396-397). The reformed teaching methods, provided by the teacher in Carlone's study, disrupted student identity formation because they valued different modes of class participation than previous courses. This change in teaching style endangered the good student identities that students, especially female students, had cultivated in previous science courses and triggered crises for some students as they struggled to position themselves around this new way of doing science. The progressive pedagogical approach used in this course impacted students' physics identity formation, which, in turn, affected their learning. Using identity as a theoretical lens allowed Carlone to understand their resistance to the reformed course in ways that would not have been possible otherwise.

Societal Impact of Physics as a Gendered Construct on Secondary Students

While teachers maintain influence over pedagogical approaches and their recognition given to students within the classroom, societal pressures outside the school must also be considered when looking at how physics identities are formed. Archer, Moote, Francis, DeWitt, and Yeomans' (2016) research investigated the identity work done by girls enrolled in a variety of secondary schools across England over a ten-year period. Their longitudinal approach to understanding identity formation examined how the way society considers physics to be a masculine domain prevented girls from identifying with the field. The researchers understood gender and classroom behaviors to be performative in nature and they also mobilized the concepts of habitus and capital (Bourdieu, 1986) to examine the ways in which the students interacted with physics (Archer et al., 2016) in light of their previous experiences outside of class. The data collected indicated a strong influence from mainstream culture on the roles that were available for girls to play and about the suitability of males for careers in physics. Identity was a useful lens in this case because it provided insights into how students positioned themselves

relative to physics and the degree to which they maintained their femininity while participating in physics. This is a particularly important study because it examined secondary students' positioning around physics relative to gender, which is a topic that had not been widely explored before this work was published. Further, it is significant because, rather than looking at differences between girls and boys learning physics, it looked for variations within the group of students categorised as girls to see what enabled some students to succeed in forming physics identities.

Gendered Roles in the Physics Laboratory

Western culture's larger understanding of physics as a masculine field is replicated within the micro-culture of the laboratory. Danielsson's (2012) study found that, while each unique, individual student's identity is molded and constrained by the norms of the field. Even in cases where her participants positioned themselves outside the stereotypical positions available, the participants were still comparing their own identities against those available to them in physics. Much like Archer et al. (2016), Danielsson (2012) conceptualized gender as performative but noted that these performances are constrained by the context within which one works. She wrote, "not only are the female physics students relating to masculine norms of the discipline, they may also have to deal with the norms and expectations about how a woman is supposed to be in a physics and engineering context" (p. 36). This passage illustrates how Danielsson's use of identity as a theoretical lens makes apparent the subtle ways that student identities are produced within and in opposition to the culture of physics.

Science Identity Trajectories

Like Archer et al. (2016), Jackson and Seiler (2013) also used identity as a lens to study students' positioning with regard to science. Rather than focusing on gender, however, they used identity to explore the trajectories of non-traditional science students at a CEGEP institution in Montréal, which spans the traditional divide between high school and university (Jackson, 2014; Jackson & Seiler, 2013). These researchers looked at how latecomers -- those students who arrive in physics after an atypical academic trajectory -- learn science, and how they position themselves relative to the field.

The most significant result of Jackson and Seiler's (2013) research was the creation of a new model of identity trajectory that captures students' science identities over time. These scholars looked at how students positioned themselves, and others, while they did identity work and found that students' science trajectories can be disrupted by the cultural models of learning present in most science classrooms. In this instance, the use of identity as an analytic lens allowed the researchers to view the latecomers who participated in the study not just as students who struggled, but as students whose ways of learning and past experiences were incongruent with the approaches that their instructors used to currently teach them science. This created a conflict between the identities that students narrated for themselves and the identities available within science. This finding can be extended to gender research–students

whose ways of learning do not fit the dominant paradigms of school science are likely to struggle to form science identities, and in turn, to learn science. From this perspective, the theoretical lens of identity produced valuable insights into the connections between instructional methods and the likelihood that students will continue their studies of science.

CONCLUSIONS

The studies highlighted above demonstrate the variety of ways in which identity can be used as a theoretical lens to produce novel insights into how students learn physics and science. In particular, this review has shown that an identity lens allows us to understand that issues with student learning are not limited to difficulties with content, but can also stem from an incompatibility between how students view themselves and the modes of behavior and learning that are expected within their physics classrooms. Carlone and Johnson's (2007) model for identity formation set the foundation for identity work by identifying competence, performance, and recognition as elements crucial to women of colour studying science at the university level. Other researchers have built upon this model, showing that multiple types of competence can garner positive recognition (Gonsalves, 2014) and that recognition is particularly important, especially for girls at the secondary level (Hazari et al., 2017).

Furthermore, Lock and Hazari (2016) found that conversations about the under-representation of women in physics have the potential to change the way students think of the field of physics and their own place in it. Both mainstream culture and the culture of physics itself constrain the gendered roles that are possible for students to assume (Archer et al., 2016). Non-dominant students struggle to create identities against the norms of the culture of physics in an effort to maintain the way they see themselves (Danielsson, 2012). Finally, the methods that instructors use in their classrooms can have a massive impact on students whose ways of learning do not align with their instructors' expectations. Students actively resist such changes when their good student identities are threatened (Carlone, 2004) and can end up on outbound trajectories from physics if they are not allowed to perform their competence and engage with the content (Jackson, 2014; Jackson & Seiler, 2013).

Taken as a whole, these studies present a wide variety in the ways that identity can be used to study how students learn science and physics. It is clear that, as a theoretical lens, identity allows for a consideration of aspects of student learning that are not possible with more traditional models. For example, the binary approach to gender precludes any mention of students who do not meet the female/male binary, and also positions female students as lesser than their male peers. Identity does not have the same sort of limitation, as it allows for a wide spectrum of gender to emerge. It also allows researchers the opportunity to look for variations within a given category rather than comparing categories of students against one another. Further, identity is a flexible lens, useful for examining the intersection of multiple facets of student identity simultaneously. For example, Carlone and Johnson (2007) showed that it could be used to understand the experiences of women of colour, who engage in the practices of science differently from both white women and men of colour. For the multiple reasons outlined above,

identity holds tremendous potential as a research lens. It is well-suited to a wide range of research undertaken from the socio-cultural perspective and permits researchers to ask difficult questions about how students engage with science and physics.

NEXT STEPS

Given the current position into which physics places non-dominant students, it would seem imperative that action be taken to redress the imbalance. Hopefully, physics education would open dialogue with students about the under-representation of women in physics, which, as Lock and Hazari (2016) demonstrated, positively affects students' physics identities and increases the likelihood that they might enter the field. However, the precise types of changes that may occur in students' thinking and identities during these discussions have not been established. In addition, while recognition of students' competence is a critical element of their physics identity formation, the forms that this recognition may take and the frequency with which it need occur are not well known. Though the interplay between students' backgrounds and the modes of teaching employed by their instructors has been documented, this area also warrants further investigation with respect to other intersectional aspects of their identities, such as socio-economic class. Finally, much of the data that has been generated by these studies relies on students' beliefs and intentions about whether or not they will continue to study physics in the future. A fruitful line of inquiry would be to follow secondary students in a long-term study to determine whether or not they follow through with their intentions.

Despite the researchers' varied lines of inquiries, this review has demonstrated that identity is a research lens well worth considering. The construct of identity allows scholars to ask difficult questions about the nuanced aspects of non-dominant students' experiences with physics. Hopefully the answers they find will enable us to improve the way that physics is taught and change the culture of physics so that future students see a place for themselves in it.

ACKNOWLEDGEMENTS

I am indebted to my supervisor, Allison Gonsalves, for helping me select the topic for this analysis and for her guidance during the writing process. I am also grateful for the careful reading done by Philippa Parks and for her many useful suggestions. I also wish to acknowledge the helpful contributions of Bronwen Low, Ying-Syuan (Elaine) Huang, and Marta Kobiela, who provided feedback on an early version of this manuscript.

REFERENCES

Archer, L., Moote, J., Francis, B., DeWitt, J., & Yeomans, L. (2016). The "exceptional" physics girl: A sociological analysis of multimethod data from young women aged 10-16 to explore

gendered patterns of post-16 participation. *American Educational Research Journal*, *54*(1), 88–126.

Berge, M., & Danielsson, A. T. (2013). Characterising learning interactions: A study of university students solving physics problems in groups. *Research in Science Education*, *43*(3), 1177-1196.

Bourdieu, P. (1986). The forms of capital. In J. G. Richardson (Ed.), R. Nice (Trans.), *Handbook of theory and research for the sociology of education* (pp. 46–58). New York, NY: Greenwood Publishing Group.

Brickhouse, N. W. (2001). Embodying science: A feminist perspective on learning. *Journal of Research in Science Teaching*, *38*(3), 282–295. https://doi.org/10.1002/1098-2736(200103)38:3<282::AID-TEA1006>3.0.CO;2-0

Butler, J. (1999). *Gender trouble: Feminism and the subversion of identity*. New York, NY: Routledge.

Carlone, H. (2004). The cultural production of science in reform-based physics: Girls' access, participation, and resistance. *Journal of Research in Science Teaching*, *41*(4), 392–414. https://doi.org/10.1002/tea.20006

Carlone, H., & Johnson, A. (2007). Understanding the science experiences of successful women of color: Science identity as an analytic lens. *Journal of Research in Science Teaching*, *44*(8), 1187–1218. https://doi.org/10.1002/tea.20237

Carlone, H., Johnson, A., & Eisenhart, M. (2014). Cultural perspectives in science education. In N. G. Lederman & S. K. Abell (Eds.), *Handbook of Research on Science Education (2nd edition)* (pp. 651–670). New York, NY: Routledge.

Danielsson, A. T. (2012). Exploring woman university physics students "doing gender" and "doing physics." *Gender and Education*, *24*(1), 25–39.

Davies, B., & Harré, R. (1990). Positioning: The discursive production of selves. *Journal for the Theory of Social Behaviour*, *20*(1), 43–63.

Francis, B., Archer, L., Moote, J., DeWitt, J., MacLeod, E., & Yeomans, L. (2016). The construction of physics as a quintessentially masculine subject: Young people's perceptions of gender issues in access to physics. *Sex Roles*, 1–19. https://doi.org/10.1007/s11199-016-0669-z

Francis, B., & Paechter, C. (2015). The problem of gender categorisation: Addressing dilemmas past and present in gender and education research. *Gender and Education*, *27*(7), 776–790.

Gee, J. P. (2000). Identity as an analytic lens for research in education. *Review of Research in Education*, *25*, 99–125.

Gonsalves, A. J. (2014). "Physics and the girly girl—there is a contradiction somewhere": Doctoral students' positioning around discourses of gender and competence in physics. *Cultural Studies of Science Education*, *9*(2), 503–521.

Hazari, Z., Brewe, E., Goertzen, R. M., & Hodapp, T. (2017). The importance of high school physics teachers for female students' physics identity and persistence. *The Physics Teacher*, *55*(2), 96–99. https://doi.org/10.1119/1.4974122

Hazari, Z., Sadler, P. M., & Sonnert, G. (2013). The science identity of college students: Exploring the intersection of gender, race, and ethnicity. *Journal of College Science Teaching*, *42*(5), 82–91.

Hazari, Z., Sonnert, G., Sadler, P. M., & Shanahan, M. C. (2010). Connecting high school physics experiences, outcome expectations, physics identity, and physics career choice: A gender study. *Journal of Research in Science Teaching*, *47*(8), 978–1003. https://doi.org/10.1002/tea.20363

Jackson, P. A. (2014). *Better late than never? Identity work, trajectories, and persistence of latecomers to science* (Doctoral dissertation). McGill University. Retrieved from eScholarship@McGill. (PID 121398)

Jackson, P. A., & Seiler, G. (2013). Science identity trajectories of latecomers to science in college. *Journal of Research in Science Teaching*, *50*(7), 826–857.

Kost, L. E., Pollock, S. J., & Finkelstein, N. D. (2009). Characterizing the gender gap in introductory physics. *Physical Review Special Topics-Physics Education Research*, *5*(1), 10101. https://doi.org/10.1103/PhysRevSTPER.5.010101

Lemke, J. L. (2001). Articulating communities: Sociocultural perspectives on science education. *Journal of Research in Science Teaching*, *38*(3), 296–316. https://doi.org/10.1002/1098-2736(200103)38:3<296::AID-TEA1007>3.0.CO;2-R

Lock, R. M., & Hazari, Z. (2016). Discussing underrepresentation as a means to facilitating female students' physics identity development. *Physical Review Physics Education Research*, *12*(2), 20101. https://doi.org/10.1103/PhysRevPhysEducRes.12.020101

May, V. M. (2012). Intersectionality. In C. M. Orr, A. Braithwaite, & D. Lichtenstein (Eds.), *Rethinking women's and gender studies*. New York, NY: Routledge.

Statistical Research Center | American Institute of Physics. (2017). *Representation of Women Among Physics Bachelors and PhDs | American Institute of Physics.* Retrieved April 11, 2017, from https://www.aip.org/statistics/physics-trends/representation-women-among-physics-bachelors-and-phds

Traxler, A. L., Cid, X. C., Blue, J., & Barthelemy, R. (2016). Enriching gender in physics education research: A binary past and a complex future. *Physical Review Physics Education Research*, *12*(2), 20114.