USING ACTOR-NETWORK THEORY TO RETHINK GENDER AND RACE IN ADVANCED PLACEMENT BIOLOGY CLASSROOMS

by

SOPHIA (SUN KYUNG) JEONG

(Under the Direction of DEBORAH J. TIPPINS)

ABSTRACT

The purpose of this study was to describe the conditions under which the capacities of gender and race were actualized in high school Advanced Placement biology classrooms. Students negotiate and manage their participation as well as the participation of others in and across cultural practices, thereby positioning themselves and others in social and cultural contexts in the classroom. Operating under the framework of actor-network theory, this ethnographically-informed qualitative study explored how identity categories such as gender and race played a role in the opportunities for learning made available to students. This study also explored how norms and conventions were negotiated by students and teachers at the level of immediate interactions in the science classroom. Accounts of interactions in the science classroom were collected through field observations and semi-structured interviews. The iterative process of data collection and analysis involved describing the interactions, reading and re-reading the descriptions, and describing the interactions some more. Drawing upon MacLure's (2013) work, these descriptions and analyses were conceptualized as sets of *glowing data*. *Glowing data* showed: (1) objects and *things* mattered in the actualization of gender and (2) actualizations of gender and race followed lines of flight that were unpredictable.

Actualization of race followed three types of lines of flight that originated from the science curriculum; that initially originated from the science curriculum, but quickly became racialized; or originated via unexpected outbursts which appeared to have little relevance to the science curriculum.  Specifically, this study brought to light how actor-network-theory helped see that objects like sinks and bells were critical actors with as much, if not more, importance than the human actors in shaping these interactions in relation to gender and race.  Exploring what gender and race *could be* and how those identity categories were actualized (or not) made visible ongoing negotiations at the nodes of these relations that could potentially shape students' science learning experiences.  This study extended existing identity work in science education by employing a new methodology and bringing theories from new materialism and emerging concepts from post-identity work to offer possibilities of *subjectivities in motion*.

INDEX WORDS: Actor-network theory, K-12 science education, Biology, Gender, Race, Identity, Ethnography

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by

SOPHIA (SUN KYUNG) JEONG

B.S., University of California at San Diego, 2008

M.A.T., University of Southern California, 2012

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SOPHIA (SUN KYUNG) JEONG

Major Professor: Deborah J. Tippins
Committee: Cory A. Buxton
David F. Jackson
Kathryn J. Roulston

Electronic Version Approved:

Suzanne Barbour
Dean of the Graduate School
The University of Georgia
August 2018

# DEDICATION

I dedicate this dissertation to my grandmother, Hwang Bok Soon, who I know will always watch over me from heaven.

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It is from the deepest bottom of my heart that I say these words of appreciation. It is my passion and goal to move forward from this chapter in my life to become a strong advocate for others, as you all have done for me. *Thank you*.

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# CHAPTER 1

# INTRODUCTION

From a sociocultural perspective science is viewed as a culturally-mediated way of thinking and knowing, which suggests that science learning can be defined as engagement with scientific practices (Brickhouse, Lowery, & Schultz, 2000). In this vein, how students participate in school science can be influenced by how they view themselves as to whether or not they are the type of person who can engage in science. Therefore, it is crucial to understand students' identity formation as they learn science. Brickhouse et al. (2000) argued that to understand learning in science, scholars need to go beyond whether students have learned the scientific explanations for how plants grow or why there are seasons. Instead, Brickhouse et al. (2000) suggested:

> We need to know how students are engaging in science and how this is related to who they think they are, and who they want to be. As students transform their identities, the requisite knowledge and skills for being a part of the new communities are learned. Thus, if students are to learn science, they must develop identities compatible with scientific identities. (p. 443)

Similarly, Nasir and Hand (2006) conceptualized learning as changes or shifts in social relations; "as individuals form and re-form themselves and their relations within and across communities, they gain (and lose) access to different sets of practices and roles, which according to the sociocultural perspectives, constitutes new learning" (p. 467). Therefore, individuals negotiate and manage their participation as well as the participation of others in and across cultural practices, thereby positioning themselves and others in social, cultural, and classroom practices.

Here, *identity* is understood as one's understanding of oneself in relation to both the past and future and refers to ways in which an individual participates in the world and how others interpret that participation; therefore, one's identity is maintained or negotiated in relation to others (Brickhouse et al., 2000). In terms of learning in science, how students view themselves as learners greatly influences their participation in science; therefore, existing scholarly work in science education highlights identity as an important mediator of learning. For instance, teachers might have preconceptions of race or gender that could reveal differential expectations for their students, or students could have conceptions of themselves as learners whose identities may or may not align with those afforded in the classroom (Martin, 2007; Nespor, 1994). To this end, prior studies often focus on students' identities as learners and the tension between students' agency and the structure of the classroom practice. While these studies provide insightful accounts of how identity categories such as gender and race can play a role in the opportunities for learning made available for the students, scholars still know very little about how these norms and conventions are negotiated by students and teachers at the level of immediate classroom interactions. In this study, the researcher argues that an individual's *identity* is not necessarily fixed or stable, as she or he can be part of different communities. As individuals participate in a cultural practice, they negotiate their identities that are "part what they have come to view as consistent about themselves in their lives, part what they perceive to be available to them in a practice, and part how they are perceived by social others" (Nasir & Hand, 2006, p. 467). Thus, the researcher argues that *identity* is not something that can be pre-defined; rather, it is defined through the observations of how individuals interacted with each other and would not be defined outside of how individuals in the network chose to do so. In this study, *identity* is defined based on the empirical social practices and what counts as "identity" from these social relations. As such, this notion of identity is grounded in understanding an individual's day-to-day practices and emphasizes particular identity categories such as gender and race that become available to students, as they engage in cultural activities. Doing so opens up new possible ways of being, as individuals tend to engage in activities that forge a perspective of themselves as becoming, while distancing themselves from activities that appear to be misaligned with the person they hope to become (Nasir & Hand, 2008). In terms of learning in science, the researcher of this study aims to explore identities and practices that students are exposed to and negotiate in their day-to-day activities that might support or hinder an array of *becoming* in the science classrooms.

In order to achieve this goal, the researcher argues that she uses the terms gender and race with a critical stance. Bakhtin (1981/1975) claimed that "an individual cannot be completely incarnated into the flesh of existing sociohistorical categories" (p. 37). Accordingly, the identity categories the researcher of this study chose to describe her participants do not carry objective definitions; she uses the terms gender and race as *entry points* to understand her students and their experiences with school science. There are critics who would argue that representations of race and gender issues have been poorly done in science education research overall. Manuel DeLanda is one such critic and explained, "I am very suspicious of any attempt to bring gender and race into discussion of science, not because I do not think there are relations, but because the subject has been handled so badly in the past…. Gender and race are abstract categories that can very easily be turned into essences - reified generalities" (M. DeLanda, personal communication, February 27, 2018). Lemke (2001) argued:

> We hear far more about race in relation to African-Americans… far more about language in the case of Hispanic groups… and far more about culture of Asian Americans or Native Americans… to some extent these imbalances may reflect on the early stage of these studies, but a self-reflexive application of the sociocultural perspective itself should make us worry that they may also reflect deep-seated ideological assumptions in the cultures of many researchers. (p. 303)

In this vein, Roth and McGinn (1998) noted that issues such as politics of gender and race so far have had little impact in science education, and hoped that the actor network approach would become a methodological tool to conduct research and construct re-presentation of sociocultural issues in science education. Therefore, throughout this study, the researcher makes every effort to push back against essentializing or oversimplifying the complexity of her participants' similarities or differences, while exploring students' experiences with school science in relation to their identity categories.

Advances in the field of science, technology, engineering, and mathematics (STEM) play a critical role in future economic performance, higher living standards, and improved quality of life (Burke & Mattis, 2007). In order to increase the number of students, teachers, and professionals trained in STEM fields, various federal programs have been implemented with an explicit goal of promoting STEM education (Kuenzi, 2008). However, women and minority groups continue to remain underrepresented in STEM (Diekman, Brown, Johnston, & Clark, 2010). The National Center for Education Statistics showed that a higher percentage of bachelor's degrees in the STEM fields were conferred upon males than females (65% to 35%) across all racial groups (Aud, Fox, & KewalRamani, 2010). Furthermore, the report showed that the percentage of bachelor's degrees in the STEM fields conferred on minority students was lower than the average, with the exception of Asian students (Aud et al., 2010). These initiatives and statistics point to gender and racial inequalities with respect to representation in STEM, which is prolifically discussed at the post-secondary level (Gunderson, Ramirez, Levine, & Beilock, 2012; Rosenthal, London, Levy, & Lobel, 2011; Shapiro & Williams, 2012). Research that seeks to explore gender and racial *inequities* in relation to students' science learning still requires rigorous investigation at the K-12 level and remains under-theorized. To this end, a brief overview of literature on the status of gender and race in education follows.

## Brief Overview of Literature: The Status of Gender and Race in STEM Education

### On Gender Literature and Critique

There is a wealth of research on how affective constructs such as attitudes, perceptions, motivations, and interests in science seem to differ between girls and boys. For instance, studies have shown decreased interests and motivation in STEM-related fields for girls and students of color (Eccles, Wong, & Peck, 2006; Shapiro & Williams, 2012; VanLeuvan, 2004; M.-T. Wang & Degol, 2013; Watt & Eccles, 2008). Other studies have shown that girls demonstrated less confidence in their mathematics and science abilities than boys (Meece & Jones, 1996; Pajares, 2005; J. Valenti, 2014, April 23). Furthermore, studies have shown that there is a production of "culture of science" and gender norms from which girls (whose science identity did not fit) have been excluded (Barthelemy, McCormick, & Henderson, 2016; Carlone, 2004; Carlone & Johnson, 2007; Harding, 1998; Haverkos, 2012; J. L. Smith, Lewis, Hawthorne, & Hodges, 2013; Traweek, 2009). For example, in a study conducted by Barthelemy et al. (2016), girls were seen as the opposite of characteristics that define science, such as rational, objective and masculine, and thus were cast out as the "unfit" members of a scientific community (p. 2). Also, many studies have reported that girls think of scientists as being white men who wear goggles and white lab coats, hindering their ability to see themselves being active participants in the culture of science (C. S. Brown & Stone, 2016; Corbett, 2016; Haverkos, 2012; Kessels, 2005). Gonsalves's work further supported this finding in which women were assumed to innately lack certain characteristics, while men were assumed to innately hold them (Gonsalves, 2014). Early in their education, girls receive a message regarding gender roles, in which they are led to believe that boys are better than girls in math and science (Barthelemy et al., 2016; C. S. Brown & Stone, 2016; Jennifer M. Grossman & Porche, 2014). Compounded with their experiences in science, the message is very clear to girls that *who they are* is incompatible with pursuing studies or careers in STEM.

One of the prominent critics of gender studies in science education is Kathryn Scantlebury. Scantlebury problematized studies that examine gender alone as a variable and overlook other sociocultural factors. In addition, Scantlebury (2012) argued that treating girls as a homogeneous group was problematic and critiqued that, as a community, there were only few studies that examined gender issues in conjunction with race, ethnicity, class, religion, and/or sexuality. Some scholars have issued a call for change in the way we think about what teaching and learning of science should be (Haverkos, 2012; Kenway & Gough, 1998). Accordingly, Haverkos (2012) argued that science education research should begin to move away from doing research that aims to "fit" girls with the culture of science. She metaphorically described the idea of "fitting" girls into the culture of science as a "grafting" of a healthy patch onto the diseased and ill section of the skin; thus, if the graft takes, then the problems may not go away, but rather, they would spread right back onto that healthy piece of skin, obscuring the root cause of the inequities that are present in science education.

**On Race Literature and Critique**

The studies that investigate various forms of discrimination in science are done mostly at the post-secondary level (Gunderson et al., 2012; Rosenthal et al., 2011; Shapiro & Williams, 2012). The lack of research that deals with race relations in a K-12 research setting is understandable, given that the topics related to racial stereotype and discrimination are considered "thorny" topics and pose challenging, ethical questions (Hutchinson, Gilbert, & Malyukova, 2016; Konstantopoulos, 2009). Nonetheless, there are studies that report on students' experiences with discrimination, racial stereotypes, and microaggressions in the context of science education (Allen, Scott, & Lewis, 2013; Barthelemy et al., 2016; Hyung Chol & Lee, 2008; J. Wang, Leu, & Shoda, 2011; Yoo & Lee, 2008). More specifically, studies showed that racial stereotypes can act as barriers to STEM for minority students (Cheryan, Siy, Vichayapai, Drury, & Kim, 2011; Shapiro & Williams, 2012; Steele & Aronson, 1995). For example, according to Gottfried and Williams (2013) African American and Latino students may not be enrolled in advanced high school courses, or may be discouraged from pursuing Science, Technology, Engineering, Mathematics (STEM) interests by external factors such as "anticipated stereotypes or discrimination" that contribute to the shaping of their self-perceptions of their career options.

With respect to the researcher's interest in understanding Asian American students' experiences with racial stereotype and discrimination, there were many studies that examined the portrayal of Asian American students as "super-stars." The body of literature on debunking the model minority myth has been prolific since the 1980s (Chun, 1980; S.-J. Lee & Rotheram-Borus, 2009; S. J. Lee, 1994; Ngo & Lee, 2007). Furthermore, studies that explored the role of racial stereotype and discrimination reported that Asian American students were subjected to harassment by their peers (Ngo & Lee, 2007; Qin, Way, & Rana, 2008; Rosenbloom & Way, 2004) and school violence such as bullying (Chung-Do & Goebert, 2009; Fiaui & Hishinuma, 2009; Peguero, 2011; Qin et al., 2008; Spencer et al., 2009) as well as experiencing adverse effect on their mental health (Jennifer M Grossman & Liang, 2008; Huynh, 2012; S.-J. Lee & Rotheram-Borus, 2009; Lipsicas & Makinen, 2010; Miller, Yang, Farrell, & Lin, 2011). When Asian American students did not fit the model minority stereotype, studies have reported incidents of "othering" (Borrero, Yeh, Cruz, & Suda, 2012; Vaught, 2012), or being stereotyped as lazy, delinquent, and not as smart/"dumb" (Borrero, Yeh, Tito, & Luavasa, 2009; Chhuon, 2014; Chhuon & Hudley, 2011; W. A. Smith, Allen, & Danley, 2007).

Similar to the notion of racial discrimination is the phenomena of microaggressions (Chhuon, 2014; Jennifer M. Grossman & Porche, 2014). Chester Pierce was one of the first scholars to articulate these "offensive mechanisms" (Chester Pierce, 1974, p. 515). Microaggressions can be defined as the "brief verbal, behavioral, or environmental indignities that communicate hostile, derogatory, denigrating, and hurtful messages to people of color" (Sue & Constantine, 2007). For example, mispronouncing a student's name is one thing; however, articulating that the student's name cannot be pronounced because it's an "Asian" name, or suggesting that the student take up an "American" name demonstrates the act of microaggression in the classroom (Kohli & Solórzano, 2012). Other examples include the seemingly harmless questions, such as asking a student about his/her ethnic background (Huynh, 2012), or comments such as "Wow, you speak English so well!" (Kohli & Solórzano, 2012). These types of comments are spoken out of an underlying assumption that Asian American students are not and can never be authentic Americans; it's a subconscious perception of Asian/Asian Americans as the perpetual foreigners in this country, and something that Asian/Asian American students have to deal with in their everyday educational experiences. In the context of science, Asian/Asian American students often hear statements such as "you are really good at math," "you people always do well in school," or "If I see lots of Asian students in my class, I know it's going to be a hard class" (Sue, Bucceri, Lin, Nadal, & Torino, 2007, p. 76). These statements are what Sue and his colleagues call ascription of intelligence via the messages conveyed by these verbal microaggressions. Though the intent of these statements were perceived as a compliment and positive in nature, the impact of assuming that Asian Americans were good at math or science were harmful, as the receivers of the comments felt pressured to conform to a stereotype that they did not endorse.

## Conceptualizing the Problem: Starting with Marginalization of Asian/Asian American Students in Science

There have been numerous K-12 STEM initiatives to attract and prepare girls and minority students to pursue coursework and careers in STEM areas (Kuenzi, 2008). For example, the U.S. Department of Education has made available programs such as Math Science Partnerships, the Minority Science and Engineering Improvement Program, and the National Science and Mathematics Access to Retain Talent Grant Programs, to support and "up" the numbers of girls and minority students pursuing studies and/or work in STEM fields (U.S. Department of Education, 2013, April 19). These initiatives make important contributions to addressing the quantitatively reported problem of inequalities at hand: the "low" number of girls and minorities in STEM. However, these solutions, which are aimed at funneling more girls and minority students into the STEM "pipeline," can be a simplistic and reductive way of addressing gender and racial/ethnic inequities in science education.

Research studies that explore the best interventions, curriculum design, and development of initiatives to increase the number of girls and minority students interested in and pursuing science are important and have their own merit. However, focusing solely on the representation problem in science education is problematic, especially for Asian/Asian American students who appear to be overrepresented in STEM. For example, Asian/Asian American students are highly represented among the winners of prestigious scholarships such as Westinghouse Science Talent Search scholars (Zhao & Qiu, 2009). Their high academic performances on standardized tests do not go unnoticed. On the 2015 SATs, Asian/Asian American students scored the highest on the SAT mathematics (average of 598) and surpassed the scores of all other racial groups, while the national average was 511. Similarly, on the 2015 National Assessment of Educational Progress (NAEP) science assessment scores at Grade 12, Asian/Pacific Islander students' average scores were the highest at 167, again surpassing other racial groups (National Center for Education Statistics, 2015).

Because Asian/Asian American students demonstrate a superior academic performance in science and mathematics, they are often portrayed as super-star students; the representation of Asian American students as the model minority poses serious problems for two overarching reasons. First, Gutierrez (2008) critiques the current discourse of the achievement gap that describes the average score differences between minority groups and White students. She points out that our obsession with the achievement gap has blinded us to the issues of inequities and social injustice in education. Similarly, Haverkos (2012) calls for paying more attention to the intricate aspects of girls' and minority students' science learning such as the underlying meanings and issues of power or the potential tensions around gender, race, and science education. Second, the impact of stereotype threat on students is an important issue to consider.

The assumption behind the stereotype threat is that an individual who is associated with a negative stereotype will perform in a manner consistent with the stereotype (Steele, 2003). For instance, multiple studies reported similar findings that performance on a problem-solving task was adversely affected when African American research participants were asked about their ethnicity before the problem-solving task (Steele & Aronson, 1995; Stricker & Ward, 2004). Stereotype threat with respect to gender is also reported by several studies (C. S. Brown & Stone, 2016). When test administrators had students indicate their gender after the AP Calculus exam, the girls passed the test at a 6% higher rate compared to those asked to indicate gender prior to taking the exam (Danaher & Crandall, 2008). Similarly, research on stereotype threat alludes to the salience of racial stereotypes on Asian American students' identities and achievement (Ngo & Lee, 2007). As noted earlier, Asian/Asian American students are often stereotyped as the model minority, despite the fact that scholars in Asian/Asian American studies have continued to debunk the myth about Asian students since the 1980s (Chun, 1980). When Asian American students are portrayed as the model minority, their racial identity is adversely affected by the stereotype of being the "smart" student in science and math (S. J. Lee, 1996) because they feel that they have no choice but to continue on with their success story (Goodwin, 2010); they feel that they cannot ask for help even when they are struggling (Zhou, Peverly, Xin, Huang, & Wang, 2003). When Asian American students are considered the opposite of the model minority, they are brushed off as being "the other" (Borrero et al., 2012). Therefore, scholars argue that positioning Asian/Asian American students as the model minority stereotype silences and perpetuates institutionalized invisibility of their voice in the larger educational discourse (Chutuape, 2016; Coombs, Park, & Fecho, 2014). Here, in this study, the notion of marginalization denotes ways in which individuals can be silenced. An example of silencing in the classroom context would be when Asian/Asian American students feel that their great academic "success" meant that they could not ask for help, because they were deemed to *not* need, or let alone deserve any assistance (Zhou et al., 2003). Furthermore, the model minority stereotype serves as the means to unequivocally and undoubtedly position Asian/Asian American students as a racial and ethnic minority. Blauner (1972) defines racism as a way to oppress and deny the members of the subjugated group "the full range of human possibility that exists within a society and culture" (p. 41). In this context, the model minority stereotype serves as a powerful form of racism that emerges out of a dynamic social and cultural construction that limits Asian/Asian American students' range of identities, power, privilege, and values.

**Rationale: The Need to Go Beyond Representation Problems in Science Education**

In the literature review conducted for this study, studies were examined for issues of gender and race in science education. In terms of gender issues in science education, various studies reported that girls' performance on average surpassed that of boys' in science (i.e., course grades), while some studies also argued that girls' representation in traditionally male dominated science subjects was improving. Similar arguments were made with respect to the representation of girls and the improvement in their achievements in science in the late 1990s. For example, Boaler (1998) reported that girls' achievement levels increased in comparison to those of boys and thus claimed that school approaches were becoming more equitable. However, there are still gendered disparities within science and science education that "play out in a number of cultural and material ways with girls still lagging behind on standardized science tests, gaining fewer science degrees overall, holding fewer science positions for less time, etc." (Haverkos, 2012, p. 6). Similarly, Connell (2000) argued that even though girls' achievement levels may be improving at the secondary level, not much has changed in terms of post-secondary opportunities, career trajectories, etc. Simply, there is more than meets the eye concerning issues of gender and race in science and addressing the representation problem does not make other issues go away.

Addressing solely the representation problems in science cannot fully address the gender and racial inequities in relation to students' science learning experiences. In terms of race issues in science education, the researcher re-examined the meaning of representation of Asian/Asian American students as the high performers on standardized tests, especially in mathematics and science. It finally dawned on the researcher that the word *average* was problematic. The question is: what can be accomplished by framing Asian/Asian American students' academic performance in terms of *average* and comparing it to the *averages* of other racial groups? The researcher of this study argues that such framing of students' *averages* effectively shifts the scholarly focus from examining what Haverkos called the intricate aspects of science learning to unseemly generalization of students of a racial group. But, to what end? Is representing the average "Asian" experience really meaningful, even if an average means combination of many? After a while, an average becomes a single case point, and thus the researcher posits that discussing the typical "[insert whatever racial group here]" in terms of *average* decontextualizes the human complexity, and overlooks the experience of the individual, all the while perpetuating a racial stereotype. At the same time, this argument is not to entirely dismiss the importance of identifying the average performances of students grouped by race categories. For instance, the achievement gap as we know it today cannot be ignored, but scholars should be aware of presentations of issues in science education beyond just the gap.

Thus, an interesting question arises: coupled with issues of gender and race in science education, how can this dissertation study go beyond the problem of representation for

Asian/Asian American students? Adapting Crenshaw's (1989) idea of intersectionality of race and gender, an individual's identity is not just about one or the other. For example, one cannot just be Asian or a woman. One is an Asian woman. If a class variable is thrown into the identity, one is a middle-class, Asian woman. Therefore, whatever this Asian-ness, female-ness is (or is not), it could be positioning Asian American students in the science classroom a certain way and potentially be causing problems for these students in their experiences with school science. Being an Asian American, whose persistent stereotype is having good math and science abilities, can shape both racial and science identity of the student, which may *not* necessarily be a "true" account of who they can be in a science class. In other words, Asian American students' racial identity can be created by the very fact that there are certain expectations about whom they should be or how they should act in the science class. As science educators, we have to deal with this highly complex aspect of science learning if we are going to create and provide equitable learning environments for our students. For the purpose of this study, the two main constructs of interest in terms of students' identity categories are gender and race, but there are others such as class. In terms of class, there is a wealth of knowledge in dealing with issues in science education as they relate to the socioeconomic status of marginalized students.

Furthermore, critical race theory (CRT) scholars have argued that, though much of the work has been accomplished to understand race and racism within schools, race is often under-theorized or subsumed within a class analysis (A. L. Brown & De Lissovoy, 2011; McCarthy, 1988). In response, A. L. Brown and De Lissovoy (2011) call for the marriage of the two variables, race and class, by theorizing and highlighting issues of race and racism as hidden dimensions of school curriculum and pedagogical practices as well as revisiting class theories to then make sense of how these dimensions work to promote a neoliberal "assault" on educational policy (p. 596). What A. L. Brown and De Lissovoy (2011) urge scholars to do is an important goal, but is beyond the scope of this dissertation. Furthermore, this dissertation uses the framework of Actor-Network Theory (ANT). Under ANT, the researcher needs to go where the interactions and relationships become traceable and visible among the actors, and where the researcher may potentially see problems that matter in science education. In this sense, she may or may not notice the class variable once she goes into the science classroom at the school. If the class variable shows up, then it will be discussed.

In summary, Asian/Asian American students check all the boxes in terms of quantitative measurement of academic success. However, there are qualitative inequities in the way they experience school science that need to be addressed. If their experiences at school are indeed positive, then many can learn from it. This study, under the framework of actor-network theory, is not about interventions nor is it about coming up with a solution to a problem. The researcher's *entry point* (rather than calling it a problem, per se) is exploring gender and race identity categories of Asian/Asian American students in the science classroom, as they experience school science. As such, their experiences will be discussed in relation to their peers in the classroom. The argument made for the class variable applies in a similar manner to the argument as to why students identified in other racial groups may be included in this study.

Here, it is important to note that, as the researcher's understanding of the methodological and theoretical framework deepened, the conceptualization of the problem also morphed into focusing on pushing back against the deterministic and essentialized notions of these identity categories of gender and race in science education research. The initial focus of this study began with Asian/Asian American students' experiences in the science classroom. However, as the study evolved, and the researcher strived to stay "true" to the tenets of actor-network theory, she aimed to critically examine all of her participants' experiences with school science in light of constantly posing the question of what gender and race could be. In the next section actor-network theory is briefly discussed followed by the purpose and research questions of this study.

## Overview of the Theoretical Framework: Actor-Network Theory

In this section, the researcher briefly presents the theoretical framework that guides the theorization of this study including methodology: actor-network theory (ANT). ANT is primarily associated with scholars such as Bruno Latour, John Law, and Michael Callon. Arising from the sociology of science and technology (i.e., Science and Technologies Studies, STS), ANT became the conceptual framework for exploring collective sociotechnical processes (Fenwick & Edwards, 2011b). Also, to counter the heightened status of science as a way of knowing and understanding the world (i.e., scientism), ANT suggested the notion that science is a *social process*, just like any other social activity (Crawford, 2004). In doing so, ANT has permitted social scientists and researchers to grapple with the processes which characterize socioscientific concerns, and contributed to the analytic approaches (i.e., ethnomethodology) and suggestions that "rupture certain central assumptions about knowledge, subjectivity, the real, and the social" (Fenwick & Edwards, 2011b, p. 1). ANT indeed ruptures and blows away any *a priori* assumptions that a researcher may have coming into a study. For instance, ANT disrupts a researcher's preconceived notions of *gender* and *race* as larger social structure. However, this is not to claim that the researcher enters the study as a blank slate; she explains later in the study how she begins the study with *entry points*.

Bruno Latour (2005) calls scholars who engage in the discourse of ANT the *little ants*. *The ants* would agree that the actor-network theory is not necessarily a theory, as it cannot be organized neatly into a box, and is extremely difficult to explain, describe, and define. It is not something that is "applied like a theoretical technology, but is more like a sensibility" (Fenwick & Edwards, 2011b, p. 1). The word, sensibility, prompted the author to recall Jane Austen's *Sense and Sensibility* where Elinor embodies *sense* (i.e., good judgment or prudence), while Marianne embodies *sensibility* (i.e., sensitivity or emotionality). Using her literary background knowledge, the author demonstrates that ANT is a way of sensing and drawing closer to a phenomenon of interest, using both good judgment and heightened sensitivity to complex relationships among the actors. As such, to be an *ant,* a researcher must re-configure the way she looks at her actors, which is elaborated below.

One of the biggest challenges in trying to understand ANT is its ontological and epistemological complexity. To make this discussion as tangible as possible, the researcher briefly outlines the following core concepts: a) the actors in an actor-network should not be understood with preexisting assumptions (i.e., *a priori* definition of certain constructs such as identity, knowledge, and etc.), but by their performance in, by and through the relations with other entities in the actor-network, b) a good ANT study demonstrates the evidence of change in the state of the *actants*, by the process of *translation*, and when an *ant* researcher *traces* the relations and links that actors make with other entities, she can reveal the nature of controversy and concerns, and lastly, c) ANT assumes that humans are not treated any differently from nonhumans. These three concepts are not the only tenets of actor-network theory. However, the researcher chose these specific tenets of ANT as they were most relevant to this study and are described in more detail in Chapter 3.

An *actor-network* is composed of multiple *actors* and *actants* that engage in relations with one another. In ANT, the *actor* is the working entity, while an *actant* is the worked-upon entity. When the *actant* becomes acted upon to become part of the network, the *actant* then behaves with intentions, morals, consciousness, and subjectivity, regardless of whether it is human or a non-human entity (Latour, 1996). When the *actant* has undergone this process of change (which Latour calls *translation*), and has become part of the network, it begins to take on a particular role and perform in a certain way; it becomes and performs as the *actor*. An *ant* researcher should not come into an ANT study with an *a priori* definition of certain constructs that social scientists often look for, such as identity, knowledge, subjectivity, *gender, race, power,* etc. Here, an important clarification to make on this point is that the researcher is not without *any* prior assumptions. She comes into this study with what she calls *entry points*. However, operating under the framework of ANT, she aims to trace her actors, as ANT studies often focus on the socio-material aspect of how minute relations among the actors (both human and non-humans) create their world (Fenwick & Edwards, 2011b). As such, in ANT, actors are understood, as they are "performed in, by, and through" the relations that are formed among the actors and other entities (Law & Hassard, 1999, p. 5). An *ant* researcher would then focus her analysis on tracing how both humans and non-human objects participate in these processes such as becoming assembled, associating with one another, exercising force/power, and persisting or declining to sustain the network. Thus, by participating or performing in these processes, the actors come to being/existing in the network, and only when the actors perform in the network can a researcher understand them through the tracing of these relations. In summary, nothing in ANT exists prior to its performance or enactment into these relations with other entities (Colston & Ivey, 2015). Lastly, both human and nonhuman actors can participate in the processes of becoming assembled, associating with one another, exercising force/power, and persisting or declining to sustain the actor-network. This notion of *flat ontology* or *symmetry* makes the researcher realize that the subject (not just a human subject) is entangled across webs of other *becomings* and subjectivities, and overlaid across newly conceived space-time matterings (Jeong et al., 2017). To this end, the actor-networks can expand and extend as far and as close in terms of space and time. What is "local" versus "global" or "micro" versus "macro" becomes a moot point in ANT analysis (unless actors are referred to in relation to another), because a science teacher could be interacting with a textbook that may have been modified or acted upon by the standards drafted miles away and months ago.

### Purpose and Research Question

Bruno Latour, among other ANT scholars, cautions researchers that concepts such as *gender, race, power,* and *inequality* have become reified within Sociology (Quinlan, 2012). Latour argues that these concepts are over-utilized to "explain away" the realities that sociologists wish to observe (Quinlan, 2012). The goal of doing ANT research is to describe how these concepts or constructs come into *being* through the performativity of the actors within the actor-network. Furthermore, ANT scholars have emphasized the need to address issues of equity, gender, and power in education research, from this novel understanding of ontological and epistemological complexity, as explained above. The very notion of multiplicity of these constructs is what will open up infinite possibilities to theorize and examine equity issues in science education, in ways that has not been done before. In this vein, re-thinking the concepts of gender and race as these identity categories relate to students' experiences with school science is an extremely challenging task. To the researcher's knowledge, this study is the first to explore these concepts of gender and race in the science classrooms using actor-network theory. To this end, the purpose of this study is to explore and describe the conditions under which the capacities of gender and race are actualized in high school science classrooms. Aligning with the assumptions of actor-network theory, the following research question is asked: how do the capacities of gender and race become actualized in a high school biology classroom?

### Overview of the Methodological Framework: Actor-Network Theory

This particular ANT research study enacts the philosophical and theoretical underpinnings of actor-network theory (ANT). Generally, many ANT scholars employ ethnomethodology as an approach to focus on the "local" and on the empirical social practices (Hilbert, 1990). In this study, the researcher *traces* the relations and links that actors connect with other entities in the actor-network in order to explore the possibility of how social constructs such as gender and race can be actualized within a particular culture of a science classroom. Latour (2005) describes an ANT scholar as "a blind, myopic, workaholic, trail-sniffing, and collective traveler," which describes the work that an ethnographically-informed researcher must do in the field (p.20). Accordingly, this study examines and describes the conditions under which the capacities of gender and race are actualized in the actor-network of a high school biology classroom. To explore how actors come into *being*, materialize, assemble, entangle, and manifest their ontological complexities through their performativities (Butler, 1988), the researcher used ethnographically-informed tools such as participant observation in the science classroom for 6 months, interviewing of students and the classroom teachers, and the researcher's reading, re-reading, and writing of her field notes and field observations.

Judith Butler's conceptualization of performativity refers to the discourse of acts that enacts or produces that which it names (Butler, 1993). Here, the acts maintain the associative semantic meanings with theories of performance and acting. According to Butler (1988), gender is "an identity tenuously constituted in time – an identity instituted through a *stylized repetition of acts.* Further, gender is instituted through the stylization of the body and, hence, must be understood as the mundane way in which bodily gestures, movements, and enactments of various kinds constitute the illusion of an abiding gendered self" (p. 519, original italics). Therefore, Butler's work on gender is useful for this study in terms of empirically examining what actors do, say, produce, etc. and remains true to the assumptions of actor-network theory. A similar argument can be applied to how race is conceptualized. In her work, Butler (1988) further extends her argument to claim that gender, as an objective natural thing, does not exist as "gender reality is performative which means, quite simply, that it is real only to the extent that it is performed" (p. 278). Bruno Latour would agree with Judith Butler on carefully making claims of what becomes real and what could become real; like Butler, Latour would be cautious about claiming what is deterministically real. Again, empirically speaking in the context of this study, performativity of an actor is the *thing* that the researcher can observe because *it* happened, occurred, showed up, etc. Because that *thing* happened, *its* effects can be observed. However, the *thing* itself is never fixed, or stable, and can never become the "locus of agency from which various acts proceed"; therefore, *there is no doer before the doing* (Butler, 1988). Translating the notion to gender or race Butler articulates that there is no gender or race identity behind their expressions; that identity is performatively constituted by the very 'expressions' that are said to be its results'" (Butler, 1990, p. 25). As such, if the researcher does not see the actualization of gender or race, then they are not real in the sense that these *things* are not visible – they have *yet* to be actualized; therefore, they are not *yet* real. How shocking is this idea? Nonetheless, this idea is one of the important philosophical assumptions that undergird this study, as Latour urges scholars to resist attempts to create essences of *things* and reify generalities. In following Latour's suggestion, this study focuses on looking at how capacities of gender and race become actualized instead of primarily focusing on their properties that could often become repeated and reproduced. In doing so, the researcher of this study aimed to follow Deleuzian lines of flight (St. Pierre, 2016) in order to think differently about situations and constructs that were seemingly stable and that seemed to have been *black-boxed* into neat categories so that these black boxes of *gender* and *race* could be opened to reveal the possibilities of what they *could be*, instead of what they should be or what they are.

## Researcher's Subjectivity Statement

Roulston (2010) stated, "researchers can critically examine their perspectives and assumptions about key elements of the research project – including theoretical perspectives, personal hypotheses concerning the research findings, and positions in relation to the research participants – through writing subjectivity statements" (p.120). As part of demonstrating quality in the research process, I understand that my subjectivity statement helps me account for my subjective position in relation to the participants in my study (Dr. Roulston, Lecture, October 2015).

One of the hardest challenges in enacting the tenets of actor-network theory in this study was to avoid black-boxing *things* into neat categories. I needed to think differently about how gender and race could exist, and it was challenging to not let my own *a priori* definitions take over when I was completing my participant observations. As an Asian American woman with direct experiences that have shaped my race, ethnicity, and gender, I had very strong ideas on identity categories, and these ideas on race, ethnicity, and gender served as the *entry points* that helped me to begin this study.

To start, though the concept seemed strange at first, I did not take too long to be convinced about the agency of *things*, or the *thing*-power theory. I knew from my past experiences that *things* could affect – that *things* could exert power and shape my interactions with others. Because I align myself strongly with Bruno Latour's notion of providing detailed descriptions of encounters or interactions, I will share a story to show, rather than tell my personal histories, cultural worldviews, and professional experiences that make up my subjectivities. The following story demonstrates: 1) my understanding of how *things* such as gender and race could become materialized through social interactions, and 2) my own *enrolment* into the actor-network of scholars who aim to focus on analyzing socio-material processes that make up our world.

When I attended a large-scale, international conference as a graduate student, I had the opportunity to dine with science education researchers at the end of a long day. Some of the researchers I sat with were much older than me and some were in their early 40s; I was the youngest at the table. Some were White, some were Asian, most were men, and it was a diverse group of nationalities. Our food came out and we began to eat. One of the middle-aged scholars decisively announced that we must have drinks to enjoy ourselves. So, the drinks were ordered. Minutes later our waiter brought out bottles of wine and glasses and set them at the center of our group's table. I was not paying attention to those glasses or the bottles because I do not drink. I ordered a regular coke and was mindlessly sipping on it. Two or three minutes had passed. When I looked up, four of the wine glasses were placed next to my left arm and the two wine bottles were placed right in front of me, which took me a while to process. I kept on sipping my coke, while looking to my left, the glasses, and in front of me, the wine bottles.

In that moment, I could not confirm what I had suspected was happening, so I had to wait until I observed another action or performative act. In the corner of my eyes, the very same man who ordered the drinks was pushing the wine glasses towards me, while he was avidly engaged in a conversation with other scholars on the other side of him. There was not a hint of hesitation in his actions, which did not surprise me. His hands moving the wine glasses across the table towards me seemed so natural for him, which really annoyed me. He was not even paying attention, but it was as if his body knew what to do.

Now, I have not told you what I had confirmed. But, I will tell you what I did do – it was the only thing that I could do in the moment: stop what I was doing, wait, and let my silence be heard. However, this does not work if I have someone who rushes in to fill the silence, and the very role that I am resisting; unfortunately, that is what happened. It turned out that there was an Asian woman sitting to the right of me. I noticed the swiftness of her gesture as she quickly grabbed all the glasses, opened up the first bottle of wine, which nobody at the table had touched until she opened it, and began to serve everyone. The important thing was that I then had the confirmation I needed for myself, but part of me telling my readers this story is to let them determine that for themselves, too.

When I first wrote this subjectivity statement, I shared it with my peers, friends and colleagues. My harshest critics were my friends and they began to raise the question of *what if's*. As I conducted my study, I painstakingly reminded myself of the tenets of ANT, one of which speaks to the notion of seeking *truth*. What Latour encourages in describing encounters and interactions is not to set out to prove a point or seek the truth that exists somewhere *out there*. The truth at the dinner *for me* is my truth, and it is OK if my readers interpret and perceive a different version or aspect of that truth.

I confess that the way I identify, see, understand, and experience race and gender has been influenced by my personal experiences with discrimination, racism and a feeling of powerlessness. My ideas on these constructs were deterministic and monolithic. For example, I viewed *gender* and *race* as larger social structures. When I began my study, I was focused on microaggressions and thought that I would find what Latour would call the larger social structure such as racism, microaggressions and discrimination, and how these *things* would cause a major impact on the way students experience science. This is because these identity categories have often materialized in my life through the interactions of others, and my Asian-ness/female-ness was used to marginalize my voice. This part of my subjectivity positions me in relation to my participants, especially students, as someone who knows better and can identify a potential racial and gender discrimination occurring in the science classroom. I am cognizant of this and I recognize that my participants may not perceive the same account the way that I do.

So, you see, I did have an initial idea that I could and would empower students with an enlightened idea of what it means to live in this country as a Korean American woman and what schooling was like as the token quiet Asian student in class. I would have said, racism is this and that; discrimination is exactly this; and, being Asian precisely entails this set of meanings! The list can go on. My ideas on gender and race, as well as power and discrimination, have been rock solid, as the layers of understanding on these ideas were built upon my lived experiences – repeatedly one after another over the years. It was truly hard to shake up those ideas initially.

At the recent 2018 AERA conference I attended in New York, I presented my study and the audience responded enthusiastically to the notion of resisting *a priori* assumptions. I framed this notion through the sharing of my struggles with shedding some of my old ideas in order to make room for new possible ways to re-think these ideas of gender and race. To that end, I had to actively shed my propensity for Pierre Bourdieu's notion that larger societal structures were at play to oppress people since Latour makes very different claims about what these social structures could be. My readers/audience must understand how hard this process has been for me, and how much intellectual and emotional effort was required to become fluid in my thinking.

There are studies that operate under the framework intended to empower their participants and empowering someone is very important. There was a time and place where I, as an undergraduate student, was *given* and *empowered with* the language to articulate my experiences with discrimination and thus form my identity – that moment of feeling empowered and enlightened is something I could never forget. However, in this study, I needed to accept and understand the notions of gender, race, power, etc. as being fluid constructs so that I could observe my actors with a new lens and a new way of examining them—in that regard, this study was, once again, an empowering experience for me as a researcher as I experienced this new way of thinking. Therefore, throughout this study, I would frequently call upon the words of Latour to align my theoretical framework, methodology, glowing data, descriptions, and analysis so that this work could provide an opportunity not only for me but also for my readers to re-think gender and race in science education.

## Overview of the Dissertation

The rest of this study is organized as follows: Chapter 2 is an extensive survey of literature on gender and race in science education. Chapter 3 describes the theoretical and methodological framework with a focus on actor-network theory. Chapter 4 includes the data, descriptions, and analysis at the heart of this study. Chapter 5 contains the discussion and concluding remarks with a section highlighting limitations of the study as well as future directions of gender and race studies in science education.

# CHAPTER 2

# REVIEW OF THE LITERATURE

Since this study examines with the way in which gender and race impact high school students' science learning experience, a review of the literature on how marginalized groups experience science in the classroom is provided. The literature review is largely divided into three parts: 1) gender in science education, 2) race in science education, and 3) school science in relation to students' science identity. Though the cultural production of school science and its relation to marginalized groups' identity in the science classroom will be discussed in each section on gender and race, the third section conceptualizes school science particularly in relation to students' science identity. Thus, the purpose of this literature review is to broadly understand the issues related to gender and race in science education and how marginalized students' science learning experiences are impacted as a result.

## Part 1: Gender in Secondary Science Education

### Gender as a Social Construction

Rennie (1998) defined *gender* as "the cultural meaning we construct around what it means to be male or female" (p. 952). According to Scantlebury and Baker (2007), "*gender* is a social construction, usually based upon the biology of one's body" (p. 258). This study adapts the definition of *gender* as a social construction, and *femininity* and *masculinity* as the culturally constructed aspects of gender, while acknowledging that these terms are generally associated with one sex or the other.

The studies presented in the literature review theorize *gender* as an identity category to understand how *femininity* and *masculinity* are constructed from social interactions and activities, which produce science that is *gendered* (Due, 2014). For example, Carlone, Johnson, and Scott (2015) theorized *gender* as a discursive performance and argue that the nature of gender identity in a science class can be contingent, ongoing and situated in learning. As the girls from the study conducted by Carlone et al. (2015) participated in school science, their gender performances served as a way to fit in, please the adults, or make themselves submissive or invisible in the classroom. In terms of understanding *gender* as a set of discursive performances, Butler (1990) summarizes the argument as follows:

> Gender is the repeated stylization of the body, a set of repeated acts within a highly rigid regulatory frame that congeal over time to produce the appearance of substance, of a natural sort of being. (p. 33)

However, gender is not just a process; it is a particular type of process that operates within a highly rigid frame and is produced through discursive and bodily acts. Therefore, gender identity is not something one has, or one is, but rather, it is something that one performs and continues to re-do (Archer et al., 2012). In this sense, students' identities are related to who they think they are, who they want to be, or how they are perceived by others in the communities of practice of which they are part, and thus play an important role in their science learning experiences (Brickhouse et al., 2000). For girls, there are many ways gender plays a part in their identities as they construct what kind of girls they are, what kind of science student they aspire to be, and their views of science, which may or may not align with their identity. Thus, it is worthwhile to examine how girls experience science in the classroom.

**Girls in Science Education**

The extensive body of literature on gender in science education has evolved around the marginalization of girls and women in science (Hill, Corbett, & Rose, 2010). Many studies have been conducted to examine and address this problem. More than 20 years ago, a comprehensive review of gender and science education was conducted by Kahle and Meece (1994), which examined the gender differences in various capacities such as the patterns of gender-differentiated classroom interactions and causal attribution patterns for success and failure in science courses. Within the wider feminist movement in education, Kenway and Gough (1998) provided a critique and analysis of the underlying premises of gender and science education discourse, such as different patterns of science participation, success and career outcomes between girls and boys, and explanations for gender differences in science achievement or attainment. Then, scholars such as Muriel Lederman (2003) began to examine issues of equity and social justice in science education. For example, Lederman (2003) critiqued the hegemonic and androcentric nature of science, which defined the rules and criteria for knowledge production, what counts as science, and who does science. Several years later, Scantlebury and Baker (2007) provided another comprehensive review of gender issues in science education. The following year Brotman and Moore (2008) published a systematic review of literature on girls and science published between 1995 and 2007. Thus, this review builds on the most recent work by Brotman and Moore (2008) and examines how girls experience science in schools.

**Scope of the Literature Review**

The following six databases were used to conduct this review: ERIC, Academic Search Complete, Education Research Complete, PsycINFO, Science &Technology Collection, and SocINDEX. First, the search terms were used in the following manner: ("gender" OR "gir*" OR "female*") AND ("high school science" or "secondary science"). The search terms, "high school science" or "secondary science" had a high likelihood of delimiting the search results too narrowly. A second search was completed using the following terms in order to broaden the scope: ("gender" OR "gir*" OR "female*") AND ("high school" or "secondary") AND ("science education"). "Science education" was used instead of "scien*" as "scien*" generated an unmanageable number of results.

The search was confined to peer-reviewed studies published between 2007-2018, as the two reviews mentioned above (Brotman & Moore, 2008) provided thorough coverage of the earlier literature on this topic. The studies pertaining to secondary (middle and high school) science education were included, since the context of my study was the high school science classroom. However, articles that dealt with elementary school girls were also examined if the studies had an in-depth discussion of how gender was theorized.

The review focused on articles that investigated the teaching and learning of science for high school girls, especially those dealing with the inequities and disparities that girls face in the science classroom. Studies pertaining to single-sex education (i.e., all girl school setting) were excluded, as the context of this study was not a single-sex science education. However, studies with implications for gender sensitivity (i.e., girl-to-girl, boy-to-boy interactions in the science classroom) were included when the studies provided useful insight into gender differences in terms of various measures of science such as achievement, attitudes, and interests.

The review excluded studies pertaining to higher education, as well as studies whose primary focus did not revolve around the issues of girls or gender in science education. The studies were also excluded if the authors did not lend deeper insights into gender differences, gendered-choices and gender- inequities. Lastly, the reference sections were examined to look for additional studies and salient review papers that provided an in-depth examination on the issue of gender in science education. These papers, which had not been initially picked up from the library search were examined and included in the review.

Based on this inclusion and exclusion criteria, 108 papers were selected. The studies were organized into three foci: 1) reports on gender inequities in science education, 2) efforts towards creating gender inclusive and gender equitable science learning environments, and 3) cultural production of school science and its relation to girls' identity in the classroom. Lastly, the term *girl* will be used throughout this section, unless the study used a particular term such as female students or females.

**Focus #1: Reports of Gender Inequities in Science Education**

This section summarizes the studies that reported on girls' science learning experiences in the classroom, particularly noting the gender differences and variations in terms of access to science. The sub-foci that emerged from the studies in this section are related to: 1) science textbooks where gender bias is evident, 2) the different ways in which girls and boys participate in their science learning activities, and 3) different factors that shape various aspects of girls' science learning experiences. These studies showed that girls and boys demonstrate different attitudes toward and levels of participation in science, and these gender differences have implications and attributable patterns for understanding why girls are marginalized in science classes and women are underrepresented in STEM careers (Brotman & Moore, 2008).

In this section, highlighting the gender differences is not intended to contribute to essentialism or binary thinking between girls or boys by treating them as homogenous groups. Surveying the results of these studies is a starting point to understanding gender differences as a production of social interactions that are situated in science learning and different sociocultural contexts, as well as investigating whether any deviating positions, actions, or events exist within the groups of girls as well as boys.

**Sub-focus #1: Gender-stereotypic images in science textbooks.** In this literature review, no studies reported on the overt act of discrimination or sexism practiced by the classroom teacher. Only two studies conducted during the period covered by this search were found related to gender-stereotypic images in science textbooks, in contrast to the prevalence of literature that used to report on the issues of discrimination or sexism in the 1990s in science education (Kahle & Meece, 1994). This finding could be an indication of the changing attitudes towards women and their roles in society as well as in science.

It has been reported that science textbooks promote gender-stereotypic images of scientists and use a large number of images of male scientists rather than female scientists (Bianchini, 1993, April). In terms of gender bias in science textbooks, Kahveci (2010) conducted a quantitative analysis of 10 middle school science textbooks and 10 high school chemistry textbooks in Turkey, and found that the textbooks failed to provide gender equitable representations. Villar and Guppy (2015) examined science textbooks in British Columbia over the last half century and found that the images of women in science were increasing. However, these authors noted that the images of men still outnumbered those of women. More men were shown to be leading experiments. Furthermore, the percentages of women in positions of authority or engaged in "doing science" were still lower than the percentages of men. While the number of women and men in pictures appear to be more balanced in recent decades, the authors described the gender-stereotypic ways in which the females and males are portrayed in those images. For example, males were often the doctors while females were more often the nurses. Goldschmidt and Bogner (2016) used gender-stereotypic images and counter-stereotypic images from science textbooks to investigate the effect of these images on students' levels of comprehension. In their study, girls showed higher levels of comprehension after viewing counter-stereotypic images of female scientists than after viewing the stereotypic images of male scientists. Boys showed no significant difference in their comprehension levels either with stereotypic or counter-stereotypic images. As reported by Brotman and Moore (2008), the effects of stereotypic images have a greater impact on girls compared to boys; however, the number of science textbooks portraying gender-stereotypic images is not as prevalent. For example, Brotman and Moore (2008) reported to have found only two studies showing gender bias in science textbooks between 1995 and 2004, which indicates that science textbooks in the 21st century are beginning to represent more gender equitable images of males and females in science. Nonetheless, it is still important to understand why and how the gender differences in girls' and boys' science learning experiences continue to exist.

**Sub-focus #2: Gender differences in science learning activities in the classroom.** In terms of gender differences in science learning activities, the studies report varying results. With respect to doing hands-on science activities, Goldschmidt and Bogner (2016) reported a substantial content knowledge increase in female students when they participated in plant genetic engineering projects, and therefore concluded that active engagement in hands-on laboratory activities was particularly beneficial for the female students in class. Similarly, a study conducted by Cheung (2009) showed that male students liked chemistry theory lessons more than female students. The male students' preference for chemistry laboratory work declined as they progressed through secondary school. However, for female students, no significant decline in their attitude toward chemistry laboratory work was observed.

Research suggests that hands-on science activities are not always beneficial for girls. Christensen, Knezek, and Tyler-Wood (2015) showed that gender differences appeared to be more favorable towards boys than girls when their dispositions in STEM (STEM science, STEM technology, STEM engineering, STEM mathematics, and STEM career) were measured. Boy's dispositions towards STEM increased after having participated in hands-on science activities. However, in a study conducted by Klahr, Triona, and Williams (2007), girls' performance, domain-general or domain-specific scientific knowledge, and efforts were equal to that of the boys, though the girls' confidence level remained below the boys throughout the hands-on activities. A study conducted by Wolf and Fraser (2008) reported results that were in line with the results published by Christensen et al. (2015) and Klahr et al. (2007), and contradicted the results from the study by Goldschmidt and Bogner (2016). Wolf and Fraser (2008) used the "what is happening in this class" questionnaire to assess the classroom learning environment and divided laboratory activities into non-inquiry versus inquiry-based instruction. The inquiry-based laboratory activities seemed to promote significantly more student cohesiveness in the classroom than the non-inquiry laboratory activities. Under these two learning environments, male students benefited more from the inquiry-based activities than female students, while female students seemed to benefit more from the non-inquiry laboratory activities in terms of their attitudes toward science, classroom task orientation, cooperation, and equity. The female students in the study were particularly concerned about performing the experiments correctly in the inquiry class to the extent that their confidence level and attitude scores were lower in the inquiry-based activities than in the non-inquiry classes. The authors posited that the openness of the inquiry-based activities allowed the male students to try explorations, which involved disruptive and dangerous behaviors such as climbing on tables. Given that the girls in class preferred not to engage in these disruptive behaviors, male students received more attention from the teacher than female students, and female students perceived not receiving equal attention as a lack of equity during the inquiry-based instruction.

There are other approaches to learning whose benefits seem more pronounced for girls. Parsons, Miles, and Petersen (2011) indicated that there was a significant difference in the type of instructional strategies that girls and boys perceived to be important to facilitating their science learning. Although their paper did not elaborate on the specific nature of these differences, other studies elaborated on this argument. Girls seemed to benefit from interactive engagement that de-emphasizes individual competitiveness in a study conducted by Adegoke (2012). Ding and Harskamp (2006) showed that cooperative learning in physics was not beneficial for female students when they had to work in a mixed-gender setting. When the girls solved physics problems in the single-gender condition, they were able to work more effectively. The authors posited that girls were more sensitive to their partner's gender than boys, indicating a high level of gender-sensitivity among the girls. A study conducted by Naugah and Watts (2013) revealed that a teacher-centered teaching approach in which students were primarily copying notes from the board or textbooks gave little opportunity for collaborative, activity-based learning, resulting in girls feeling frustrated during their science lessons. Girls said that the lessons were too didactic and failed to involve them in practical work, which they preferred. Girls preferred hands-on activities because these activity-based learning exercises helped them understand biology and physics as they engaged in the practical work. Furthermore, girls' feelings of frustration became a decisive reason for losing interest in science. In the absence of practical, hands-on activities, the nature of collaborative learning mitigated some of their frustration. Even if the girls were not doing practical work, it was found that their frustrations were alleviated if their science lessons allowed them to be collaborative. In a study conducted by

Juuti, Lavonen, Uitto, Byman, and Meisalo (2010), boys were more satisfied with the traditional method of teaching such as direct teaching, reading textbooks, and conducting practical work, while girls preferred more discussions.  In line with girls' preference for discussion, Guzzetti and Bang (2011) identified that female students perceived themselves to be better in language or humanities, while male students perceived themselves to be better in science and mathematics. Leveraging these self-concepts of ability, the authors implemented a literacy-based approach to teaching science, which was found to have a positive impact on girls' inquiry skills and attitudes towards science.  In particular, girls indicated more positive attitudes towards science than boys and were encouraged to consider careers in science in the future.  Other studies have tried incorporating emotional literacy (Matthews & Snowden, 2007) or context-based/science-technology-society approaches (Judith Bennett, Lubben, & Hogarth, 2007) and have achieved positive results in increasing girls' interest in furthering their science education.

**Summary of sub-foci #1 and #2.** As these studies highlight the differences in what girls and boys prefer in terms of the way they learn science, the intention is not to promote essentialism or to claim that a particular way of learning science is inscribed with one gender over the other.  Hughes (2001) warns against the gender-hierarchical binaries between what is considered male or female, since an essentialist divide obscures the complexity of gender relations with power as well as with other identity categories such as ethnicity or class. Therefore, studies that move beyond single dimensional, gender binaries are needed in order to develop a deeper understanding of marginalized groups' participation in science.

**Sub-focus #3: Factors Shaping Girls' Science Learning Experiences**

According to Mitchell and Hoff (2006) the overt acts of discrimination based on gender or sexism in the classroom have disappeared, but girls' attitudes, interests, and engagement in science continue to lag behind that of the boys. However, even though science teachers may not explicitly discriminate, they may interact differently with female students than they do with their male students and not realize that their teaching methods may not be effectively reaching the girls in the class. In the next section, studies highlight factors that continue to shape girls' science learning experiences in ways that differ from those of boys.

**Girls' perceptions of their classroom learning environment.** In terms of the factors that shape students' science learning experiences, this section begins with girls' perceptions of their science classroom environment. Spearman and Watt (2013) make an important argument about how girls' perceptions of their classroom environment shape their learning experience as well as influences their motivation for learning science. The authors hypothesized that girls' perceptions of the classroom environment were the most influential factor in determining their motivation for learning science. In their study, students' perceptions, the teacher's perception, and the actual classroom environment dimensions, which were defined as the actuality of classrooms rated by a trained observer, were compared. Even though the "actuality" of the classroom was rated high on a certain dimension such as instructional support or student learning outcomes, there was a discrepancy between the actuality of classrooms and girls' perceptions of the classroom that impacted their learning experiences. For example, girls felt less capable than boys and demonstrated less participation than boys in science classrooms, even though their achievement levels were on par with the boys. All the while, the classroom teachers' perceptions of the classroom environment were often more positive than those of the girls in their classes (Spearman & Watt, 2013). Urdan and Schoenfelder (2006) defined the classroom environment as the "general class atmosphere including attitudes towards learning, norms of social interactions, acceptance of ideas and mistakes, and learning structures set by the teacher" (p.

340). Building on this definition of the classroom environment, Spearman and Watt (2013) investigated the influence of a constructive classroom environment, which constitutes particular types of instructional practices and teacher-student interactions, on students' motivation and engagement. Though the authors acknowledged the importance of peer interactions when considering student outcomes and classroom environment, a particular focus in their observation of the classroom was teacher-student interactions and relatedness. Relatedness included various aspects of teacher-student interactions in terms of fair treatment of students, consideration for students' feelings, and taking interest in students. Their findings showed that the construct of relatedness and students' perceptions of the constructive classroom structure were the most significant predictors of girls' science motivations.

Another study also reported on the discrepancy between girls' perceptions and the teacher's perception of the learning environment (what might be described as epistemological fit). In a study conducted by Mitchell and Hoff (2006), girls interpreted autonomous learning time as being ignored by their teacher. The girls' comments were reflective of the socio-emotional warmth that was only available to certain students in the classroom. The tenets of socio-emotional warmth indicate that teachers who care about their students should facilitate student engagement, persistence on academic tasks and develop achievement-related perceptions. In Mitchell and Hoff's (2006) study, girls reported that they did not feel accepted or confident to approach the teacher when they needed assistance on a challenging task. However, a trained observer of the class noted no teacher bias and the teacher did not perceive that the classroom was unfriendly to the girls, which was different from the way the girls were feeling. Notwithstanding, the authors highlight the importance of what the girls reported and how they felt, as their perceptions strongly influenced their motivation for science. Given these findings, the authors recommended future research that investigates a range of classroom interactions across different classroom contexts and varied learning domains.

The following section presents other factors that contribute to the gender differences in the way girls and boys experience science in the classroom (sub-focus #3). Since 1995, there have been myriad studies documenting gender differences in students' science achievement and attitudes (Brotman & Moore, 2008). The findings of this review of literature echo the persistent trends for girls in science.

**Girls' achievement in science.** In terms of academic achievement, girls perform equal or higher than boys, but gender differences show in other ways. For example, Yerdelen-Damar and Peşman's (2013) study on the direct relation of gender to physics achievement showed that female students' achievement in physics was higher than male students; however, girls demonstrated lower physics self-efficacy than the male students in the class. Similarly, Yeung, Kuppan, Kadir, and Foong's (2011) study on boys' and girls' self-beliefs, engagement, and aspirations in physics revealed that there was no significant differences between girls and boys on the following domains of physics: engagement, inquiry, perceived job opportunity, and career aspirations. However, boys had significantly higher self-efficacy in physics and aspirations for a career related to physics, even though both girls and boys indicated that they worked similarly hard and were inclined to engage in scientific inquiry. Under the premise that students' academic effort, which can be manifested through a range of dispositions, beliefs, and behaviors, is predictive of achievement in science, a study conducted by Adamuti-Trache and Sweet (2013) investigated the relationship between students' scores on teacher-assigned grades in science and their scores on a science literacy test. In this study, the authors compared four gender-immigrant profiles for Canadian students: Canadian-born males, immigrant males, Canadian-born females, and immigrant females. Findings indicated that from among the four student-profiles, the Canadian-born male students had the highest performance in science literacy, though they demonstrated the lowest achievement in the science classroom and the least amount of time doing homework. Immigrant female students put in the highest academic effort and demonstrated the highest achievement in science courses; however, their achievement level did not match their own science literacy tests. Provided that schooling generally reflects Western scientific thought, Adamuti-Trache and Sweet (2013) posited that the pattern of gender and immigrant differences could be attributed to different socialization experiences such as students' experiences of living in a scientific and technological society and the daily interaction of their lives with products of science. Another study conducted by Shumow and Schmidt (2013) showed no significant gender differences in achievement as measured by science grades; however, significant gender differences were found in factors that promoted motivation and persistence in science. For example, female students reported significantly lower perceived competence in science and more negative science attitudes than male students. Similar findings that show girls' lower interest in science than boys are reported by S.-N. Chang, Yeung, and Cheng (2009) and Desy, Peterson, and Brockman (2011).

**Affect measures such as self-efficacy, attitudes, competency, and motivation.** Gender differences in terms of affect measures have been reported extensively. In terms of self-efficacy, Tellhed, Bäckström, and Björklund (2017) measured self-efficacy (i.e., competence beliefs) and social belongingness expectations (i.e., socially fitting in) as mediators of gender differences in interest in science, technology, engineering, and mathematics (STEM) and STEM careers. Their study showed a strong relationship between female students' interest in STEM careers and their lower-self efficacy for STEM. However, gender differences in interest in STEM majors was related to a lesser degree to their social belongingness expectations. Nonetheless, the authors posited that an intervention was needed to lessen the gender segregation in the labor market and reduce gender stereotypical competence beliefs related to STEM careers to increase girls' interest in pursuing STEM majors.

Mitchell and Hoff (2006) challenged the assumption that good grades might not be enough to affect girls' self-efficacy in science. In their study of girls' perceptions about grades, they found that girls achieved higher grades in science than boys; however, girls did not perceive the grading system to be fair. The girls in class would say that their hard work alone would not lead to higher grades and that the boys were better at science, an indicator that more subtle factors might be at play to have affected the less than positive perceptions of girls. For example, girls would say that the boys were better at science and that they did not need help in class, as they did not ask as many questions as the girls did when they worked on an assignment. The girls' experiences with the grading system were complicated by the interactions they had with their teacher and peers in the classroom even though they had higher grades than the boys in class. Thus, the authors suggested that subtle socializing factors need to be further examined. For example, Mitchell and Hoff (2006) claimed that in order to increase self-efficacy of girls in science, the continuing socialization that science is for boys needs to be offset by focusing on gender-inclusive teaching approaches aimed at actively combating gender stereotypes and negative reinforcement that girls might internalize. The authors also suggested that efforts to give encouragement for good work, not just through grades on exams, would be a step towards altering the belief girls might hold about assessment in the science classrooms.

In terms of attitudes and competency, Giallousi, Gialamas, and Pavlatou (2013) explored the impact of a chemistry classroom environment on tenth-grade students' attitudes towards chemistry and enjoyment of the chemistry class. In a traditional chemistry class, which consisted of high content coverage and low cognitive processes (i.e., teacher-centered lesson), students' enjoyment of class was low. The lack of enjoyment towards chemistry was more pronounced for the girls in the class than the boys. In terms of motivation, Britner (2008) indicated that girls earned higher grades and reported stronger science self-efficacy in earth science, life science, and physical science classes. However, girls reported higher levels of science anxiety in all three science classes. Girls in the study conducted by Britner (2008) were strongly concerned about their perceived competency in science, which influenced their feelings of anxiety. Thus, the authors posited that these negative concerns might be a factor in girls' lack of persistence in science-related courses and careers. Similar findings on girls' anxiety, as well as on girls having less motivation in and enjoyment of science than boys were also reported by Desy et al. (2011).

In terms of competency, Souchal et al. (2014) reported that presenting assessment as a tool for improving mastery rather than as a tool for comparing performances increased girls' performance in science classes. In light of Britner's (2008) findings on girls' concerns about being perceived as competent in class, these two studies have the potential to complement each other in terms of finding a way to decrease girls' anxiety and increase their perceived competency in science by effectively using assessment in science classes.

Along a similar vein, Yosso, Smith, Ceja, and Solórzano (2009) investigated the role of science competency beliefs for science learning in girls. Their study showed that boys' willingness to engage in scientific argumentation and to participate in science suppressed the role of competency beliefs in their learning of science content. By contrast, girls showed an increasing need to have high competency beliefs in order to achieve strong content learning gains. Though girls were equally willing as boys to participate in scientific argumentation and to participate in science, their stronger need to develop high competency beliefs to achieve significant growth in science learning may be a barrier in having a positive experience in the classroom. Studies conducted by Vijil, Combs, and Slate (2012), Oluwatelure (2015), and Ziegler et al. (2014) also indicated that girls have less positive attitudes toward science when compared to boys. Therefore, Oluwatelure (2015) recommended that a gender inclusive approach be employed to bridge the gender differences in science achievement, attitudes and participation.

In terms of motivation, mixed findings have been reported. Zeyer and Wolf (2010) investigated the relationship between cognitive style and motivation to learn science. They found that there were no significant gender differences in students' motivation to learn science and other measures of science orientation. This particular finding runs counter to the studies that report on gender differences in science achievement, science course taking, and choice of science careers. Schumm and Bogner (2016) also noted that female and male students in overall science motivation scores were equal; however, their study found that girls' higher perceived self-determination score compensated for their lower self-efficacy beliefs in science, which led to the overall equality of the science motivation score.

**Gendered-choices in subject matter.** The extent of girls' participation in science can be explored by examining the factors that influence their decision to take science courses in school. Friedman-Sokuler and Justman's (2016) study of students' choice of matriculation electives in science and mathematics showed gendered-choices in terms of subject matter. Male students chose advanced electives in physics and computer science 2.5 times more than female students and they were over-represented in the most advanced level of mathematics. By contrast, female students were 60% more likely to take advanced biology and 40% more likely to take advanced chemistry. In terms of girls' preference for chemistry, similar results were reported in the study by Hatice (2012) where male students' attitudes towards chemistry showed a sharp decline in Grade 10, while girls' attitude towards chemistry increased. Özgün-Koca and Şen (2011) reported that female students preferred biology more than male students, while male students preferred physics more than female students. Similarly, Koul, Roy, and Lerdpornkulrat (2012) reported that female students showed significantly higher levels of mastery and performance in biology, while male students showed significantly higher levels of mastery and performance in physics.

Baram-Tsabari and Yarden (2011) reported that there was no significant difference between boys' and girls' science interests during early childhood, but the difference increased over twenty-fold by the time they finished high school. Similar findings were reported in studies conducted by Christidou (2011) and Krapp and Prenzel (2011). Using a different approach, Lavonen, Byman, Uitto, Juuti, and Meisalo (2008) investigated the gendered choice in subjects by looking into students' interest and experiences in physics and chemistry-related themes. Similar results were found where girls preferred "observing natural phenomena," while more boys were interested in "science and technology related hobbies or activities," which were correlated with interests in biology or physics/technology, respectively (Lavonen et al., 2008, p. 28). Similarly, Naugah and Watts's (2013) study of science class practices and their effects on girls indicated that boys preferred physics and girls preferred biology because girls perceived biology to be more feminine due to its relevance to their personal, everyday lives. Boys perceived physics to be masculine and objective, and remote from the affective aspects of scientific knowledge. These findings are also supported in a study conducted by Hasni and

Potvin (2015) where girls were more interested in biology, while boys showed more interest in physics and technology.

In addition, girls' affinity for biology and boy's affinity for physics was also noted in Prokop, Prokop, and Tunnicliffe's (2007) study of students' attitude on biology; however, what was noteworthy in this study was that girls found biology to be boring. The evidence of declining science interest in girls as they progressed through high school was also reported by Barmby, Kind, and Jones (2008), Judith Bennett and Hogarth (2009), and Mujtaba and Reiss (2013). What is important in these studies is the sharp decline in girls' attitudes towards learning science in schools. Recall that Spearman and Watt (2013) emphasized the importance of girls' perceived classroom environment on shaping their classroom experiences. Likewise, Legewie and DiPrete (2014) posited that the high school environment plays an important role in reducing gender differences in science and engineering. These findings have implications for changing the way science is taught in schools, which may be alienating girls from school science as we know it today.

Contrary to these studies on gendered-choice in science subjects, Riegle-Crumb and Moore's (2014) study of gender gap in high school physics found that there was gender equality in the representation of girls in physics courses and claimed that the male advantage in high school physics was nonexistent or significantly minute within their research setting. However, the authors acknowledged that gender disparities in science, technology, engineering, and mathematics (STEM) still remains a problem and that female students continue to lag behind male students in terms of taking physics in high school. The authors attributed their findings to the specific communities in which their schools were located in which there was a larger STEM female work force and STEM-related corporations or organizations that established outreach programs with the local schools. These context-specific factors contributed to shaping the girls' beliefs and actions in ways, which might have been otherwise negatively influenced by traditional gender norms. Thus, different communities may or may not have traditionally gendered expectations, which play a role in shaping the girls' beliefs, science course choices, and interest in STEM careers. Tyson, Lee, Borman, and Hanson's (2007) study of high school science and mathematics course-taking pathways reported similar findings in that even though female students were significantly more likely than male students to take courses in life science, they were equally likely as male students to take physics, as well as advanced mathematics such as trigonometry and statistics. However, the authors noted that female students did not always opt to take the highest-level courses, while male students often chose to take the highest-level courses.

In line with the discussion of gendered-choice in subject matter, Ding and Harskamp 's (2006) study of partner gender influences on female students' problem solving in physics found that girls were sensitive to their classmates' gender, which was also supported by studies conducted by Krapp and Prenzel (2011). The study conducted by Ding and Harskamp (2006) reported that same-sex friends' academic performance significantly influenced the girls' decision in taking advanced courses in all subjects, but no such influence was seen among boys. Particularly in mathematics and science, the effects of friends' performance were greater within a predominantly female friendship group. Thus, the authors posited that friendship groups could counter the effects of gendered-choice in science subjects, and gendered stereotypes and identities in these science classes.

**Family functions both as barrier and support.** In terms of this review, the role of students' families functioned both as a barrier and support in girls' participation in science. In terms of family as a barrier, studies have reported different parental expectations for boys and girls in pursuing mathematics and science, or the lack of parental support (Fouad et al., 2010; Rodrigues, Jindal-Snape, & Snape, 2011; Schulze & Lemmer, 2017). As a function of support, both Molina-Gaudo, Baldassarri, Villarroya-Gaudo, and Cerezo (2010) and Stake (2006) reported the importance of social encouragement as a mediator between girls' science motivation and confidence. In studies where family functioned as support, girls represented a wide range of science students and reported that they received encouragement from family, peers, and teachers. This particular finding may be evidence for the changing view on women in science and a change toward greater support for girls in science from the people closest to them (Brotman & Moore, 2008).

**The role of the science teacher.** Several studies indicated that the perception of encouragement from students' teachers was mixed. For example, despite the encouragement from their teacher to continue to pursue physics, girls reported that they had less positive experiences in physics lessons than boys (Fouad et al., 2010; Mujtaba & Reiss, 2013). The discrepancy between the students' and teacher's perception of the classroom environment in terms of support aligns with the findings from Spearman and Watt's (2013) study of the influence of actual and perceived classroom environment dimensions on girls' motivations for science. Furthermore, Thomas (2017) reported that teachers' implicit gendered stereotypes (i.e., science is male stereotypes) had a less than positive impact on girls. Boys' self-concept of science and its intrinsic value aligned with male stereotype, while girls' self-concept of science did not, which was supported by Christidou's (2011) findings on girls' self-concept in regards to science. Similarly, in Andersson's (2012) study of teachers' conceptions of gender and science, teachers had ideas about gender equity in science, but they also held onto stereotypical conceptions of girls and boys, which impacted the evaluation of their students. Some teachers showed condescending attitudes toward girls and devalued their ways of participating in science, which the teachers did not recognize until they were asked to reflect upon their beliefs. As such, Andersson (2012) posited that teachers' implicit conceptions about gender-stereotype in science have consequences in the shaping of girls' attitudes towards science. Archer, Moote, Francis, DeWitt, and Yeomans (2017) also found similar results in terms of a teacher's implicit gender bias playing an important role in dissuading girls from science. Gender stereotypes were unknowingly reinforced by the teacher either through communications in terms of expectations for the girls or failing to acknowledge girls' science competence and achievement.

Several studies called for a way to address teachers' implicit bias and to make teaching practices more equitable and inclusive. For example, Battey, Kafai, Nixon, and Kao's (2007) study of professional development for teachers on gender equity in the sciences characterized effective professional development programs for promoting gender equity. These authors recommended that in order for a professional development program to be effective at achieving gender equity, the following four components must be present: 1) students' engagement in inquiry as a way to embed gender equity in content, 2) strong content knowledge development in STEM (i.e., subject matter training, 3) discussion of gender equitable practices in the classroom, and 4) increasing teachers' awareness of gender equity in the classroom. In addition, Hand, Rice, and Greenlee (2017) showed that both teachers and students held onto subtle gender biases as they attributed masculine characteristics to the sciences and feminine characteristics to the humanities, which influenced their career choices. As students form their identity, which includes choosing a career, the authors suggested that the teachers' tendencies to underestimate girls' mathematics abilities, or subtle gender biases were discouraging girls from being interested in science and science-related careers.

**Girls' experiences with science classroom talk.** Several studies of science classroom talk in terms of girls' share of the classroom space as they engaged in verbal communication also emerged in this review of salient literature. In terms of science classroom talk, Eliasson, Karlsson, and Sørensen (2017) investigated the type of questions male and female science teachers posed in class. The two types of questions were open or closed questions and the study examined whether the type of questions influenced the extent to which boys and girls responded. The results showed that closed questions were often posed and the majority of the responses to such questions came from the boys in class. The authors explained that closed questions were easy to answer by shouting out an answer. Past research has shown that there are factors that contribute to giving more classroom space for male students in terms of answering questions posed by the teacher. For example, Tobin and Gallagher (2003) described the classroom norms that allowed boys to shout out answers without raising their hands. Often, these were a group of boys who were very active in responding to the teacher's questions. To move the pace of teaching along, the teacher would pose questions to the group of boys. Therefore, the findings from Eliasson et al. (2017) is not surprising, considering that boys tend to dominate the greater share of the classroom space in terms of verbal engagement. The study found no significant gender differences with open questions, as open questions were rarely used in class. However, the authors emphasized that gender inequality existed since the boys responded to closed questions twice as much as girls and suggested that boy's dominance over the classroom communication may affect girls' attitudes towards science and alienate girls from opportunities to practice their ability to talk about science.

The same authors conducted a similar study and explored the notion of classroom talk in terms of the specific interactions between the teacher and the students (Eliasson, Sørensen, & Karlsson, 2016). The study showed that both male and female teachers called upon boys in class more than girls, which supported their other study on boys' taking control of a greater part of the available interaction space in the science classroom than girls. However, the study also reported evidence of girls attempting to increase their proportion of the science interaction space and posited that this trend of boys' dominance over classroom space is changing. Similarly, Jurik, Gröschner, and Seidel (2013) investigated girls' and boys' verbal engagement in a physics class. The study was conducted based on the premise that classroom talk plays an important role in enhancing students' motivation and knowledge development in science class, as well as engaging both boys and girls meaningfully in science learning. They found that the girls who were strong in science ("strong girls") were highly engaged in verbal communication in the classroom in terms of frequency, duration, and student answers (Jurik et al., 2013, p. 41). Overall, the frequencies of verbal engagement were higher for boys than girls. However, the few "strong girls" showed a different pattern of verbal communication, which indicated a high level of engagement in the classroom talk. These findings suggest that student characteristics play a role in mediating gender differences by reducing the effect of gender stereotypes.

A study conducted by Sullivan, Kapur, Madden, and Shipe (2015) explored the role of gendered discourse styles in online science discussions in a physics course. Two discourse styles were defined: oppositional/direct and aligned/indirect. Oppositional/direct style was the socialized discourse pattern typically used by male students, while aligned/indirect style was the socialized discourse pattern typically used by female students. The results of the study indicated that the presence of the two discourse styles were present in both male and female students; the authors found no major impact of discourse style on the uptake of ideas in the physics class. The authors posited that the anonymity of the users in the online format might have helped reduce the gender bias in the class, or the disadvantages that female students face in a traditional classroom setting. Though identity-seeking behaviors were observed, female students had the opportunity to equitably participate in science discussions with males, regardless of discourse style.

Lastly, Dhindsa and Abdul-Latif (2012) investigated verbal interactions between students in a secondary biology course. These authors found that students preferred female-to-female, or male-to-male communication more than communicating with the opposite gender. However, the authors attributed this pattern of verbal communication to the cultural contexts in Brunei where socialization within the same gender rather than with the opposite gender is encouraged.

**Girls who are academically advanced and are high achievers.** The experiences of high achieving girls' in the science classroom also emerged in this review of the literature, a finding that is particularly relevant to the specific student populations in this study. Rudasill and Callahan (2010) focused on the academic self-perceptions of ability and course planning among academically advanced students. The study showed that mathematics was the most interesting school subject for both girls and boys; however, the interest was stronger for boys. Along the same vein, both girls and boys were equally interested in science; however, boys had higher perceived science ability than girls. The authors posited that gifted or academically advanced students can also be affected by gender stereotypes in terms of their self-perceptions of ability, course choice and career choice, but to a lesser extent. However, it remains unclear to what extent gifted or academically advanced students are buffered from the effects of gendered stereotypes or insulated from the negative impact of the stereotypes on their career aspirations in science. Nonetheless, Rudasill and Callahan's (2010) discussion of the relationship between girls' perception of ability and their plans for future science courses has implications for encouraging girls to explore their interests and a wide range of career trajectories in science. Another study conducted by Buday, Stake, and Peterson (2012) investigated the relationship between gender and the choice of a science career in high achieving science students. The sample of student populations in the study had strong scientific ability and achievement. The study reported that there were no significant differences between boys and girls in terms of their perceptions of support for pursuing a science career, their science career-related possible self, or their career outcome. Closely related to the concept of self-confidence, Markus and Nurius (1986) defined the term *possible self* as an aspect of the self-schema that represents what the self may become at a future time. In a study conducted by Buday et al. (2012), the possible self in question was the possible self as a developing scientist as a future career self. As they participated in their high school science enrichment program, female students reported that they felt just as supported and optimistic about their ability to pursue a science career as their male counterparts and were equally likely to enter a science-related career. Thus, the authors posited that a strong vision of a possible self in a science career was associated with the social support and positive perceptions of a science career.

**Summary of sub-focus #3.** Through a review of an extensive body of literature, the researcher has teased out different factors that are influencing girls' persistence in science. Despite equal or higher achievement in science, girls generally reported less than positive attitudes and interests toward science than boys. Girls who enjoyed science showed evidence of a persistent pattern of self-assessment that put them lower than that of the boys (i.e., lower self-efficacy, motivation, attitudes, competence). Their interest significantly declined with age as they progressed through school because of their tendency to perceive science as difficult and uninteresting (Villar & Guppy, 2015). In these studies, gender differences in science participation was attributed to environmental and situational factors that were further complicated by social interactions with peers, teachers, and family. These factors ranged from gender-biased parental guidance, teacher's implicit beliefs about girls and boys in science and peers' influences, as well as the lack of experience or exposure to science (Patterson & Johnson, 2017). Thus far, different studies have provided both promising and discouraging findings about girls' experiences with science in terms of achievement, attitudes, and participation. As Riegle-Crumb and Moore (2014) highlighted, different contexts and factors play a role in determining the extent to which traditionally gendered-stereotypes, expectations, and norms shape the science beliefs, perceptions and behaviors of girls. In addition, it is important to recognize that *gender* is one of the many factors that contribute towards shaping girls' experiences with science.

**Focus 2: Efforts Towards Gender Inclusive and Gender Equitable Science Learning Environments**

In this section, studies that aimed to increase girls' access to equitable science learning experiences were reviewed.

**Girl's experience with technology in the science classroom.** In terms of gender equitable practices, it is not surprising that scholars are looking into the role of technology in the science classroom. According to Linn (2003), personal computers are becoming more powerful than ever and students are enabled to both learn with and learn about technology in science courses. Digital technologies provide resources for learning science via new modes of instruction. With these new opportunities, the increasing use of technology in science education sheds new light on issues of access and equity. For example, Linn (2003) posited that well-designed, online discussions with different formats for participation engaged equal numbers of males and females. More importantly, more than 90% of the students in a study conducted by Linn (2003) contributed to the online discussion. Similarly, Sullivan et al. (2015) demonstrated that gender equity was achievable as male and female students participated in online discussion in a science class. Meij, Meij, and Harmsen (2015) used animated pedagogical agents in an inquiry-learning environment to increase girls' perceptions of task relevance and self-efficacy. Carbonaro, Szafron, Cutumisu, and Schaeffer (2010) implemented a computer-game construction environment as a vehicle to encourage girls to participate in computing science. These authors claimed that the gender-neutral approach to teaching computing science increased girls' participation in the discipline by increasing their confidence and competence with computers. In this study, the authors referred to the course as computing science, which is similar to a computer science course in the U.S. Similar results were supported in studies conducted by Çakır, Gass, Foster, and Lee (2017), Khan, Ahmad, and Malik (2017), and Papastergiou (2009).

Not all effects of technology in the classroom were reported as positive for girls. For example, Lin, Tutwiler, and Chang (2011) claimed that virtual learning environments cannot be gender neutral because of the way students interact based on the their gender. Their study showed that boys demonstrated superior skills at navigating the virtual space, as they had higher frequencies of use over time than girls. Girls reported less frequent use of the virtual world and showed smaller learning gains than the boys. Incantalupo, Treagust, and Koul (2014) investigated the use of technology in biology classrooms and reported that boys' attitudes toward technology were more positive than girls. Though the study did not measure the students' perceptions with respect to science, the authors posited that creating an instructional technology tool that is gender inclusive takes a constructivist, student-centered approach to increase engagement and achievement with those technologies. In line with the notion of the constructivist environment, Dhindsa and Shahrizal (2011) evaluated whether the use of an interactive whiteboard technology in a constructivist teaching approach could reduce gender differences in chemistry achievement. Their study revealed statistically significant differences on pre and post achievement in that gender differences in chemistry achievement were minimized.

**Achieving gender equity through outreach programs.** A different group of studies looked to extracurricular programs and camps to achieve gender equity in science education (Hong, Lin, & Veach, 2008; Kralina, 2009). For example, Godwin, Sonnert, and Sadler (2016) demonstrated that learning experiences offered outside of the school setting provided more unstructured ways of meaningfully engaging with science and engineering, and sparked interests that were not confined by the traditional high school science curriculum. Their study showed that these experiences had a positive impact on students' likelihood for choosing a career in science and engineering. Wegner, Strehlke, and Weber (2014) invited girls and boys to participate in a science project conducted at their university and explored the differences between the girls and boys in terms of frustration, boredom, and insecurity that they might experience during the science lessons. The results showed that girls were less frustrated, less insecure, and less bored than boys, and the authors posited that the autonomy and success the girls experienced in their science learning could be attributed to these measures. Similarly, several studies reported the positive impact of extracurricular or afterschool programs in science or STEM on girls' science interests, attitudes, and career choices. For example, Ferreira and Patterson (2011) improved gender equity through a science enrichment program where African American girls' achievement and attitude towards science significantly improved. Similar studies such as that conducted by Phelan, Harding, and Harper-Leatherman (2017) supported the positive impact of a summer camp on underrepresented high school girls particularly in terms of increasing their interest in pursuing a STEM or health-related career. H. Kim (2016) and Dubetz and Wilson (2013) both reported the positive impact of a science and engineering outreach program for secondary female students, which encouraged them to consider engineering, mathematics and science careers.

However, these enrichment programs do not always work, as demonstrated by Lang, Fisher, Craig, and Forgasz (2015). The authors developed and implemented an outreach program to encourage secondary school girls' interest in computing courses and careers. Even though there was an immediate positive effect of the program, the authors could not find a long-term effect of the program with respect to influencing the girls' desire to pursue a career path in computing. This study is important because girls need to sustain their interests in science or science-related subjects as well as future careers. Researchers cannot be too quick to conclude that an intervention would be sufficient to keep the girls' interest sustainable. Thus, Lang et al. (2015) acknowledged that there were myriad factors such as a school culture and teacher biases that account for these less than ideal results. Similarly, Archer, DeWitt, and Dillon (2014) developed an intervention to raise students' awareness of science, technology, engineering, and mathematics (STEM) careers as well as to broaden their views of the nature of jobs in STEM. Their study reported that the intervention did not significantly change students' views of science or their aspirations to pursue a career in STEM. However, for the girls from the high achievement group, the intervention influenced them to become aware that there were different paths to a career in science and the way they thought about science. For example, girls realized that jobs in science entailed more than working in laboratories or medical professions.

Lastly, Bhattacharyya, Mead, and Nathaniel (2011) investigated the influence of science summer camps on Louisiana African American high school students' attitudes towards science and career choices in STEM. By participating in the program, students received parental support, benefited from increased science academic ability and deepened their scientific knowledge. Therefore, these authors posit that these perceived benefits shaped the identities that students constructed for themselves in relation to science in their everyday lives. In line with the notion of constructing science identity, Robnett and Leaper's (2013) study of friendship group characteristics, motivation and gender reported that friends' support of STEM and science motivation predicted the students' level of interest in STEM careers. These findings suggest that social identities and self-concepts influence students' STEM career choices.

Outreach programs designed specifically to include girls is important but scholars argue that this is only a partial solution in addressing the problem of the marginalization of girls in science. Mitchell and Hoff (2006) argued that these programs did not address the beliefs that students, teachers, and parents might have and bring to the learning environment, which might affect the way girls view science. Though encouraging girls to participate in science is important, scholars continue to stress for the importance of addressing the way girls are socialized to perceive the place of women in the sciences, and the way they develop their science identities, which impact their interest in science, science course choices, and aspirations for a career in science.

**Encouraging girls' science identities through female role models.** Gilmartin, Denson, Li, Bryant, and Aschbacher (2007) investigated whether middle and high school students who have a science role model develop more positive attitudes toward science and scientists, increase persistence in advanced science courses, and increase interest in pursuing science careers. These authors operated under the assumption that students' science teachers could be perceived of as a science role model. What the authors found was that students did not perceive of their science teachers as a science role model and female science faculty did not have a significant impact on girls in terms of understanding scientific practice, science self-concept, or interest in science. The findings from the study conducted by Gilmartin et al. (2007) can be understood in light of a study conducted by Buck, Plano Clark, Leslie-Pelecky, Lu, and Cerda-Lizarraga (2008) who examined the cognitive processes of girls and women scientists in identifying science role models. What they found was that girls' process of identifying a science role model involved personal connections, and their initial image of a scientist led them to believe that they did not have a personal connection with a scientist. Women scientists felt pressured to portray the "perfect scientist" in order to become a role model for these girls (Buck et al., 2008, p. 689). The authors further posited that a common understanding of a science role model was agreed upon only after changes had occurred in both the girls' image of a scientist and women scientists' image of a role model.

In the earlier work by Britzman and Pitt (1996), the authors challenged the notion that the provision of role models and positive curricular representation would ensure the success of marginalized students. This notion assumed that marginalized students would want to be just like their teachers or the role models who are portrayed in a book. However, Britzman and Pitt (1996) argued that "teachers and students alike, do not map neatly onto sociological categories of identity" and therefore, "the reliance on positive role models to do the work of pedagogy stops short of the full implications of psychoanalytic conceptualizations of 'identification' and 'identificatory processes,' or the ways ideas, people and events become relevant to selves…. Identification and dissociation with representations are far more complicated because, as a dynamic, identifications are partial, ambivalent, and shifting." (p. 120). In a study conducted by Gilmartin et al. (2007), girls respected their science teachers, but did not consider them as a science role model or someone who exemplified a "possible self." The girls in this study felt that science teachers were not scientists and did not know "what it took" to become a scientist (p. 998).

In addition, Hazari, Sonnert, Sadler, and Shanahan (2010) found that students held onto gender biases against their female teachers and evaluated the female science teachers lower than the male science teachers despite the fact that both female and male science teachers were equally effective at doing their jobs. Students' discipline-specific gender bias was widely reported in teacher evaluations and the authors suggested that gender bias may negatively impact the female students and contribute to the loss of women in STEM fields. These three studies have implications regarding how girls construct their science identities, their perception of what constitutes "real science," and what it takes to become a "real" scientist. Together, these factors may be alienating girls from science.

**Summary of Foci #1 and #2.** Studies presented under Focus #1 reported the ways in which gender bias, stereotypes and inequities exist in the science classroom, especially focusing on the factors that contribute to inequitable access to science for girls. The gender differences in terms of achievement, attitudes, and participation among other measures of science were highlighted. Moreover, many studies examined teaching approaches that seemed to work especially well with girls in order to increase their interest, motivation and attitude in science. Studies presented under Focus #2 reported strategies, including teacher professional development as well as extracurricular and outreach programs, to address the gender inequities in science education, and to increase equitable access to science for girls. By identifying teaching approaches that specifically align with the way girls learn and experience science and ways to broaden curriculum and pedagogy, research in gender and science education is moving away from the notion that girls need to be "changed" (Brotman & Moore, 2008, p. 974).

These studies, which highlight gender differences, aim to explore ways to understand, and perhaps, alter the gendered patterns of science achievements, interests, etc. However, scholars should be aware of the essentialism and dualism trap when we participate in such discourse with respect to gender and science education. Kenway and Gough (1998) caution scholars about identifying the feminine aspect of science, school curriculum and pedagogy that might align with the essential nature of girlhood, or that girls are positioned solely by their female-ness part of their identity. Instead, using the words of Lyn Yates, the authors urge scholars to develop "sensitive, differentiated understanding" (as cited in Kenway & Gough, 1998, p. 18).

The perspective that school science needs to change in order to increase the participation of girls in science is emerging. A number of studies focus on better understanding how girls learn and experience science, which Brotman and Moore (2008) argue is an important step towards challenging the ways in which science is portrayed and practiced in the classroom. As the curriculum and pedagogy are changed to become gender-inclusive, dominant ways of thinking about science and what kinds of knowledge are legitimized in science will be challenged, which will have an impact on how girls construct their identity and are enabled to see a "possible self" in science. Thus, the following section further elaborates on girls' science identity in relation to the cultural production of school science.

**Focus #3: Cultural Production of School Science and its Relation to Girls' Identities**

The studies discussed in this section focus on revealing and understanding girls' perceptions of school science and how their identities are shaped. Grounded in situated cognition theory, Brickhouse's (2001) seminal work in theorizing *identity* has drawn the attention of science educators in understanding how science identity is informed by students' lived experiences as well as their social interactions in the home, school, and the larger world. As such, science identity has been defined as "the sense of who students are, what they believe they are capable of, and what they want to do and become in regard to science" (Aschbacher, Li, & Roth, 2010, p. 566). This science identity has widespread implications on girls' perception of science and decision of whether to pursue a STEM career. Unfortunately, girls persistently tend not to identify with science, which impacts their science learning experiences as they move along the science trajectories in school (Barton, Edna, & Ann, 2008). Often, girls reported that science was boring, uncreative, and difficult to understand. Furthermore, the classroom environment plays an important role in shaping students' attitude toward school science. Studies have reported that students become disinterested in science because school science seems disconnected from the real world (Christensen et al., 2015). School science is often perceived as unappealing, boring, irrelevant and outdated. Dijkstra and Goedhart (2011) emphasized that school science seems as if its aim is to educate only the small portion of future scientists rather than educating all students to develop scientific understanding, reasoning, and literacy. Giallousi et al. (2013) noted, "The trouble with school science is that it provides uninteresting answers to questions we have never asked" (p. 362). Given the less than positive perceptions of science in girls, Brotman and Moore (2008) argued that the portrayals of the nature and culture of science need to be challenged to increase the participation of marginalized groups in science.

**Science is difficult and is only for "smart" people.** In the studies included in this section, science is viewed as being difficult and available only for "smart" people with an innate ability to excel. Due (2014) investigated girls' view on what constituted a competent physics student. In the study, both girls and boys viewed physics as being a difficult subject that included logical reasoning based on abstract formulas. Related to the association of understanding physics with abstract formulas was the notion of elitism where science was viewed as being reserved for a few elite students in class. Nyström (2007) reported similar findings in that the discourse surrounding a natural science student was produced as being cleverer, brighter, and superior to other students. In addition, the natural science students were portrayed as being born with the ability to develop abstract reasoning qualities. In Nyström's (2007) study, not only did the natural science students set themselves apart from non-science or social science students, teachers also positioned them as the cleverer students and nurtured the students' feeling of being superior. Though both girls and boys set themselves apart from the other non-science students, the girls emphasized the notion of complementarity rather than superiority and oppositionality. For example, the girls rejected the notion of hierarchy among the students. When they were told that they were bright or clever, the girls responded with uncomfortable laughter and denial. Also, both girls and boys engaged in the discourse that girls had a different structure of the brain that caused boys and girls to reason differently. According to the boys, developing an understanding of natural science was more difficult for girls because they learned the content by heart, which was an approach associated with the non-science students, rather than through specific reasoning skills appropriated only for the science students. Throughout the course, girls were positioned as being intrinsically less capable of becoming natural scientists. Another study conducted by Archer et al. (2017) reported that students constructed physics with the qualities of cleverness and masculinity due to perceiving the subject as one of the hard sciences. Students in the study discussed physics as having more of a natural fit with masculinity, and biology having more of a natural fit with femininity. In line with thinking about hard sciences, Madara and Namango (2016) reported similar findings of how engineering was perceived by girls as being masculine and too hard. Grounded in Pierre Bourdieu's theory of social reproduction, Archer et al. (2017) posited that girls are socialized to accept the pervasive construction of science as being difficult to understand, masculine, and uninteresting. In the process, girls' identity is shaped in such a way that they see themselves as "not good at physics" and science as something that is "not for me" (Archer et al., 2017, pp. 97-98)

**Science's association with masculinity and objectivity.** Previous studies have shown that masculinity was associated closely with cleverness. Masculinity is also associated with objectivity, rationality, and lack of emotion, which are often associated with the nature of science. Because femininity is viewed as mutually exclusive with masculinity, science is often perceived as being unassociated with culturally defined feminine traits, which could affect the way in which girls see themselves in science. Cousins and Mills (2015) reported that girls perceived chemistry as a masculine subject, which shaped the way they constructed themselves as the outsiders of the subject. Akgün (2016) investigated secondary school students' images of a scientist, and found that the prevailing image of a scientist was a male wearing glasses and working in the laboratory. Barton et al. (2008) discussed the continuing problem that girls face in engaging with and succeeding in science where school and societal attitudes portray science as masculine. The association of science with masculinity often forces femininity to oppose science in such a way that femininity is "pitted against other highly valorized attributes, such as intelligence, objectivity, and logical reasoning" (Villar & Guppy, 2015, p. 5). As such, these authors posited that girls are turned away from science, which leads to the continuing problem of marginalization of girls and women in science. In addition, Archer et al. (2017) also argued that the culture of science, which is fundamentally aligned with masculinity, disadvantages female students. Similarly, Due (2014) suggested that the association between masculinity and science has implications in that girls perceived themselves as not belonging to the discipline and not being able to succeed in science. For example, peers actively perceived the girls in the physics class as less competent. In Due's (2014) study, girls talked about not understanding physics and showed little interest; however, it was not just the girls who were perceived as being less competent. Boys who were perceived to lack mature masculinity were also perceived as less competent compared to their more masculine counterparts. Among four of the five mixed gender groups, a boy from each group positioned himself as the most competent physics student and took the role of the leader. The boys who became the leaders of the groups clearly demarcated themselves from the rest of their peers and positioned themselves within the boundaries of masculinity, while they positioned the boys who were perceived as lacking mature masculinity as "the other." (p. 452). In this study, both girls and boys constructed and positioned themselves within the traditional gendered discourses with respect to masculinity.

There are girls, however, who benefitted from the connection between science, masculinity and power. For example, Buschor , Kappler, Keck, and Berweger (2014) reported that female students emphasized their status as being "unique in a men's world" and highlighted their status as an "exotic specimen" with an affinity for succeeding in a male-dominated field (p. 743). However, the notion that girls were different created an inequitable access to science for girls nonetheless. In a study conducted by Nyström (2007), boys agreed that girls were better at chemistry than physics.  Given that physics was considered to be the most difficult subject among other sciences, physics was strongly associated with the boys' way of thinking and interests.  In Due's (2014) study, students talked about the different attributes that they felt explained why physics was more suitable for males than females.  A similar finding was supported by Nyström's (2007) study in that students focused on highlighting the sex differences with respect to the development of the specific reasoning skill that was necessary in becoming a scientist.  In this sex difference discourse, girls could not possibly become a "proper" scientist.

**Narrow Definition of Scientific Practices.** The practice of science is often portrayed as being rational, objective, and unemotional.  As such, the historical association of science with masculine characteristics has led to understanding the practice of science as also being masculine (Villar & Guppy, 2015).  In a study conducted by S. S. Valenti, Masnick, Cox, and Osman (2016), girls perceived science as lacking creativity, which had an implication for the way it shaped girls' attitudes towards science.  van Eijck and Roth (2008) reported that scientists' representations in biology textbooks did not fully represent the dynamic processes of scientific practice, which is often mediated by the scientist's community.  Scientists were often represented as working alone, removed from other scientists in space and time.  For example, Pasteur's work was part of a larger movement in the scientific community during his time, which impacted other scientists, policy makers and the public as a whole.  However, science textbooks showed only the heroic and individualistic representations of his experiments, rather than presenting it as part of the societal movement itself.  This narrow and reductive representation of the scientific practices by scientists impacts the way in which students understand how scientific knowledge is created. Another study by Orlander (2014) critiqued the way biology lessons are taught as a series of facts.  This study highlighted examples in which studying a series of facts were given priority over understanding the complex nature of science. Godwin and Potvin (2017) argued that students began their participation in science through narrowly defined communities of practice, which failed to embrace the concerns of equity and diversity. For example, a participant of Godwin and Potvin's (2017) study, Sarah, initially developed a strong science identity. However, as she progressed through high school, her science learning experiences began to chip away at her identity and agency, which ultimately pushed her out of science. The authors of this study emphasize the importance of the science classroom as a space in which students can begin to develop their science identities so that they are able to see themselves as a legitimate participant of science. Humans shape scientific knowledge and practices, and societal and cultural values influence the actions and thoughts of the humans who do science (Brotman & Moore, 2008). Thus, it is important to bring into the science classroom the discussion of the role of subjectivity, creativity, and personal expression in science as part of the nature and culture of scientific practice and knowledge.

**Gender role bias.** Studies have shown that both teachers and students have gender role biases that affect students' view of science. Hand et al. (2017) explained how teachers and students believed that boys performed better in STEM disciplines, while girls performed better in the humanities. Both teachers and students attributed masculine characteristics to science, while feminine characteristics were attributed to the humanities. Patterson and Johnson (2017) investigated the impact that gender role socialization had on girls and their science trajectories. The authors found that STEM-related career interests remained constant throughout high school, but boys were more inclined towards engineering, while girls were more inclined towards medicine. The authors reported that parental influence, such as the mother's gender-stereotypic beliefs, shaped a student's science and mathematics achievement and persistence as well as predicted girls' STEM-related career interests. Furthermore, the study suggested that people are socialized to perceive the type of talent needed for various disciplines as either innate or developable. For example, people may hold the belief that physical sciences and mathematics abilities are innate, particularly for males, and thus girls may be less likely to consider or participate in those fields. Though girls have shown comparable achievement in sciences, the role of gender as a decisive factor in girls' science trajectories is evident.

**Positioning and navigating the science classroom with its own subculture.** Historically, science has been constructed as a male arena and a male-only activity from which women were largely excluded (Nyström, 2007). Though female participation in science has changed, the cultural production of science is still male dominated. Several studies revealed examples of girls not having equitable access to science to fully participate in school science. In Nyström's (2007) study of student perspectives of school science, even though the boys felt that it was not acceptable to boast about one's own cleverness, they spoke about the differences between the natural science students from other non-science students and explained how they learned specifically to think logically and abstract, while the non-science students did not. In doing so, characteristics of non-science students were associated with the girls in class, while characteristics of science students were associated with the boys. In Parker's (2014) study of school science experiences of Latina students, Latinas were explicitly inhibited from fully participating in their science education, as they navigated the middle school structure, their culture, and school science environment. Carli, Alawa, Lee, Zhao, and Kim (2016) showed that female students were perceived to lack the qualities that were needed to become successful scientists and experienced discrimination and prejudice. In a study conducted by Master, Cheryan, and Meltzoff (2016), girls experienced stereotype threat and experienced a loss of belonging, which the authors traced to their lower feelings of fit in the science classroom. Given that the context of the study was a computer science class, the authors posited that girls might avoid computer science courses due to the prevailing gender stereotypes that signal to the girls that they do not belong.

How girls position themselves or are positioned by others is central in understanding how girls develop their identities. Studies have shown that girls are often positioned with less power in the science classroom. Such positioning of girls can be accomplished in several ways. For example, Barton et al. (2008) noted that girls were called on less often to answer questions, or were not given equal attention as the boys by the teacher. According to these scholars, girls developed their identities through engaging with tasks of the science class, during which learning science became a process of coming to be "identities-in-practice." From this perspective, learning science becomes an embodied activity where learning science is no longer just about learning the content of science, but rather, it is about learning to become a legitimate participant in the science learning community. Thus, investigating how girls push back against the norms, which function to silence or marginalize them in the science classroom, is important. For example, in the study conducted by Barton et al. (2008), the girls took up different identities that were new and distinct from the usual science class identities. These new identities of the girls did not fit neatly into the norms in the science class. Amelia, one of the participants, drew upon her knowledge to find an entry point to participate in science, while she maintained her position in class as the disruptive student. In doing so, she demonstrated her knowledge of the spoken and unspoken rules for the norms of participation in class. Another example is how Ginny used a song to participate in the science class. She used the song as a resource for entering into the science classroom discourse in class and taking up a playful identity, while not fully assimilating to the normative culture of the science classroom.

There are examples where girls choose to be compliant, submissive and follow the norms of heteronormative femininity in the science class. In a study conducted by Carlone et al. (2015), priority of the science classroom norms over the girls' science interests and competencies functioned as a barrier for girls of color in terms of equitable access to science. Archer et al. (2017), in their study exploring gendered patterns of students' science participation and career aspirations, showed that girls perceived physics as being both masculine and hard, an observation that was evidenced not only among the girls who did not plan to continue with physics but also among those who aspired to be exceptional physics students. Additionally, Carlone et al. (2015) noted that girls were at conflict with ideas about how to be a good science student and how to be a girl. A group of girls engaged in "girling" science, while another group of girls de-emphasized their "girliness" to perform a "blue-stocking femininity" that was asexualized and associated with being clever and academically superior. However, the authors argue that both versions of science created complications that impacted the girls' science trajectories. Carlone, Scott, and Lowder (2014) explained that William and Amy, participants in the study, seemed to be successful in the science class. However, their identities in class diverged where Amy no longer was the celebrated science student, while William's identity was recognized more as the successful science student. Similarly, another girl in the same class was unable and unwilling to position herself as the celebrated science student even though she was a capable student academically. In a study conducted by Nyström (2007), girls maintained the identity of a "good girl" in that they knew what was expected of them. Even though their identities were constructed as being less competent as science students, they chose to construct themselves as the nicer girls in class; it was more important for them to show the teacher that they had the “right” female attributes.

Many girls connect and engage with science in a range of positive ways. For example, in a study conducted by Archer et al. (2017) exploring gendered patterns of students’ science participation, girls were proud to be different from other girls in their physics class. They conveyed a sense of boldness and independence. They described themselves as being academically competitive and secure in their academic abilities and identities. For example, Mienie in the study exhibited competitiveness in relation to her peers and showed that she wanted to be one of the highest achievers in her science class. The girls who ascribed to a similar nature of competitiveness recognized themselves as being “brainy.” These girls also possessed high levels of family capital in that they came from family with parents who valued and prioritized science and mathematics and had STEM backgrounds. This particular group of girls shared a preference for theoretical physics and were able to articulate that physics and engineering were currently male-dominated domains but did not seem to be discouraged by being outnumbered by men in the classroom or the laboratory. Within this group of girls, there were some girls who disassociated from femininity and invested in aligning their identity closer to what was perceived to be more congruent embodied performance of a good physics student. By contrast, there was also a group of girls who explicitly performed their girly identity.

**More than just gender: shifting the direction of research in science education**

It is important to acknowledge that gender is an important part of a girls’ identity but not the only part. Brickhouse et al. (2000) argued that it is necessary to know "what kind of girls they are (p.457). To this end, more studies are needed to examine the diversity within gender groups and to push back against the simplistic dichotomy between "girls" as one group and "boys" as the other. A similar argument was made by Barton et al. (2008) who called for research that does not generalize girls as a homogeneous group and achievement as the only marker for academic success, as girls are socialized and internalize subtle messages that science is not for them. Watermeyer (2012) argued that gender could no longer be theorized as the only determinant of a learner's identity. Dentith (2008) further posited that issues of race and class should be also be considered in light of issues of gender equity. Thus, using gender as a launching site, there needs to be a broader analysis and an intervention for social justice and full equity. Prior to 2007, Brickhouse et al. (2000) analyzed how African American middle school girls from working-class backgrounds viewed themselves as the kind of person who engages in science. The authors aimed to understand whether the girls' identities overlapped with school science identities and highlighted how ethnicity, class and gender interacted to influence the variety of ways the girls chose to engage in science with respect to their views of what kind of girl they were. Another notable qualitative study was conducted by Carlone and Johnson (2007) but with successful career women in science. Since 2007, only a small number of qualitative studies have explored the intersection of other identity categories, such as class, ethnicity and gender in relation to students' science learning. For example, Barton and Tan (2010) conducted an ethnographic study to focus on how low income urban youth asserted themselves as community science experts in such a way that they not only garnered the respect of scientists and engineers through education of their community on the urban heat island phenomenon, but months after the completion of the project, these youths said this project gave them a sense of power and importance. This statement fights against the stereotype that minority urban youths are "lazy" and are not interested in science. These youths crossed the threshold from being consumers of knowledge to producers of knowledge, which proved to be very beneficial in the development of their science identity. Parker (2014) used ethnographic methods to understand how Latino girls interacted with science in their tracked, urbanized middle schools. Lastly, Carlone et al. (2015) examined how larger social structures such as race, class, gender, and sexuality as well as classroom structures constrained female students' agency and defined identity in the science classroom. Though only a handful in number, these studies provide a starting point to deeply examine how the intersection of identity categories within different cultural and socioeconomic contexts shape and influence girls' science learning experiences in schools. Given the extensive literature on gender and science education, my study is situated at the cusp of examining and understanding the cultural production of school science in relation to marginalized groups' identity categories of gender and race. The next section provides a review of literature that centers on the issue of race or ethnicity in science education and in particular, the school science learning experiences for Asian/ Asian American students.

## Part 2: Race in Secondary Science Education

### Race as a Social Construction

There are two perspectives regarding how race is understood as a social category: objective or illusory. According to Omi and Winant (2014), an objective view of race is rooted in the biological differences ranging from skin color to variations at the genetic levels. From an objective view, race is therefore fixed and concrete. In contrast, an illusory view of race is rooted in an ideology that argues that race is not real. Thus, from an illusory view, Omi and Winant (2014) posit that a "fundamental material distinction or axis of identity" such as ethnicity, class, and nation is masked, and that race is treated as "an epiphenomenon of culture, or inequality and stratification, or primordial peoplehood (p. 109).

In this study, race will be understood as a social construction (Walls, 2016); however, in line with Omi and Winant (2014), race cannot be dismissed as being unreal. This study adapts the definition of race as a category of social analysis with complex social meanings that are being constantly transformed. In other words, race is a concept, or a representation of one's identity that signifies different types of human bodies based on the "perceived corporeal and phenotypic markers of difference as well as the meanings and social practices that are ascribed to these differences (Omi & Winant, 2014, p. 110). In considering both the visual differences and social practices as the two defining axis of race, Carlone and Johnson (2007) summarize the definitions of race and ethnicity well: *ethnicity* is referred to as systems of meaning sharing among a group and *race* is referred to as what students "look like" at first glance (p. 1193). The distinction made between ethnicity and race signifies that race is not solely defined by the observable visual differences, but also by the social practices such as interpersonal, institutional socializations and practices that give rise to the "visual" understanding of race (Omi & Winant, 2014, p. 111). In that sense, ethnicity can become an equally useful category of social analysis when diversity within a race category becomes important. Given that Asian is a broad racial category that includes a person having origins in East Asia, Southeast Asia, or the Indian subcontinent, whenever a specific ethnic category is called for in terms of discussing the science learning experiences of minority groups, the associated terms for the ethnic subpopulations such as China, India, and Korea will be used.

**Particular Focus on Asian/Asian American Youth in Science Education**

Our K-12 schools' classrooms have become more diverse than ever in the last few decades, as the nation's immigrant population is reaching 40 million (Suh, An, & Danielle, 2015). In line with this trend, Asian/ Pacific Islanders are one of the fastest growing, most highly diverse and heterogeneous ethnic populations, including persons of Chinese, Korean, Japanese, Vietnamese, Filipino, Laotian, Cambodian, Indian, and Native Hawaiian origin, among others (S.-J. Lee & Rotheram-Borus, 2009). In the context of education, the academic success and achievements of Asian American students have garnered the attention of education researchers and policy makers alike in recent decades (Asakawa & Csikszentmihalyi, 2000). For example, on the 2015 SATs, Asian American students scored the highest of any racial group on the SAT mathematics (average of 598), while the national average was 511. Their scores were higher than Hispanic students, whose average was 457; African American students, whose average was 428; and White students, whose average was 534 (The College Board, 2015). In examining the National Assessment of Educational Progress (NAEP) science assessment scores at Grade 12, Asian/Pacific Islander students' scores were 167 in 2015 (National Center for Education Statistics, 2015). In comparison, their White peers' science assessment scores were 160, while the scores for Hispanic students and African American students were 136 and 125, respectively. Overall, male students (score of 153) outperformed female students (score of 148). Because Asian American students demonstrate superior academic performance in science and mathematics, their educational experiences are sparsely discussed, especially in science education literature. As noted earlier, in the dominant education discourses, Asian American students are portrayed as the super star students. The 2015 NAEP report highlighted the "achievement gap," a term that the report used to describe the score differences between the minority groups and white students. Reporting that African American and Hispanic students performed much lower than their White peers and Asian American students seems to implicitly support deficit thinking model and the negative narratives about African American and Hispanic students, while portraying Asian American students as the super star students.

When Asian/Asian American students are persistently portrayed as super star students different aspects of their science learning experiences may be obscured. For example, Coombs et al. (2014) have reported on Korean American students' experience with silencing as they remain outwardly invisible in the mainstream culture of U.S. high schools. In terms of challenges that go unnoticed, Hsin and Yu (2014) reported that there are "growing pains" and that Asian American students' academic success might come at high costs including psychological problems and social conflicts in terms of their relationships with parents and peers (p. 8420). Specific to the challenges in the science classrooms, a study conducted by Ryu (2013) is one of the very few studies that reports on the challenges of Asian immigrant students with verbally participating in their science class and their *othered* identity and positioning according to the quiet and passive stereotypes of Asian students. The next section presents studies that report on the educational experiences of Asian/Asian American students in the science classroom, particularly as these experiences relate to their racial identities.

**Scope of the Literature Review**

The following databases were used to carry out this section of the literature review: ERIC, Academic Search Complete, Education Research Complete, PsycINFO, Science&Technology Collection, and SocINDEX. First, the search terms were used in the following manner: ("high school" OR "secondary") AND "science education" AND ("rac*" OR "ethnicit*" OR "minorit*). A second search was completed using the following terms, which were used to delimit the studies on race in relation to students' identity in science: ("high school" OR "secondary") AND "science education" AND ("rac*" OR "ethnicit*" OR "minorit*) AND "identity"). A third search was completed using specific terms that represented the ways in which students could be stereotyped. Therefore, the following terms were used: ("rac*" OR "ethnicit*" OR "minorit*") AND ("high school" OR "secondary") AND ("science education") AND ("stereotype*" OR "myth" OR “model minority” OR "other*" OR “belong*” OR "bully*" OR "discrimination" OR "microaggression" OR “position*”). A fourth search was completed using the term “education” instead of “science education” to broaden the scope of understanding with respect to the educational experiences of Asian American youth in relation to their racial identities. Lastly, instead of further delimiting the search terms by adding another descriptor, “Asian” or “Asian American,” I selected articles that focused on the secondary educational experiences of Asian American students.

The search was confined to peer-reviewed studies published between 2000-2018. Since the early 1980s through the late 1990s, there was a plethora of seminal scholarly works that emphasized the issue of the model minority myth in the educational experiences of Asian American youth. With the 2001 No Child Left Behind Act (NCLB) and its prescriptions for curriculum, teaching, and testing towards making “adequate yearly progress,” this “American Curriculum” ignited a slew of discussion around the racial differentiation of the academic achievement gap and the mechanism by which to reduce it (Goodwin, 2010). In this context, stereotyping Asian American students as the model minority took on a different turn at the start of the 21st century, and thus demarcates the rise of a new discussion of how race and ethnicity shape the secondary educational experiences of Asian American youth.

Studies pertaining to secondary (middle and high school) education were the primary focus since the context of this study focuses on high school students. However, a select few seminal works at the elementary or postsecondary level were included when these studies added value to the discussion of race in education. Operating under Actor-Network Theory, this study’s analysis began with Asian American students. However, educational experiences of other marginalized students were also relevant since the analysis focused on examining the actors/actants in an actor-network. Understanding what marginalized students' educational experiences look like with respect to their racial identity is important. Therefore, this literature review included studies that discussed the educational experiences of marginalized students with respect to the issue of race in science education where deemed appropriate. Using the fourth search, the scope of this literature review was broadened to the overall educational experiences of Asian American youth because the literature specific to their experiences in science education was sparse. This literature review excluded studies that were on higher education, as well as studies whose primary focus was not particularly on the issues of race, or intersection of race and gender in science education. Lastly, the references of the papers were browsed to look for additional studies and salient review papers that provided an in-depth examination of race in science education. These papers, which had not been initially picked up from the library search were examined and included in the review.

Based on this inclusion and exclusion criteria, 93 papers were selected. The studies were organized into two foci: 1) Asian American youths' educational experiences related to their racial identities, and 2) exploration of Asian American youths' science learning experiences at the intersection of race and gender.

**Focus #1: Asian American Youth's Educational Experiences Related to Their Racial Identities**

**Model minority myth.** Race is intricately woven into the discussion of the disproportionately successful Asian/Asian American students' academic achievements and school performance, whereby we refer to them as the "super-stars," or "model minorities" (Wing, 2007). Under this stereotype, Asian/Asian American students are perceived to be quiet and passive in the classroom, presumed to be successful in school subjects, especially science and mathematics, and perform well on exams (Ryu, 2013). However, the underlying assumption of the model minority stereotype is that Asian/Asian American students are successful due to their unique cultural orientation for hard work and strong belief in the value of education. Operating under a prescribed notion of success, which is entirely based on the individual's efforts and mobility, the model minority myth perpetuates racist practice and maintains the racial status quo by dismissing both the historical and contemporary factors contributing to racial disparities and injustice (Yoo, Miller, & Yip, 2015). The model minority myth effectively perpetuates the notion of meritocracy in schools (Wing, 2007). The opportunity exists for all and anyone, does it not? When and if students fail to be academically successful, the model minority myth implies that only they are to blame for their inadequacies, thereby shifting the blame away from the inequitable education system towards blaming an individual for his or her failure to succeed (Park, 2011). Hence, defining academic excellence as the norm for Asian American students is problematic and continues to reify the model minority stereotype.

The model minority stereotype is a myth. Throughout the 1980s and 1990s, scholars have critically investigated the implications of the model minority myth and its impact on Asian/Asian American students. For example, Ngo and Lee (2007) *complicated* the assumptions of the myth, while M. J. Chang, Park, Lin, Poon, and Nakanishi (2007) called for *going beyond* the stereotype. Most notably, Museus and Kiang (2009) sought to *deconstruct* the myth, while many others have called to *demystify* (Inkelas, 2006), *overcome* (Nadal, Pituc, Johnston, & Esparrago, 2010), and *contest* (Ng, Lee, & Pak, 2007) the model minority myth. Under the stereotype of being the model minority (i.e., smart, quiet, passive), Asian American students are positioned in the classroom as the "honorary Whites" (Tuan, 1998). This model minority myth pits Asian American students against one another, as well as against their non-White peers: academically successful “good and honorary” Asian American students versus “bad” Asian American students who could not live up to the image (Park, 2011). Lew (2006) reported similar findings, as two groups of Korean American students were compared: high achieving versus low achieving. The effect of the model minority myth became evident when the low achieving group of students referred to the high achieving group as the wealthy “near whites,” while they referred to themselves as the invisible minorities or being “just like blacks” (p. 348). Asher (2002) called this simultaneously being exalted and ignored a double marginalization for Asian American students. In addition, Wing (2007) stated that “Asian American students demonstrated a high academic profile on average, but faced difficulties and failure in ways rendered invisible by widespread acceptance of the ‘Model Minority Myth” (p. 455). The consequence of such positioning of Asian American students is the silencing and institutionalized invisibility of their voice in the larger educational discourse (Chutuape, 2016; Coombs et al., 2014). An example of silencing that can be seen in the classroom context might occur when Asian American students felt that their great academic “success” meant that they could not ask for help, because they were deemed to *not* need, let alone deserve, any assistance (Zhou et al., 2003). For example, Lew (2004) described the “other” story of Asian American youth who have dropped out of their high schools. In addition, studies conducted by Whaley and Noel (2013) and S. Y. Kim, Wang, Deng, Alvarez, and Li (2011) further supported students’ internalization of the model minority stereotype versus inferior minority stereotype, and the negative impact of the assumptions of both stereotypes on students’ mental health.

The model minority stereotype serves as the means to unequivocally and undoubtedly positioning Asian American students as the racial and ethnic minority. For instance, Lew (2006) reported that high-achieving Korean American students saw their racial identities as a form of exclusionary stereotypes and false constructs of homogeneity. Though they were typically thought of as "honorary whites," the students pointed out that their racial minority status was accompanied by marginalization to which they resisted by using education. In the study, the Korean American students were firmly convinced that as racial minorities, they had to work harder in school to obtain economic parity with the white Americans. Blauner (1972) defined racism as a way to oppress and deny the members of the subjugated group "the full range of human possibility that exists within a society and culture" (p. 41). In this context, the model minority stereotype serves as a powerful form of racism that emerged out of a dynamic social and cultural construction that sought to limit Asian American students' range of identities, power, privilege, and values.

**Forms of bullying.** Studies that explored the role of racial stereotypes and discrimination report that Asian American students were subjected to harassment by their peers and school violence such as bullying (Qin et al., 2008). Rosenbloom and Way (2004) reported that Asian American students experienced physical and verbal harassment by their peers, who began to resent the teacher's preference for the Asian American students. The image of Asian American students was based on the model minority stereotype, and non-White peers resented this teacher bias. Teranishi (2002) reported similar findings where both Chinese and Filipino students expressed their fear of being made fun of by other students. The students reported incidents where they were the target of offensive and hurtful jokes. For Chinese students, the most common stereotype they experienced involved their academic achievements; they felt that their peers took advantage of them in class. The Filipino students experienced being singled out as troublemakers. Peguero (2011) investigated the relationship between dropout rates and victimization or exposure to school violence. Although the results showed that Asian American students who were victimized were less likely to drop out of school, the author cautioned against making that conclusion too quickly. Students may not be dropping out of school, and visible or audible forms of harassment and bullying might not be obvious. However, Asian American students reported more subtle, nonverbal forms of bullying such as being ignored, ostracized from social groups, and receiving “disgusted” or “bad looks” (Qin et al., 2008, p. 33). Other studies continue to investigate the relationship between model minority stereotyping and negative discrimination, and how these experiences are directly related to each other and become a source of bullying (Kiang, Witkow, & Thompson, 2016; Liang, Grossman, & Deguchi, 2007; Ryu, 2012).

Some studies move beyond the lived experiences of harassment and bullying of Asian American students in schools. Deng, Kim, Vaughan, and Li (2010) investigated the relationship between high levels of chronic, daily discrimination and increased risk for delinquent behaviors. Similar results were reported in the small, but growing literature exploring the relationship between discrimination and issues of violence among Asian American/Pacific Islander youth (Chung-Do & Goebert, 2009; Fiaui & Hishinuma, 2009; Spencer et al., 2009). The model minority stereotype may be masking issues that Asian American students have with their educational experiences in school. Thus, the potential exclusion, alienation, marginalization, and discrimination experienced by Asian American students in schools needs to be further investigated.

**“Othering” versus “belonging.”** The concept of “othering” defines “other” groups that have been traditionally marginalized in society (Borrero et al., 2012). In the context of education, “othering” happens to students of color, underrepresented minorities, and students who are perceived to be different. This concept of "othering" can be extended to any students who are not part of the norm, or do not belong to the dominant culture. The following studies report on the "othering" experiences of Asian American students, specifically through racial labeling and hierarchical power dynamics that place them inferior to their White-peers. Borrero et al. (2012) posited that school could be a place for "othering" youth. The "othering" can be practiced through specific actions or inactions by teachers, staff, and peers, in order to assert power over a certain group of students. These actions can be an overt form of racism or subtle forms of oppressive acts, such as microaggressions. In a study conducted by Borrero et al. (2012), Native Hawaiian students experienced "othering" through labeling based on racial stereotypes. When the teacher divided the classroom into the smart kids versus the dumb kids, Native Hawaiian students experienced "othering" when they were labeled as being outside the norm. In this study, the norm was defined as being White and speaking correct English, which was equated with being smart, while being Native Hawaiian and speaking the wrong English was associated with being unintelligent. Other studies report "othering" of students based on racial stereotypes. For example, in Vaught's (2012) study of the racialization of Sa'moan high school students, Samoan students were othered based on the negative stereotype that they were lazy or troublemakers. Borrero et al. (2009) reported similar findings about the "othering" of Samoan students at school. The school emphasized the notion of diversity by juxtaposing the cultural world of Samoan students against the academic world. As a result, Samoan students were alienated and marginalized.

In contrast to the notion of "othering" is the sense of belonging. Murphy and Zirkel (2015) highlighted the importance of having a sense of belonging at school, which impacts students' academic aspirations, motivation, and performance. As such, when Asian American students were subjected to negative stereotypes (i.e., viewed as perpetual foreigners), they began to question and doubt whether they belonged in their school. In this vein, Goodwin (2010) framed "othering" with respect to the model minority stereotype, which implies that Asian Americans can be the "honorary" White, as long as they maintain their high level of academic achievements. As Zhou et al. (2003) reported, their great academic "success" meant that they could not ask for help, because they were deemed to *not* need, or let alone deserve any assistance. Under the model minority stereotype, Asian American students in Goodwin's (2010) study felt that they should put their head down and continue their success story of the "American dream" against all odds. In doing so, a political wedge was driven between Asian Americans and the other minority groups. A study conducted by Zhou et al. (2003) further supported these lived experiences of Asian Americans, in which they found that Chinese American students felt that they could not ask for help from their teachers when they were not doing well in school. Instead, they depended on their own ethnic peers for help. In addition, Ryu (2013) investigated Korean immigrant students' "othered" identity, as certain practices in the science classroom limited their participation. For example, Korean immigrant students in Ryu's (2013) study did not feel confident in their English speaking ability. As a result, in a classroom where the teacher emphasized oral participation (i.e., scientific discourse), the students did not feel comfortable with participating.

As Borrero et al. (2012) pointed out, students' sense of belonging in school may positively impact their interest in learning, and the way they reflect on their cultural values and identities. Other scholars have also argued that school belonging plays an important role in promoting academic achievement in minority students (Mello, Mallett, Andretta, & Worrell, 2012). Osterman (2000) identified the elements of school belonging, which included students' sense of relatedness or connection to school or classroom membership. Also, Osterman (2000) found that school belonging predicted academic outcomes such as achievement, motivation, dropout rates, as well as positive attitudes toward school, teachers, and peers. Similarly, Faircloth and Hamm (2005) explored the relationship between motivation and academic achievement, using school belonging as a predictor, among African American and Latino students. Similarly, Sirin and Rogers-Sirin (2005) showed that school belonging positively predicted the academic performance of African American youths in school. Thus, students' sense of belonging to school influenced the way students engaged with school activities and their behaviors directly related to their academic outcomes.

This fragile and complex negotiation through the "othering" process is not unique to any one ethnic group. Murphy and Zirkel (2015) explained how a sense of belonging in school is a complex construct and is important to all students. However, the nature of belonging in school is different for students who are targeted by negative racial stereotypes such as "othering." When "othering" occurs to minority students, the impact is long lasting, as students understand that they are the victims of a hierarchical power that subjugates them, silences their voice, and perpetuates the notion of being a "forever foreigner" (Borrero et al., 2012; Murphy & Zirkel, 2015).

**Microaggressions.** Similar to othering, microaggressions are effective mechanisms that make students feel "othered." According to Chester Pierce (1974), microaggressions can be defined as follows:

> The major vehicle for racism in this country is offenses done to Blacks by Whites in this sort of gratuitous never-ending way. These offenses are microaggressions. Almost all black–white racial interactions are characterized by white put-downs,

> done in an automatic, preconscious, or unconscious fashion. These minidisasters accumulate. It is the sum total of multiple microaggressions by whites to blacks that has pervasive effect to the stability and peace of this world (p. 515).

Derald Wing Sue considered one of the preeminent scholars on microaggressions, defined the term as the "brief verbal, behavioral, or environmental indignities that communicate hostile, derogatory, denigrating, and hurtful messages to people of color (Sue & Constantine, 2007). There are various studies that report cases of microaggressions experienced by Asian American students in schools. Borrero et al. (2012) reported the shared experiences of Native Hawaiian students with microaggressions and vicarious racism. Through these experiences, Native Hawaiian students felt "othered" like an outsider. The students in the study conducted by Borrero et al. (2012) explained that these forms of racism were not overt, but were more subtle and indirect and shared incidents where they felt inadequate or inferior as a Native Hawaiian through seemingly harmless slights or insults from their teachers or peers. For example, in response to what a Native Hawaiian said in a class, a peer retorted with a comment, "such a Hawaiian" (Borrero et al., 2012, p. 14). In addition, Kohli and Solórzano (2012) provided an example that demonstrated the harmful effect of racial microaggressions in the classroom. Adult participants of different races, ethnicities, and cultures recalled their memories of when and how they experienced racial microaggressions due to their names. For example, Nitin, a South Asian man shared that his teacher announced to the class that Nitin's name was to be *Frank*, as *Nitin* was a difficult name to pronounce. Nirupama, a South Asian woman shared that her peers often teased her because of her name. In other contexts, microaggressions can be as simple as asking a student, "where are you really from?" as reported in a study conducted by Huynh (2012). These types of comments are spoken out of an underlying assumption that Asian American students are not and can never be authentic Americans; it is a subconscious perception of Asian Americans as the perpetual foreigners in this country (S. Y. Kim et al., 2011). Wing (2007) reported similar incidents of microaggressions where a teacher dismissed Vietnamese students' correction in the pronunciation of their last name, *Nguyen*. In addition, the students shared how they received comments that "[they] were supposed to be smart" or good at math, because they were Asian (Wing, 2007). Furthermore, when they excelled in school, their peers dismissed their efforts at achieving high marks in class since they were "Asian." Lastly, Tran and Lee (2014) reported the experiences of Asian American students receiving remarks such as "you speak English well," or "you speak English well for an Asian" (p. 484). What the study by Tran and Lee (2014) showed is an *exceptionalizing stereotype*, which is a specific type of racial microaggression that appears to be a compliment to an individual, but perpetuates negative stereotypical views of a racial or ethnic group. The authors had Asian American students interact with a partner who would say the racially loaded phrases and demonstrated the way in which Asian American students chose to interact with their partner. Some may argue that exceptionalizing stereotypes are positive stereotypes. This argument is not a new one, as some individuals perceive the model minority stereotype as being positive. However, there is no such thing as a positive stereotype even if the message assigns "positive" characteristics to an individual. Ascribing a stereotypic characteristic to an individual because of his or her membership in a particular racial/ethnic group, no matter how well-intended by the speaker, can be damaging and depersonalizes the individual to a mere stereotypical view of that racial/ethnic group. To this point, J. Wang et al. (2011) articulated succinctly: racial microaggressions can never be innocuous – they sting.

These empirical studies highlight how schools function as an important cultural and learning site for students to articulate, negotiate, enact as well as challenge their social, cultural, and ethnic identities (Stritikus & Nguyen, 2007). In this vein of thought, schools are a site of cultural production where notions of academic success and failure are embedded, formed, and negotiated within the values and beliefs of an assimilationist agenda that are reproduced within the classroom. Even though microaggressions are not overt acts of discrimination, the subtle form of racism that occurs in the daily school life of Asian American students is harmful. Compounded with the model minority stereotype being imposed on Asian American students, microaggressions, that is, verbal and behavioral slights that go unnoticed in the classroom, continue to reinforce the unequal power structures and create barriers in achieving equity in our schools. As harmless as these racially charged comments may appear, microaggressions can pose a great risk to the recipients when they begin to believe and internalize the message (Kohli & Solórzano, 2012). Students begin to doubt their place and cultural worth, which can adversely impact their aspirations, motivation, and self-esteem. It is important to recognize that the impact of racial microaggressions do not end once the moment of that experience is over. As demonstrated by Kohli and Solórzano (2012), the adult participants were able to recall when they experienced microaggressions due to their names; these experiences may be brushed off at the moment, but are not forgotten, and can have a profound effect on the individual's self-esteem and other self-concepts.

Empirical research on the internalized effects of racial microaggressions is challenging to conduct since thorny topics such as microaggressions, racial bias, or racism can be difficult to probe at the K-12 level with younger students. As such, incidents, or the lived experiences with microaggressions are mostly conducted at the postsecondary level (Choi, 2010; Ong, Burrow, Fuller-Rowell, Ja, & Sue, 2013; Tran, Miyake, Martinez-Morales, & Csizmadia, 2016). Also, microaggressions are not specific to Asian American students, nor are they identified uniquely through race relations. There can be microaggressions with respect to gender, ergo as a form of sexism (Barthelemy et al., 2016). In relation to race, racial microaggressions can be identified as a form of racism. One of the leading scholars studying racial microaggressions, Solórzano, together with his colleagues described microaggressions that African American students experienced on their college campuses (Solórzano, Allen, & Carroll, 2002; Solórzano, Ceja, & Yosso, 2000). Individuals who came from multiracial backgrounds were often asked the question of "what are you?" or "where are you from?" which Tran et al. (2016) referred to as "racial identification inquiries" (p. 26). This type of questioning can be perceived as noninclusive, alienating, hostile, or discriminatory, and conveys the attitude that the multiracial individual is different, a foreigner, or an outsider. Sue, Capodilupo, et al. (2007) cautioned against rationalization by the speaker that his or her intention was to express genuine interest in the other person's heritage or background. What plays a critical role in framing such inquiries within the framework of microaggressions is the historical context of racial identification in the decades before the civil rights movement in the U.S. Rooted in the mono-racial classification system known as the "one-drop rule," individuals with a traceable amount of African ancestry were forced to identify themselves as Black regardless of personal identification (Davis, 1991).

In the science education context, B. A. Brown et al. (2016) reported the pervasive impact of racial bias and microaggressions on African American college students' choice in STEM careers. At the K-12 level, Allen et al. (2013) investigated racial microaggressions and their effects on African American and Hispanic students with respect to how they were academically tracked and perceived by their teachers. Additionally, the same study showed that the major effects of microaggressions were on the health and well-being of these students in that they suffered mental health problems such as depression, anxiety, trauma and low self-esteem.

Similar results were reported in a study conducted by Huynh (2012), which investigated the effects of microaggressions on the depressive symptoms of Latino and Asian American youths.

Building on Derald Sue Wing's conceptualization of microaggressions, G. Wong, Derthick, David, Saw, and Okazaki (2013) provide a comprehensive review on racial microaggressions, but their review is not specific to the context of education, let alone science education. In order to deeply examine how these encounters affect the educational experiences of Asian American students in the K-12 classroom setting, a study that closely examines the daily behaviors and passing comments among teachers, students, and school staffs is needed.

**Stereotype threat experienced by minority students.** Closely related to the concept of microaggression is the concept of stereotype threat. Steele and Aronson's (1995) seminal work on stereotype threat has many implications in education for minority students. The assumption behind stereotype threat is that an individual, who is associated with a negative stereotype, will perform in a manner consistent with the stereotype (Stricker & Ward, 2004). Stereotypes of students of color as low achievers, and of female students as less competent in science than male students have been well documented (Hill et al., 2010; Nguyen & Ryan, 2008). Scholars refer to the stereotype threat as the "unmeasured psychological factor," which impacts the academic performance of minority students, especially students of color (David M. Quinn & Cooc, 2015, p. 344). According to Nguyen and Ryan (2008), stereotype threat affects these students such that their science test scores are negatively affected through the activation of stereotypes prior to test-taking. Furthermore, the effect of stereotype threat has been documented in science and mathematics (Maholmes, 2001; D. M. Quinn & Spencer, 2001). For example, stereotype threat has an impact on lowering students' motivation to learn science and dissuading them from pursuing a career in science due to the internalized racial biases students experience or the sense of not belonging (Hill et al., 2010). Ultimately, students' lower self-efficacy in science can further prevent them from pursuing experiences necessary to be successful in science.

The research on stereotype threat alludes to the salience of racial stereotypes on Asian American students' identities and achievement (Ngo & Lee, 2007). In a study conducted by Wing (2007), Asian students suffered from test anxiety, routinely worked long hours into the night to keep up with their school work and to maintain their high grades. None of the high achieving Asian students interviewed in the study attested that the high grades were easy to attain, but that these grades were earned with "unseen sacrifice" (p. 465). When Asian American students were considered the opposite of the model minority, they were brushed off as being "the other." For example, Pacific Islander students discussed the negative racial stereotypes associated with the notion that they were not good at school, so they felt that they should not bother trying (Borrero et al., 2012). They were persistently seen as "the other," and could not be seen or see themselves as becoming successful students at school. In either case, the stereotype threat with respect to their science and math abilities and undue pressure have shown to adversely impacting their mental health and career trajectories, as well as contribute to their experience with harassment and bullying in school (Huynh, 2012; Qin et al., 2008).

**Racial stereotypes and identity.** Similar to the arguments made about recognizing diversity within gender, heterogeneity of different racial groups should also be appreciated. Students from different ethnic groups are often lumped together into a monolithic racial category (Teranishi, 2002). For example, Blacks are often treated as a homogeneous group with respect to race relations. In education, the term "Asian American" has been defined as the categorical label that created a single panethnic representation to perpetuate the model minority stereotype (Asher, 2002). However, Teranishi (2002) found that there existed diversity with respect to ethnicity, immigration backgrounds, and social classes among Asian Pacific American youths, and thus urged scholars to not assume that a student would identify with others from the same background or culture simply because he or she is from a particular racial group. In this context, the racialization of Asian American students into a homogeneous and monolithic group who, for the most part, seems untroubled, compliant, and excels in mathematics and science camouflages the realities of their uniqueness (Asher, 2002; Teranishi, 2002). Such a broad category of "Asians" or "Asian Americans" grossly obscures the diverse ethnic subgroup populations as well as the individual differences in their academic performances.

**Focus #2: Exploration of Asian American Students' Science Learning Experiences at the Intersection of Race and Gender**

Scholars call for the need to explore in greater details the influence of the students' racial background and its complex interaction between gender, social classes and other axis of social categories, in order to better understand marginalized students' achievement, subject matter choices, interest and attitude toward science, post-compulsory participation in science, and future career decisions in science. Else-Quest, Mineo, and Higgins (2013) argued that the experience and issues of gender are not identical for African American, Asian American, Latina, and White girls. Thus, more studies need to explicitly analyze the interactions among race, gender and other variables to provide a better picture of the experiences for different populations of marginalized students (Adamuti-Trache & Sweet, 2014). The following section will present a number of studies that aim at accomplishing this goal of exploring the intersection of race and gender as they investigate the science learning experiences of marginalized students.

**Experiences with the discursive practices of science classrooms.** One of the ways to acculturate students with respect to the values, epistemic beliefs, and practices that are consistent with those of science is to provide opportunities for them to participate in the cultural practices of the science classroom. However, scholars argue that the process of acculturation can bring about potential cultural costs. For example, B. A. Brown (2004) reported that the cultural practices of high school science classrooms created cultural conflict for ethnic minority students, as they took up, maintained, avoided, or resisted the appropriation of science discourse. In B. A. Brown's (2004) study, four domains of discursive identities emerged: opposition, maintenance, incorporation and proficiency status. Opposition status avoided the use of science discourse. Maintenance status involved the maintenance of students' normative discourse behavior, despite their ability to appropriate science discourse. Incorporation status featured the active incorporation of science discourse into their normative discourse patterns. Proficiency status centered on the demonstration of fluency in applying scientific discursive. The same author, B. A. Brown (2006), investigated how students' engagement in scientific discourse could present cultural conflict for the minority students in the science classroom. Instead of dealing with gender and race as broad cultural categories, the author aimed to deeply explore the role of individual agency as students learned to adjust to the culture of science classrooms. In doing so, the study provided understanding of how individual students developed identities that were balanced with their academic, ethnic, and gender identities. As such, the focus of the investigation shifted away from the mere problem of the minority students' underperformance in science towards examining the meaning of the students' discursive behavior, which shed light on their experiences of being marginalized in science. Ryu (2013) investigated Korean immigrant students' "othered" identity, as certain discursive practices in the science classroom limited their participation. In Ryu's (2013) study, Korean immigrant students did not feel confident in their English speaking ability. As a result, in a classroom where the teacher emphasized oral participation (i.e., scientific discourse), the students did not feel comfortable with verbally participating, which alienated them in the science classroom.

**Experiences in advanced-level science classes.** The literature on high performing Asian American girls' learning experiences in advanced-level science classes is sparse. The lack of literature calls for better understanding of how Asian American students enrolled in advanced level science classes may navigate the saliently pervasive assumptions of the model minority stereotype in science classes. Ryu (2015b) interviewed Korean transnational girls enrolled in advanced placement biology classes to inquire about their reasons for taking higher-level mathematics and science courses. Ryu's (2015b) study shed light on the girls' decisions to take advanced-level science and mathematics courses and how they negotiated their positions as members of a racial minority. Even though the girls were not interested in science, taking AP biology was a decision that the students attributed to the prevalent notion that Asian students were good at these subjects. They also chose AP biology because they perceived that mathematics and science classes demanded less in terms of proficiency in English. Students often indicated that they could learn science by reading books, as opposed to learning by discussions. An earlier study conducted by Ryu (2013) on the challenges that Asian American girls faced when they participated verbally in the science class support this finding. Furthermore, the same author conducted a similar study in which she investigated the positioning and learning of newcomer Korean students in an advanced placement biology class. As the Korean students struggled to participate in the classroom discourses due to their limited English proficiency, they were positioned at a lower status and relationally positioned based on their biology achievement and their level of discursive participation (Ryu, 2015a). A study by B. Wong (2012) explored how minority girls developed their identities in ways that were consonant with the field of science. The findings of the study suggested that the discourses surrounding family, gender, and cultural expectations operated in complex ways. For example, Samantha, a student in the study, developed an identity for being smart and clever, which was supported by her available social and cultural capitals. Even though she was labeled as a nerd, she re-interpreted these remarks as recognition for her competency in science. In other words, Samantha desired to perform an identity of intelligence, as she saw the value of science for her future education and career. The case of Samantha is what concerns some scholars such as Brickhouse et al. (2000) in that girls who aspire to study and perform in school science as part of producing an identity of a good student can be problematic in the long run in terms of implications for their science trajectories over time. For instance, Sheela from the study conducted by Brickhouse et al. (2000) also performed a good science identity. Although Sheela was academically successful, she had no particular interest in school science that went "beyond participating in science class as part of being a good student" (p. 456). Simply put, her identity had no strong science-specific component to it; what was required of her in science classes simply overlapped with the social role of a good student. Therefore, Brickhouse et al. (2000) debated whether Sheela would continue in science beyond the compulsory courses.

**Marginalized girls' science learning experiences at the intersection of race and gender**

To better understand how girls from marginalized groups experience school science in the classroom, salient studies were selected for discussion in this section. Pennock (2016) examined how African American girls' lived experiences from home, school, family, church, and their identities played a role in the way they constructed and evaluated their scientific arguments. Beeton (2008) conducted a case study that explored the science identity formation of Mexican

American girls in high school chemistry, and how they conceptualized their social and educational experiences in chemistry and science.

Since this study operates under the realm of actor-network theory, ethnographic studies that explore the intersectionality of gender and race provide important insights. For example, Angela Calabrese Barton and her colleagues conducted an ethnographic study and examined how two middle school Latina girls exhibited agency through engaging in nontraditional ways of knowing in their science class (Tan & Barton, 2008). In a similar study, Tan, Barton, Kang, and O'Neill (2013) explored how non-White, middle school girls articulated their future career goals in the STEM field and negotiated their identities-in-practice in science. Informed by critical ethnography West-Olatunji et al. (2008) aimed to explore how African American middle school girls positioned themselves as mathematics and science learners, as they investigated the intersection of three topics: African American student achievement, mathematics and science education, and schooling children in poverty. The study showed that the girls demonstrated an awareness of how they felt supported or unsupported in their mathematics and science classes, meaning, students were able to articulate the privileges that were afforded to the students who attended the magnet program, but not to the mainstream students. Here, the authors argued that such awareness of “one’s own positionality and positioning in relation to others facilitates the construction of metaknowledge. When an individual is aware of his/her position, he/she is then able to challenge that position and the power structures that have created that position” (West-Olatunji et al., 2008, p. 225). To that end, the authors posited that students can increase their self-awareness if they are provided with appropriate experiences and can be positioned positively as mathematics and science learners. A study by Barton and Tan (2010) investigated the development of agency in science among low-income urban youth, as they participated in a summer project activity. The results of the study showed that as students asserted themselves as community science experts on green energy technologies, they actively challenged the types of roles and student voices that would have been typically present in the classroom.

In an ethnographic study conducted by Carlone (2003), the author demonstrated that the practices utilized in the science classroom produced dutiful science students, and caused students to perceive science as authoritative rather than a field that encourages its participants to question and investigate. Though students embraced the prototypical meanings of science and were "good" science students, they did not consider themselves as "science people," and showed no indication that they would pursue science further. In a longitudinal study conducted by Carlone et al. (2014), the three middle school students' identity work, which was mediated by race, class, and gender in school science became less scientific over time. One of these participants, an African American girl named Aaliyah, was silenced by her teacher because she did not take up the celebrated subject position in the classroom as the "good science student" (p. 853). Another study by Carlone et al. (2015) explored how larger social structures such as race, class, gender, sexuality, and classroom structures defined scientific practices in ways that constrained girls' agency to engage in science identity work.

**Part 3: School Science and Students' Science Identity**

School science is what students experience in the science classroom, which is a figured world that is constituted by both socially produced and culturally constructed activities. Gilmartin et al. (2007) argued that the science classroom is where students' science identities are realized through the "local science practice in reference to local science meanings" as well as where students develop a sense of themselves as scientific participants (p. 981). On a similar note, Markus and Nurius (1986) defined the term *possible self* as an aspect of the self-schema that represents what the self may become at a future time. Therefore, the *possible self* functions as a way to organize an individual's task-relevant thoughts and behaviors as well as link specific plans and actions to desired goals in the future (Stake, 2006). To this end, it can be argued that a student's social environment, such as the science classroom, can activate his or her possible self in science or in a science career. Science identities involve one's awareness of being a member of a group such as a figured scientific community and the "subjective value" that is ascribed to the membership (Gilmartin et al., 2007, p. 982). As such, students' self-perceptions and interest in science play an important role as mediators of their science identity and affect how students assess themselves in a given science context. For instance, Gilmartin et al. (2007) reported that students can have a strong positive science identity when they

> see science as compatible with their own values and personalities; see science practices and domains as accessible to them and relevant to their lives; want to participate and have participate- in out-of-school science activities; enjoy 'doing' science on an affective level; feel confident about their science abilities; and aspire to conduct – or express strong interest in- science-related work. These are the students who see themselves as the 'science type,' as belonging in a scientific world, a world that they value and respect and feel engaged in. (p. 982)

Shanahan and Nieswandt (2011) argued that identity studies often highlight aspects related to individual and individual agency without consideration of the dynamic interplay between structure and agency. In this vein, agency is defined as individuals' ability to "shape the world around them" as well as their everyday actions and their broader goals (Godwin & Potvin, 2017, p. 442). On a similar note, agency in science is related to feelings of empowerment in science and is intricately associated with students' science identity development. To that end, students' experiences within science classrooms have the potential to foster agency, as students become full participants in the culture of school science. Similarly, Carlone et al. (2015) point out that social structures, such as classroom structures, constrain students' agency to "engage in untroubled and sustained science identity work" (p. 474). Drawing on Judith Butler's (1990) work on gender, Carlone et al. (2015) explored ways of "doing gender" that became normative and often involved heterosexualized versions of femininity within the structures of school science. The social structure governed not only gendering, but also the choices girls made and the actions they took to position themselves in relation to normative versions of femininity in a school science setting. Other scholars explain this dynamic structure-and-agency relation in light of Pierre Bourdieu's (1977) work on structure-agency dialectic, which emphasizes the recursive loop involving actions and social structures. In other words, an individual's actions are enabled or constrained by the social structures available, which are then recreated or reinforced by the actions the individual takes. An example is a study by Olitsky (2006) where the discourse of school science limited the subject positions for the students to take up within the science classroom. Yet, students could creatively take up resources within the constrained structure to reveal tensions that existed between dominant expectations and their efforts to re-create themselves in science. Carlone et al. (2015) reported similar results in that the structures of school science narrowly defined subject positions for the girls. Tensions between girlhood and becoming scientific emerged, as girls became less engaged with how to become scientific and more concerned with becoming the type of girl acceptable in the school science setting. Situated amongst other identity studies with a focus on the relationships between structures and agency, Carlone's work continues to probe the cultural meanings of science in students' school science experiences that might impact their interest, motivation and attitude toward science. In a study conducted by Carlone et al. (2014), the authors ask challenging questions such as

> Who are students obligated to be in science? What does it mean to perform oneself scientifically? How interesting and achievable are those scientific performances for all students? Who do these celebrated performances privilege and marginalize? How do individuals perform themselves within and against these implicit norms? What resources do they draw on to construct meanings of their experiences and themselves? (p. 837)

In this particular study, normative scientific practices in the science classroom were identified: 1) epistemic practices, 2) communicative practices, and 3) investigative practices. Being a good science student was the celebrated subject position in the class, and students came to understand that being a good science student meant being able to perform these normative scientific practices. However, the celebrated subject position defined by these practices not only impoverished scientific engagement of students, but also excluded the behaviors, interests, and other forms of participation. Because school science is subject to institutional and cultural narratives of "what counts as legitimate science," there is often little room to celebrate different kinds of students' science identity work. To this end, the authors pose a challenging question, "is it possible to re-figure" a school science classroom such that "structures of race, class, and gender become increasingly salient in the social lives of adolescents and in the figured worlds of traditional schooling and school science?" (Carlone et al., 2014, p. 863).

This study differs from the majority of identity studies in science education. Operating under the assumptions of Actor-Network Theory, the researcher would not necessarily ask the question "what *are* the social structures, such as race, gender, or class, that might impact the way a school science classroom can be re-figured?" Rather, the researcher asks the question of "what *could* be the actants (such as people, objects, laws, rules, etc) that are re-assembled to allow the *capacities* of the social structures (such as race, gender, or class) to be actualized in ways that impact a students' science identity." Therefore, this study focuses on what actants are mobilized and assembled to cause the actualization and the *how*. This is a subtle but important distinction that reflects the fact that the researcher does not presuppose that these structures exist outside of the enactments of the actors.

## Gap in the Literature

This dissertation addresses various gaps in the literature. First, Scantlebury has observed that there is a dearth of studies that attempt to theorize the interaction of gender and race, as they relate to science learning in the secondary education setting. Second, a critical gap in the literature is that the majority of studies investigate the students' lived experiences (in the past) as related to gender and racial inequities in science education. Their experiences have occurred in the past, and the findings are based on the participants' reflections of their past experiences and the researcher's interpretations of these experiences. For instance, in trying to understand the experiences of successful women in science, Carlone and Johnson (2007) interviewed women of diverse racial and ethnic groups. However, the researchers eloquently highlighted a limitation in that they were not able to observe the *performance* dimension of their proposed science identity model and investigate how the women's *performances* of scientific practices may have impacted their identity. In other words, though Carlone and Johnson (2007) hoped to understand the contexts in which their research participants may take up, reject, and/or transform scientific practices in whatever setting, the answer to this question could not be obtained in the way they conducted their study. Since 2007, there are a small number of studies that are taking up the challenge of paying very close attention to the intricate aspects of marginalized students' science learning experiences and exploring the underlying meanings and issues of gender and race and its potential tension with power in K-12 science education (Haverkos, 2012). Predominantly, these studies thus far have been the work of Heidi Carlone and colleagues, or of Angela Calabrese Barton and colleagues. These are ethnographic data studies, which deeply explore the lived experiences of marginalized students in science as they develop their identities in the science classroom. Through the ethnographically informed study, the researcher aims to closely examine the *performance* of science in relation to the *performativities* of gender and race and shed light into how students' identity categories become actualized in the classroom space. With that said, the next chapter will discuss the theoretical framework of this study: Actor-network theory.

# CHAPTER 3

# THEORY AND METHODOLOGY

Chapter 3 elaborates on the tenets of actor-network theory that were introduced in the overview of Chapter 1. Actor-network theory is deeply embedded in every aspect of this study, and thus this chapter is divided into two parts: 1) theoretical framework and 2) methodological framework.

## Part 1 Theoretical Framework: Actor-Network Theory

Bruno Latour, John Law, and Michel Callon are the primary scholars of Actor-Network Theory (ANT). Stemming from the sociology of science and technology (i.e., Science and Technology Studies), ANT became a conceptual framework for exploring collective sociotechnical processes (Fenwick & Edwards, 2011b). In order to counter the heightened status of science as a way of knowing and understanding the world (i.e., scientism), ANT suggested the notion that science is a social process, just like any other social activity (Crawford, 2004). Since the 1980s, ANT has extended its influence to other fields such as organizational studies and organizational changes (Fenwick & Edwards, 2011b), sociology, geography, management, economics, anthropology, and philosophy (Cressman, 2009). In doing so, ANT has permitted social scientists and researchers to grapple with the processes which characterize socioscientific concerns, as well as contribute to the analytic approaches (i.e., ethnomethodology) and suggestions that "rupture certain central assumptions about knowledge, subjectivity, the real, and the social" (Fenwick & Edwards, 2011b, p. 1). Briefly here, ethnomethodology is an approach that focuses on "empirical social practices whereby both microstructure and macrostructure are produced by and for the membership" (Hilbert, 1990, p. 794). In this vein, ANT does not differentiate between science and technology; between society and nature; truth and falsehood; agency and structure; context and content; human and nonhuman; microlevel phenomenon and macrolevel phenomenon; or, knowledge and power (Fountain, 1999). Instead, these categories are understood as effects of collective activity, or of particular trails and translations. To this end, ANT promotes a relational materiality, which presupposes that all entities exist in relation to others. The focus of ANT's analysis is on the minute relations among entities that assemble the world. The purpose of following the details in the everyday interactions is to make visible the ongoing negotiations at the nodes of these relations that produce agency, power, identities, beliefs, and knowledge. The rupturing of foundational assumptions about the social can be done via ANT precisely because following the local (i.e., the day-to-day interactions) allows ANT scholars to focus on the particular, rather than the abstract categories of the social.

To begin, salient terms are defined in this section. According to Latour (2005), an *actor-network* is composed of multiple *actors* and *actants* that engage in relations with one another. Here, the framework allows actors and actants the ability to change back and forth. In other words, *something* can be an *actor* sometimes and an *actant* other times; the idea that an actant can become actors as well as the reverse is one of the interesting ideas for this framework. An actor-network is "not in the sense of a structure but in the sense of a chain that connects actants" (Kale-Lostuvali, 2016, p. 293). Therefore, the *actor* is the working entity, while an *actant* is the worked-upon entity such that an actor makes *things* happen in the actor-network. *Actants* can associate or dissociate with other entities, and they can enter into networked associations. The actor-network, in return, defines, names, and provides the actants with substance, action, intention, and subjectivity. From an ANT perspective, actants/actors are without *a priori* assumptions. In other words, it is through the actor-networks they associate by which the actants/actors derive their nature. According to Fountain (1999), *actant* or *actor* are:

> not an agent in the normal sociological sense; instead actor and actant are used as semiotic terms. The semiotic actors in ANT are hybrids, which create their own actor-worlds. As such, an actor is not an entity to which human intentional behaviour can be attributed, but a more abstract term, which can refer to either human or non-human entities. It is not a specific, unitary entity but, rather, the product of a more or less stable relation between various effects that together form an actor-network. An actor-network exists when there is an interrelated set of entities that have been successfully enrolled by an actor and that is thereby able to act with their support or on their behalf. (p. 344)

When the *actant* becomes acted upon to become part of the network, the *actant* then "behaves with what appears to be particular intentions, morals, even consciousness, and subjectivity", regardless of whether it is human or a non-human entity (Fenwick & Edwards, 2012, p. xii). When the *actant* has undergone this process of change (which Latour calls *translation*), and has become part of the actor-network, it begins to take on a particular role and perform in a certain way; it becomes and performs as the *actor* (Latour, 1999). *Actors* are combinations of symbolically invested *things*, identities, relations, inscriptions, and networks that are capable of nesting within other diverse networks.

In actor-network theory, *actor* and *network* are linked by the hyphen as an effort to reject the dichotomy between agency and structure, which is often an important distinction to be made in sociology as well as other disciplines. However, in ANT, such distinction is not necessary or useful. For example, macrolevel phenomena are simply networks that become more extensive and stabilized. Networks are performed by the actants out of which networks are composed. What is interesting from an ANT perspective is how networks overcome resistance, strengthen internally, stabilize, organize, and translate network elements; how networks prevent actors from becoming durable; how networks enroll others; how networks become transportable and useful; and how networks become obligatory points of passage and functionally indispensable.

Actor-network theory (ANT) is best to understand not as a theory, but more like a "sensibility" (Fenwick & Edwards, 2011b, p. 1). ANT is also considered to be a method used in examining networks and thus provides three key tenets. First, ANT abandons any *a priori* assumptions about the nature of networks, causal conditions, or the accounts of the actors/actants. All interpretations in ANT are unprivileged and impartial. Second, the notion of symmetry exists when examining humans and nonhumans. Third, ANT abandons any distinction between natural and social phenomena. These distinctions are understood as the effects of networked activities and are not causal and cannot provide explanation. To this end, central to ANT analysis is following the actor into translations.

**Grounding ANT in Science and Science Education Research**

Through the lens of ANT, science can be conceptualized as a social process. This theoretical framework enables scholars to examine various facets of the social construction of science and scientific knowledge (Richard & Bader, 2010). To account for the social character of the production of scientific knowledge, ANT problematizes the presentation of nature of science that is removed from a description of how science is done on a day-to-day basis. To this end, a seminal work by Latour and Woolgar (1979) documented how science was actually done (i.e., day-to-day actual scientific practices). In their ethnographic studies of the scientific laboratory, they were able to describe the diversity of scientific practices and the complex relationships that were involved in what Latour called the social domains of the construction of scientific facts. These social domains are represented in what Latour (2001) calls the horizons model that includes five categories: 1) mobilization of the world, 2) the *autonomization* of research, 3) alliances, 4) public representation, and 5) scientific knowledge qua *links and knots*. The detailed explanation of what each of these categories entail is beyond the scope of this study; however, the goal of the horizons model is to track the movements of association and trace the actors and their relations, thereby revealing the social character of the construction of scientific knowledge. In this context, these movements and actors can be traced particularly when one examines how both human and nonhuman actors are involved in the process of research *in the making*. Latour (2001) proposed that all actors are accounted for in an unending loop that involves: 1) peer recognition that provides opportunities to obtain 2) grants and funding that are required to purchase 3) laboratory equipment that are used to 4) produce data in order to make claims and arguments, which structure 6) articles that are published to earn 1) peer recognition, and the cycle repeats. When one examines each step of the cycle, its relations between humans and various entities are revealed, accounting for the social aspect of how scientific knowledge is constructed (Richard & Bader, 2010). Drawing close attention to the processes at work in the social construction of science became critical in pushing back against certain reifications of the usual conception of science as a distinct, monolithic entity, which does not account for the dynamic interplay of relations and negotiations in producing scientific knowledge as well as its complex nature (Richard & Bader, 2010). In the context of science education, articulating these social processes that are central to the construction of scientific knowledge enrich science-education-related discourses as well as school practices. As such, some would argue that these aspects in the social domains of science and scientific knowledge should be accounted for in science classrooms. Here, this is not to say that in the science classrooms, students should do science the way it actually is done. Instead, Richard and Bader (2010) argue that the goal is to cultivate among students "not only an interest for scientific research and its dynamic character" but also a critical attitude and an engaged understanding of current scientific knowledge as a social process in the making (p. 747).

So, what would socialized representation of science look like in the science classrooms in the specific context of this study? To begin is to address one of the criticisms of science studies that aim to examine sociocultural issues in science education. For instance, DeLanda argues that the content of science should be foregrounded as methodological choice, instead of foregrounding the social context in science studies (DeLanda, personal communication, February 27, 2018). Providing a full literature review on this particular argument is beyond the scope of this study. However, there are scholars ranging from critical theorists to feminist scholars who would avidly argue that foregrounding sociocultural contexts is important in science education. Grounding this sociocultural argument in ANT is to return to Latour's argument that there is no separation, any more, between science, technology, and the rest of the world – just *relations*. In this context, the researcher of this study argues that *school* science is different from *science*; therefore, students' experience with science is *situated* in the cultural practices and norms of *school science* in the science classroom. For example, a gendered dress code can be enforced in science classes such that girls' clothes versus boys' clothes can exemplify a culture of science that may exclude one group of students, thereby creating a culture of otherness. Generally, girls' clothes such as tank tops, long hair, and skirts are used as an example of what is not appropriate within a laboratory setting. Thus, conversations can be had in science classes to generate a gendered idea of the appropriate garments for a science lab. This idea then can extend to establishing a pattern of practices and norms that are now projected onto the perception of science. In this vein, an argument can then be made that these cultural practices are shaped and impacted by the situated nature of actions, interactions, social relations etc. which are shaped by who students are and can be in science classes. This is where identity categories such as gender and race matters in science education: so to examine what actors are involved, what assemblages are formed, stabilized, or de-stabilized, and what relations emerge to better understand how students' experience with school science may or may not be impacted by their *identities* in the science classrooms. With that said, the following section elaborates further on the three tenets previously mentioned.

**Overview of The Tenets of ANT and Connections to This Study**

The three tenets of ANT are summarized as follows: 1) the actors in an actor-network should not be understood using preexisting assumptions (i.e., *a priori* definition of certain constructs such as identity, knowledge, and etc.), but by their performance in, by and through the relations with other entities in the actor-network, 2) ANT assumes that humans are not treated any differently from nonhumans, and 3) a good ANT study demonstrates the evidence of change in the state of the *actants*, by the process of *translation* (Latour, 2005). The researcher of this study synthesized salient points about ANT that matter to this study and highlighted how those points guided the researcher as the study was conducted.

**No *a priori* assumptions: Only through performances.** From an ANT perspective, actors are considered foundationally indeterminate with no *a priori* assumptions. A researcher doing an ANT analysis, therefore, should not come into an ANT study with an *a priori* definition of constructs that social scientists often look for, such as identity, knowledge, subjectivity, etc. Because ANT focuses on the socio-material aspect of how minute relations among the actors (both humans and non-humans) create their world (Fenwick & Edwards, 2011b), ANT scholars understand the actors, as they are “performed in, by, and through” the relations that are formed among the actors and other entities (Law & Hassard, 1999, p. 5). An ANT researcher would then focus his/her analysis on tracing how both humans and non-human objects participate in these processes such as becoming assembled, associating with one another, exercising force/power, and persisting or declining to sustain the actor-network. Thus, by participating or performing in these processes, the actors come into *being* in the actor-network, and only when the actors perform in the network can a researcher understand them through the tracing of these relations. When an ANT researcher *traces* the relations and links that actors make with other entities, he/she can reveal the nature of controversy and concerns. In the simplest terms, nothing in ANT is given; *things* and entities do not assume the *a priori* definitions such as “the human,” “the social,” “subjectivity,” “mind,” “the local,” or “the global” (Fenwick & Edwards, 2011b, p. 2) because nothing in ANT can exist prior to its performance or enactment into these relations with other entities (Colston & Ivey, 2015).

From an ANT perspective, *a priori* binaries of social theory are problematic. Therefore, ANT opposes assumed foundational distinctions such as the social vs. natural, the material vs. cultural, and the global vs. the local. These are taken to be *effects* of the webs of relations within the actor-network (Latour, 1996). Law (2009) described ANT as follows:

> Actor network theory is a disparate family of material-semiotic tools, sensibilities, and methods of analysis that treat everything in the social and natural worlds as a continuously generated effect of the webs of relations within which they are located. It assumes that nothing has reality or form

> outside the enactment of those relations. Its studies explore and characterize the webs and the practices that carry them. (p.141)

Everything in the social is not treated as an outcome of human intent, but rather it is treated as an effect of the mobilization of the actor-network and an assemblage of heterogeneous material relations among the entities. ANT, therefore, describes the social as an assemblage with “an infinite scale of interconnections that support, through their relations, the meaning of our world” (Beech & Artopoulos, 2016, p. 262).

In education, there are many dichotomies such as teacher versus students, and formal education versus informal education that are usually taken up with *a priori* distinctions. For example, a classroom teacher is an effect of the “timetable that places her in a particular room with particular students, in a class” among “textbooks, class plans and bulletin boards and stacks of grade papers with which she interacts, teaching ideas and readings she has accumulated in particular relationships that have emerged” with the particular year’s class of students (Fenwick & Edwards, 2011b, p. 7). The classroom teacher becomes a “knowing location” that is produced through “the laboratory, with its electricity points, water and gas lines. The Bunsen burners and flasks set up by the technicians, who have also ordered and prepared the necessary chemicals according to the requisition sheet, the textbooks and worksheets that the students are using. Mobilized also are the teacher’s experience and education” (Fenwick & Edwards, 2011b, p. 7). If we were to consider how we could conceptualize the classroom teacher’s agency and subjectivity, the important question is not concerning ourselves with where the teacher’s agency is located or what kind of agency is human or nonhuman; rather, we should consider the nature of action and the conditions under which the teacher’s agency is distributed, assembled, maintained, and stabilized. From this perspective, all objects, persons, knowledge, agency, power, and identity are relational *effects*.

Latour cautioned us that concepts like gender, race, power, and inequality have become reified within sociology (Latour, 2005; Quinlan, 2012), and that these terms are over-utilized to explain away the realities that sociologists should be observing in detail (Quinlan, 2012). Thus, the goal of conducting an ANT study is to provide description of how these concepts come into *being* through the performativity of the actors within the actor-network. Here, the researcher has emphasized previously that she does not claim to come into this study as a blank slate. She conceptualized and designed this study with two *entry points*: gender and race. However, operating under actor-network theory, and later enacting it as a method, what is important is that the researcher does not assume the relational effects of gender and race and remains open to what those relational effects of gender and race *could be*, instead of what they *are*.

**Symmetry: Humans and nonhumans.** In Latour's (1993) critique of modern science, he posited that the dichotomy between human and nonhuman produces a false separation between nature, object, and human activity. To this end, ANT analysis assumes that humans are not treated any differently from nonhumans. This assumption is described as *symmetry*. According to Latour (2005), "to be symmetric, for us, simply means *not* to impose *a priori* some spurious *asymmetry* among human intentional action and a material world of causal relations" (p. 76). Everyday things, objects, entities and parts of those things can exert force onto other entities, and become assembled into the network together in which they can change and be changed by one another (Fenwick & Edwards, 2011b). The notion of symmetry would equally apply agency to a sitting rock as it would be applied to a human in the actor-network. This idea of agency is different from the traditional definition of agency that comes from *intentionality*, which is often ascribed to be a human characteristic.  Simply put, agency in ANT is decoupled from *intentionality.* In doing so, the question of agency is not necessarily the question of *who* is acting, but more so of *what* is acting and "what action consists of" (Latour, 2005, p. 70). These uncertainties pertaining to *what is acting* and *what action is* begin to pluralize the notion of agency. Intentional action is one type of action, but it is not the only type of action. All other forms of agency are included from an ANT perspective. For instance, agency is something "more" than just causal (Latour, 2005):

> There might exist many metaphysical shades between full causality and sheer inexistence: things might authorize, allow, afford, encourage, permit, suggest, influence, block, render possible, forbid, and so on. (p. 72).

Full causality denotes being the source of an action, while inexistence denotes being inert or without influence. Latour (2005) argued that anything that has power to do would have agency. In this sense, nonhumans will never have inertia or agency "*by themselves*, if only because they are *never* by themselves" (Sayes, 2014, p. 144). Here, it is important to understand and recognize that, while ANT asserts that nonhumans may have agency, they do not have the same type or intensity of agency, as each other, or as humans. However, as participants in chains of events, nonhuman actors help modify states of affairs, and help shape outcomes and influence actions. Once again, ANT does not abandon all distinctions between humans and nonhumans. Callon and Latour (1992) emphasized that ANT does not deny the differences between nonhumans and humans, but simply "refuses to consider them *a priori* and to hierarchize them once and for all" (p. 356). Thus, ANT scholars are urged not to pre-determine what these distinctions are prior to analysis or based on foundational assumptions.

ANT's conception of symmetry states that human and nonhuman entities should not be distinguished based on foundational features, but rather they should be distinguished based on the differences that are created based on their collective performances in the actor-network. Fenwick and Edwards (2011a) further elaborated:

> The point is not to indulge in "symmetrical absurdity," pretending to banish human meanings, subjectivities, desires, values, and so forth from the process and representations of analysis. The point is, rather, to insist upon recognizing important influences in ….assemblages emanating from nature, technology, objects, and all manner of quarks, which may overlap and infuse what is human. (p.720)

In the context of science, ANT problematizes the objectification of nature, which denies the relation between the natural world and the sociality of objects as well as the objects' role in the discourse and practice of science. As Latour (1993) states:

> Yet the human, as we now understand, cannot be grasped and saved unless that other part of itself, the share of things, is restored to it. So long as humanism is constructed through contrast with the object that has been abandoned to epistemology, neither the human nor the nonhuman can be understood. (p. 136)

For example, in his book *Science in Action*, Latour (1987) flattened agency to the extent to which all entities, including physical objects in the actor-network, had agency and the potential to become network members. In this sense, the science laboratory exemplifies "hybrid networks constituted of both human and nonhuman actors," which are involved in "a process of mutual agency" and "codetermines social environments and ways of communicating through networks of standardized practices" (Clayton Pierce, 2015, p. 89). To this end, he calls for the need to trace and give detailed descriptions of the associations between objects, humans, and other entities, as he deftly responds to the epistemological mode of modern science that draws a separation among nature, object, and human activity.

To elaborate on the notion of symmetry, the researcher focused on what nonhumans *could* mean in ANT. According to Callon and Latour (1981), nonhumans are necessary stabilizers of the human collective, as their capacities last longer than the interactions that formed them. In *Science in Action*, Latour (1987) focuses on how scientists decide on what a scientific object is. For example, an enzyme is now a well-known object in science. However, when the term first emerged, enzyme was a list of written answers that scientists observed in experimental trials. Scientists observed what this scientific object did in experimental conditions and offered ideas of what it could be until it gradually became a "*thing*" that the scientific community agreed to refer to as an enzyme (Latour, 1987, p. 92). To this end, objects not only have a relative existence which is established through scientific work, but also have agency in such a way that scientists try to "*enroll* yet-to-be-defined scientific objects to behave as their hypotheses predict" (Kale-Lostuvali, 2016, p. 283). However, Latour acknowledges that these objectives may or may not behave according to predictions, and thus, may or may not validate scientific claims; this is what Latour refers to as nonhumans having agency.

Nonhuman actors were often dealt as placeholders or as entities that merely relay force or transport action from elsewhere to a specific direction in the actor-network. Nonhumans stood in place for more meaningful actors and were treated as "an effect of stable arrays of relations" (Law, 2002, p. 91). Here is where the distinctions between intermediaries and mediators are made and become important. An intermediary acts a placeholder, while a mediator does something more than just act as a placeholder. Therefore, treating nonhumans as mediators would mean that nonhumans add something to a chain of interactions or associations. In this sense, nonhuman actors no longer just stand in as simple substitutes for human actors: nonhumans, as mediators, help modify relations between the actors.

Central to ANT is the notion of associations. In order to understand nonhuman actors in the actor-network, it is useful to conceive of them as gatherings. According to Sayes (2014), an actor-network is

> the assembling together of a network of actors of variable ontologies, of variable times, and of variable spaces. Any actor – which, of course, includes nonhuman actors – is seen as necessarily a part of a more or less structured network. In turn, this is possible only after time itself has been structured or folded accordingly. (p. 140)

The concept of *the fold* or *folding* in Latour's work denotes "a type of acting that produces socio-technical relations, through the connecting (in a network-relational sense) of one place and time with another that it would otherwise not have been connected to" (Latour, 2002, p. 251). For example, any technology, or socio-technical hybrid can be conceived of as accumulations of folds. In *Morality and Technology*, Latour (2002) elaborates on this point when he provides an example in which machines activate a "garland of time" and his assertion is applicable not only to machines but also to a more general category of nonhumans (p. 248). Nonhumans have the potential to gather or assemble other actors and in doing so provide the "relative solidity of human associations" (Sayes, 2014, p. 140). Latour (2004) elaborates on this point:

> It is when power is exerted through things that don't sleep and associations that don't break down that it can last longer and expand further – and for this, of course, links made of another social contract are required. (p. 225)

In this sense, it is not only time that is gathered by nonhumans, but also other actors in constant interaction and association. To this end, nonhumans allow an actor that is no longer present to exert power and influence through interaction, which is shared with variable actors, and of variable ontologies, times, spaces, as well as durability. Thus, nonhumans are gatherings; they act as a gathering with other actors (Sayes, 2014).

In ANT, heterogeneous entities become assembled to perform particular practices and processes. Along the same vein, the researcher can start to think about an educational setting through the conception of socio-material symmetry and consider how certain practices, norms, and processes become assembled in the science classroom. Nonhuman entities such as laboratory equipment, laboratory tables, laptops, textbooks, bulletin/newsletters on the walls of the classroom, and lecture slides may become assembled to produce a relational effect as well as shape the interactions with other entities or actors.

**Translation and inscription.** Actor-network theory is sometimes described as the sociology of translation, which is a process by which actors are understood as a consequence of their relations to other entities and are performed in, by, and through those relations. Therefore, a good ANT study demonstrates the evidence of change in the state of the *actants*, by way of *translation* (Latour, 2005). Nothing is given in an ANT analysis; ANT refuses *a priori* definitions on any type of representation on social groupings, and Latour (2005) suggests that

> social aggregates are not the object of an *ostensive* definition – like mugs and cats and chairs that can be pointed at by the index finger – but only of a *performative* definition. Groups are not settled and static but are rather sustained through group-making efforts: If you stop making and remaking groups, you stop having groups. (pp. 34-35, original italics)

Briefly, an important clarification on this point is that the researcher is not without *any* prior assumptions. She has ideas that she calls *entry points*. However, operating under the framework of ANT, she aims to explore how entities come into *being* or existence by their "*performative*" definition (Latour, 2005, p. 34). In the actor-network their performances leave data, a trail, or a *trace*, which the researcher can follow. Because ANT permits the researcher to focus on not what the entities/objects mean, but rather on what they do/perform, the researcher can then trace and deeply explore the connections between human and nonhuman entities in a network in order to better understand how they form an "identifiable entity, or assemblage" (Fenwick & Edwards, 2011b, p. 3). When an ANT researcher *traces* the relations and links that actors make with other entities, she may reveal the nature of controversy and concerns. As stated earlier, actants and actors can transform into one another (i.e., actants to actors and vice versa). The ability of actants and actors to change back and forth makes it interesting to examine the *nodes* at which controversies or concerns may occur. In the context of this study, underlying issues of power, or tensions around issues of gender and race can be conceptualized as being *relations,* instead of thinking about them as fixed and stable entities.

*Translation* happens when actors assemble, connect, and have an effect on one another through their relations. As one entity works upon another to *translate*, modify, change, or transform, the entities become part of the network. In other words, the process by which an actor *enrolls* other entities is referred to as the process of *translation* (Fountain, 1999). Upon tracing these links and connections among the actors, the researcher may find, at the points of these connections, the negotiations, connections, persuasion, force, mechanical logic, seduction, resistance, pretense, and subterfuge that may sustain or disturb the network (Fenwick & Edwards, 2011b). Given that ANT is an action-oriented perspective, these points of connections and negotiations are referred to as the *nodes of action*, or social spaces, where power is enacted and performed. As actors undergo a plethora of negotiations through the process of translation, they continue to produce effects of their interactions with other entities, concurrently acting upon each other (Latour, 2005), making such interactions and relationships dynamic. Harman (2007) argues that this is one of the critical contributions of ANT in that it allows the researcher to trace exactly how entities come into *being* in the network, which can eventually become either stabilized or de-stabilized.

As an *ant* researcher explores how such social aggregates (i.e., *gender, race, power*) are constructed, as well as destroyed, she can reveal the nature of disputes, concerns, controversies, and negotiations that occur. Most importantly, *translation* describes a relation that does not necessarily denote causality, but instead "induces two mediators into coexisting" and generates "traceable associations" among the actors (Latour, 2005, p. 108). Latour makes this argument in an effort to problematize the philosophy of causality and social explanations in social sciences. This point becomes important as ANT pushes the researcher of this study to not only re-think what gender and race could be, but also cautions against making hasty causal statements regarding students' identity and their science learning experiences. In other words, the researcher is challenged and pushed to focus on exploring a possibility space over deterministic conclusions.

There are four moments of translation in the establishment of an actor-network: 1) *problematisation*, 2) *interessement*, 3) *enrolment*, and 4) *mobilisation*. These terms are spelled as they were originally coined by Callon (1986). *Problematisation* involves determining which subjectivities and interests are allowed in a specific actor-network. During problematisation, *something* tries to establish itself as an "obligatory passage point" that frames an idea, intermediary or problem, such that this step functions as a gatekeeper as to what should be included or excluded in the actor-network (Fenwick & Edwards, 2011b, p. 5). *Interessement* defines the practices through which barriers are built between what is and what is not part of the network. According to Nespor (1994), these can be material barriers, material organizations of space and time that restrict contact with outsiders, discursive barriers, taste, style, and language. Simply put, *interessement* is where actors are enticed away from other networks and other interests are excluded. *Enrolment* is what assembles alliances within the actor-network. This is where the actors in a given network accept their particular role. *Mobilisations* are the practices and processes through which the established actor-network becomes stabilized, manageable and mobile. However, the stabilization of the actor-network is temporary because the process of *translation* is always insecure and is susceptible to failure (Edwards, 2011).

When an actant becomes translated and a performing part of the actor-network, the actant begins to behave with particular intentions, morals, consciousness, and subjectivity (Fenwick & Edwards, 2011b). This is when translation has succeeded and the actant that was being worked on is mobilized to assume a role and perform in a particular way; it becomes a performing actor. For a while, the dynamic attempts by actors to translate other entities become stabilized and the actor-network starts to settle into a stable process and maintains itself. This is what Latour calls a black box. A black box appears immutable, inevitable and conceals all the processes of negotiation that brought it into existence in the first place. For example, in education, a black box would be a mandated list of teaching competencies, or an evidence-based practice that is accepted as the "gold standard" (Fenwick & Edwards, 2011b, p. 5). The gold standard becomes a seamless whole and the heterogeneous entities that were assembled to produce the network become obscured. However, continuous effort is required to maintain the establishment of an actor-network and the actor-network is not stable for long. Black boxes begin to open up and show the complex chains of actor-networks when controversies and struggles are examined. In the context of science, a D2 dopamine receptor is a taken-for-granted black box for scientists (Fountain, 1999). This scientific knowledge is unproblematic, does not need an explanation, and allows scientists to hypothesize causal relations between genetics and behaviors. All the social relations, new associations, different space and time, and actions of other entities have been reworked and folded into this enzyme. However, opponents to this cause-and-effect linkage may require that the black box – the D2 dopamine receptor - be opened up and examined for its validity. Opening the black box is the act of *unfolding* so that the black box can be re-described in detail. Latour (1999) therefore asserts that re-description may be difficult, but it is possible in principle. In the context of this study, the re-description of *things*, especially social constructs like gender and race, is challenging. Gender and race appear to be *immutable* entities in the sense that social relations, associations, and *folding* of space, time, and actions of other entities that were assembled to produce them are no longer visible. However, gender and race are relational, and efforts made by actors to negotiate these relations can be examined to *re*-describe them.

Science can be understood as a network of heterogeneous elements that were actualized within a set of practices in such a way that materials, actors, and texts are translated into *inscriptions,* which then allow influence at a distance as networks become more extensive. From an ANT perspective, the appropriate method for examining science is to follow and describe what scientists actually do. In *Science in Action*, Latour (1987) follows what scientists and engineers do in the laboratory. What also becomes interesting is to analyze how scientists manage to enroll other actors to extend the actor-network that they create within the laboratory and beyond the laboratory. According to Fountain (1999), *inscriptions* are:

> Literary and/or visual forms ascribed to information. They can include graphs, numbers, tables, resonance imaging, photographs, diagrams, etc. They are usually produced in a laboratory and become a kind of 'visual evidence' in publications. They become evidence of phenomena most non-scientists will never witness. However, in a reflexive turn, the phenomena are themselves constituted by the inscriptions. For example, most of us will never see a 'gene' but we respond to the terms 'chromosome *Xq28*' as a representative sequence therein. The gene is constituted by this literary term and by accompanying visuals of DNA sequences. (P. 346)

Fountain (1999) also defines *immutable mobiles* as:

> Objects which are mobile but do not change their form when moved. Such objects are mobile, immutable, readable, and can be combined with one another in texts. These characteristics enable the inscriptions produced in the laboratory to have effects on networks at great distances from the laboratory. While the objects in the laboratory, or the scientists themselves, can move beyond the laboratory in only a limited fashion, the immutable mobiles and the texts of which they form a part become parts of far greater networks, and hence have far greater importance. (p. 346).

For example, we would not expect viruses to venture outside the lab, or even out of the test tubes. However, the records and graphs in which the viruses are inscribed do leave the lab.

Extending this notion, Latour argues that science is intricately involved with power. Here, Latour (1990) asserts that the few dominates the many:

> Instead of using large-scale entities to explain science and technology as most sociologists of science do, we should start from the inscriptions and their mobilization and see how they help small entities to become large ones. In this shift from one research programme to another 'science and technology' will cease to be the mysterious cognitive object to be explained by the social world. It will become one of the main sources of power. To take the existence of macro-actors for granted without studying the material that makes then 'macro' is to make both science and society mysterious. To take the fabrication of various scales as our main centre of interest is to place the practical means of achieving power on a firm foundation. (pp. 56-57)

The chain of inscriptions and "cascades of files" become the means by which a few actors can exert power and effect millions of others because they can be circulated intact, as immutable mobiles, in larger actor-networks.

In the context of education, the role of inscriptions in an educational actor-network in the construction of knowledge and practices can be examined through the study of grade and grading practices. For example, Roth and McGinn (1998) showed how grades and grading practices, one type of inscription, generated knowledge and power that brought about the stabilization of an educational actor-network. It was in the best interest of the students to *enroll* into the educational actor-network by learning to do well and to study in order to earn high grades. Students were constructed by means of grades. In order to translate students into grades, tests and examinations were used, isolating students from contexts and relationships in which they typically function. To that end, exams became the technologies of inscription. Through exams, knowledge was not only tested but produced: the new knowledge was inscribed in students' records. Grades stabilized educational actor-networks because the interests of some actors were translated into the interests of others such as teachers and universities, through *interessement*. Teachers understood that their job was to prepare their students for postsecondary studies. In order to do so, teaching covered the mandated subject matter in order to equip students to take exams and be successful. When students' grades arrive in the admissions offices of colleges and universities, the negotiations, influences and complexities of producing inscriptions (i.e. grades) as well as those that participated in the process are obscured and "DELETEd. Once these records pass into another discourse community, the voices and work of those contributing to the dossier have been DELETEd" (Roth & McGinn, 1998, p. 413). *Inscriptions* can function as boundary objects, which denote "relatively stable *things*, people, projects, texts, places, maps, and ideas that are part of and mediate between heterogeneous practices, actors, communities of practice, and social worlds" (Roth & McGinn, 1998, p. 403). Grades, as one of the most important boundary objects in schooling, can be used to measure science teachers' competencies, and thereby constitute discourses of accountability, discipline, and punishment. Grades can also function to define relationships between teachers and students. Accordingly, actors accrue power if they become the gatekeepers at obligatory passage points for other actors. What this means is that grades define particular power relationships between the teachers who hold and distribute grades and students who want to earn the highest possible grades. In relation to the students, teachers are in the position of power. Obligatory passage points would be science classes that are required for students to take, and in which they must be successful by means of earning high grades to gain admission to universities. Teachers who teach science courses would become the gatekeepers with power.

An actor-network can be stabilized but building and maintaining actor-networks depends on the actors who may enroll or resist the actor-network. Actors can resist enrollment. On the other hand, actor-networks can be stabilized by institutional arrangements that make resistance and reforms impossible (Roth & McGinn, 1998). Boundary objects play an important role in holding actor-networks together. If those boundary objects were removed, then an actor-network would de-stabilize. For example, if grades and grading practices were eliminated from the educational actor-network, they could no longer be used to construct or reduce students to a single grade. This, in turn, would make it far easier for students to resist the actor-network, which would destabilize the network. However, grading practices are deeply engrained in the educational actor-networks, allowing their stabilizing tendencies to continue to exist. As boundary objects are passed through actor-networks, they transport conventions, standards, and norms that are indexed to a community of practice. For example, in science, a boundary object can be a scientific theory or a standardized set of technologies (Fujimura, 1992). A boundary object can pass on *some* narratives about the production of science and its practices; it functions or acts to police the actor-network. Here, boundary objects can be artifacts, objects, or concepts; they can be abstract and concrete; general and specific, etc. Therefore, as boundary objects are transmitted through networks, they become increasingly reified because they presuppose "the existence of a minimal structure of knowledge which is recognized by the members of the different social worlds" (Trompette & Vinck, 2009, p. 8). Similar to the prior example of grade and grading practices, the researcher of this study argues that these boundary objects could be the standardized tests, the data resulting from these tests, the type of categorization of students, and coordination of *some* knowledge which is then subsequently distributed. In the context of this study, the researcher considered questions such as: what boundary objects can be passed through the actor-network of science classrooms in a manner that creates expectations for someone's race or gender and thus reify these social concepts? In other words, what boundary objects are used to ascribe some narratives about gender and race in the science classrooms?

In summary, ANT provides a framework for understanding how actors may enroll, drop out, or mobilize other entities in the actor-networks. The process of *enrolment* is key in creating and establishing actor-networks, as actants/actors enroll other entities into a network of aligned interest and a common goal (Johannesen, 2013). In this way, an actor-network becomes the object of *negotiation* and renegotiation, as it frequently changes: it is fluid, never static, and always dynamic. To this end, an ANT analysis pays close attention to the formation of networks of aligned interests with respect to how gender- and race- identity categories are navigated by students in the science classrooms. Concepts such as boundary objects, immutable mobiles, inscriptions, and obligatory passage points may or may not show up in the classroom interactions. Nonetheless, the three tenets summarized in this section helped the researcher not only form but also answer her research questions as well as guide her in regard to what she could and should be observing and looking for in the classroom observations.

**Other Important Philosophical Assumptions: Borrowing Ideas from Assemblage Theory**

Gilles Deleuze and Félix Guattari (1987) theorized the concept of *assemblage* in their book, *A Thousand Plateaus*. Actor-network theory shares similarities with philosophical *assemblage* thinking that is useful for this dissertation work in terms of understanding gender- and race- categories of students' identity in the science classroom. Recently, DeLanda (2016) streamlined the underpinning assumptions of *assemblage* thinking in his book, *Assemblage*

*Theory*. In this section, three ideas central to DeLanda's (2016) assemblage theory are discussed to enhance understanding of actors in actor-networks.

**Assemblages, properties and capacities.** First, assemblages are *relational* and *heterogeneous*. According to DeLanda (2016), *assemblage* (*agencement* in French) denotes multiple, heterogeneous parts linked together to form a whole. Therefore, there are no pre-determined hierarchies, and all entities, both humans and nonhumans, have the same ontological status to begin: this is similar to the notion of *symmetry* in ANT or Deleuze's *flat ontology*.

Second, assemblages are *productive* and *dynamic* through the process of *territorialisation, deterritorialisation* and *reterritorialisation*. These processes are similar to the four moments in *translation* where assemblages are established, held together, but also are changed, transformed, and de-stabilized. They produce new territorial organizations, new behaviors, new actors, and new realities.

Third, assemblage theory asserts that people, objects, and entities have autonomy from the relations and associations between them. To elaborate on this point, DeLanda (2016) describes how the *properties* of the component parts can never explain the relations that make up the combined whole, the concept of *exteriority*. The concept of *exteriority* focuses on the component parts of an assemblage and their intrinsic qualities that are outside the associations, which in turn, have an impact on and shape the assemblage. At first, the concept of *exteriority* can be conceived of as being in opposition to ANT's notion that "there is nothing outside of associations," or enactments, or performances (Müller & Schurr, 2016, p. 30). However, true to the notion that *assemblages* are *relational*, assemblage theory posits that an open-ended set of *capacities*, which exceed the *properties* of the component parts, emerge from the relations among the parts. In other words, *capacities* emerge from the associations and interactions of the parts that make up the assemblage. DeLanda (2006) defines *properties* as "given and may be denumerable as a closed list," while *capacities* are not given and "may go unexercised if no entity suitable for interaction is around – and form a potentially open list" (p. 10). Therefore, *properties* are what traditional qualitative researchers typically look for, as *properties* are descriptions that can be examined. *Capacities* cannot be seen or examined as simply as *properties*. Simply put, *capacities* are the potential a component has based on its properties. A simpler example demonstrates that a blade's property is sharpness, while the blade's capacity is to cut, which does not become actualized until the action of cutting occurs. As such, a *capacity* is fulfilled when it becomes actualized and is determined when the individual components interact. For example, DeLanda (2016) elaborates on the example of the human-horse-stirrup war assemblage. Each of the components has its own properties but together, the human-horse-stirrup assemblage extends the fighting *capacity*. In other words, *properties* define the identity of an assemblage's component, while *capacities* of an assemblage have the potential to affect and be affected (DeLanda, 2009).

**How the concepts from assemblage theory interact with actor-network theory**

In actor-network theory, the goal is to unmask black-boxing of social concepts such as gender and race and reveal the processes that assemble, stabilize, and/or destabilize actor-networks as well as help define relationships between the different actors. From an ANT perspective, the researcher should trace mediators or intermediaries to achieve this goal. In order to conduct this study in terms of knowing what to observe and look for, the concepts of *properties* and *capacities* from assemblage theory were more useful (empirically speaking) to the researcher than the concepts of mediators and intermediaries. For example, *properties* of steel can include formability, durability, thermal conductivity, and resistance to corrosion – a closed list that describes steel as a type of metal. *Capacities* of steel can be that if made into a knife, it can not only cut, chop, and slice, but also stab if used as a weapon – an open list of new possibilities. Therefore, making the distinction between *properties* and *capacities* of gender and race parallel the question of what gender and race are vs. what gender and race can be, and guides the researcher to push back against any preexisting deterministic conclusions.

The analytical method of Actor-Network Theory, as the sociology of associations, aspires to *reassemble* the social, by following the connections and the associations among the entities that make up the social. In doing so, ANT addresses the heterogeneous actors (both humans and nonhumans), as they construct and reconstruct material and semiotic forms of sociality (Müller, 2015). To this end, the concepts, especially about *properties* and *capacities*, are important in this dissertation work because the researcher of this study posits that actors can be understood through their relations with other entities in the actor-network, and therefore gender and race can be examined as effects of those relations that arise. Thus, revisiting the purpose of this study, the following research question is asked:

- How do the capacities of gender and race become actualized in a high school biology classroom?

To observe the ways in which actor-networks are assembled, ANT offers both a concrete theoretical, conceptual, and methodological approach. Therefore, coupled with the three ideas from Assemblage Theory, ANT wields powerful applications for empirically grounding this study. In the words of Latour (2005), ANT analysis is "trail-sniffing" to wherever tracing associations may lead the researcher (p.9). The next section (part 2) of this chapter describes the methodological framing of this study.

**Part 2 Methodological Framework: Actor-Network Theory as a New Empirical Inquiry**

*"The new cannot be described, having not yet arrived" (Massumi, 2010, p. 3).*

This study is an ethnographically informed study whose theoretical and methodological frameworks are guided by actor-network theory (ANT). Generally, ANT scholars employ ethnomethodology as an approach to focus on the "local" and on the empirical social practices (Hilbert, 1990). For instance, in their ethnographic studies of scientific laboratory, Latour and Woolgar (1979) proposed to document actual scientific practices in order to describe the diversity of practices and the complex relationships involved in the construction of scientific facts. To this end, Latour was able to gain insight into science through direct observation of those working in a scientific laboratory, as opposed to considering science as a distinct, monolithic entity. From an ANT perspective, examining the day-to-day interactions at the local, minute level is central to avoiding reifications of the social, and thus, Latour argues that the local is all that matters. To be able to answer the research question as well as remain open to how gender and race could be actualized, the tenets of ANT continue to guide the researcher as the methodological framework.

Latour (2005) urged scholars to follow the actor by tracing multiple associations in the actor-networks, rather than theoretically interpreting solely human actions. To that end, actor-network theory is a sociology of associations that pushes scholars to shift the focus from society to collectives of both humans and nonhumans. True to the assumptions of ANT, the way in which an ANT researcher conducts an ANT study changes as well. Latour (2005) said:

> So, network is an expression to check how much energy, movement, and specificity our own reports are able to capture. Network is a concept, not a thing out there. It is a tool to help describe something, not what is being described. It

> has the same relationship with the topic at hand as a perspective grid to a traditional single point perspective painting: drawn first, the lines might allow one to project a three- dimensional object onto a flat piece of linen; but they are not what is to be painted, only what has allowed the painter to give the impression of depth before they are erased. In the same way, a network is not what is represented in the text, but what readies the text to take the relay of actors as mediators. The consequence is that you can provide an actor-network account of topics which have in no way the shape of a network—a symphony, a piece of legislation, a rock from the moon, an engraving. Conversely, you may well write about technical networks—television, e-mails, satellites, salesforce—without at any point providing an actor-network account. (p. 131)

Here, Latour helped scholars differentiate between the network that is drawn by the description and the network that is used to make the description. Latour (2005) further provided an analogy to clarify the point that drawing *with* a pencil is not the same thing as drawing the *shape* of a pencil and cautions researchers not to confuse the *object* of the description with the *method* (p. 142). Simply put, ANT is a method of describing. To accomplish this task, Latour (2005) suggested:

> Just describe the state of affairs at hand. To describe, to be attentive to the concrete state of affairs, to find the uniquely adequate account of a given situation, I myself have always found this incredibly demanding. (p. 144)

Latour (2005) further elaborated on describing versus explaining:

> I'd say that if your description needs an explanation, it's not a good description, that's all. Only bad descriptions need an explanation. It's quite simple really.

> What is meant by a "social explanation" most of the time? Adding another actor to provide those already described with the energy necessary to act. But if you have to add one, then the network was not complete. And if the actors already assembled do not have enough energy to act, then they are not "actors" but mere intermediaries, dopes, puppets. They do nothing, so they should not be in the description anyhow. I have never seen a good description in need of an explanation. But I have read countless bad descriptions to which nothing was added by a massive addition of "explanations". And ANT did not help. (p.147)

In line with Latour (2005)'s suggestions, this study describes, writes, describes, and writes some more: "The name of the game is not reduction, but irreduction" and to get back to empiricism (p. 137). Here, Latourian empiricism is primarily concerned with describing who and what might constitute issues and controversies. Entities are viewed as heterogeneous assemblages that are irreducible to homogenous sociological categories such as human, natural, social, and technological; thus, painstakingly describing the affairs at hand is to pay an empirical attention to the ontological multiplicities of entities as well as recognize a diversity of emergent collectives (Ward & Wilkie, 2009).

Coupled with ANT as the theoretical framework, this study is guided by the methodological framework of *new empirical inquiry* and its assumptions (St. Pierre, 2016). A researcher always works within a structure whether he or she realizes it or not. Therefore, *new empirical inquiry* is the methodological framing the scholar of this dissertation chose to work with, as it fits well with the task at hand of an ANT scholar – that is, to *describe*.

**New Empirical Inquiry and Its Assumptions**

Massumi (2010) said, "The new cannot be described, having not yet arrived" (p. 3). True to Massumi's (2010) comments, *post-qualitative* scholars leave the *doing* of post-qualitative studies purposefully open-ended. However, the researcher of this study acknowledges that she is working within an academic structure where the conversation about the quality of one's research process is relevant. To this end, the researcher of this study presents two assumptions regarding 1) the dogmatic image of method and 2) the dogmatic image of representational thought. She presents *new empirical inquiry* as a way to change the conventional ways of doing qualitative research that have traditionally been grounded in humanism.

**A case against the dogmatic image of method.** Methods define techniques for gathering evidence; methodologies denote theory-driven frameworks for how research projects should proceed; epistemology is the theory of knowledge; and ontology is the theory of being (St. Pierre, Jackson, & Mazzei, 2016). The terms *method, methodology, epistemology,* and *ontology* have served well in guiding social scientists on how to conduct research, as these definitions have become "teachable research methodologies and methods" (St. Pierre et al., 2016, p. 105). A fixed image of method, or a method that precedes inquiry validates research in a form of *trustworthiness*, for methods have become recognizable: Scholars trained in qualitative methods know "what it means to collect valid interview data" and the method's visibility has been "institutionalized by qualitative textbooks, coursework, publication standards" (Jackson, 2017, p. 666). Jackson (2017) argues that to create something *new*, the dogmatic image of method must be disrupted:

> Everybody knows that if you learn how to conduct inquiry, you can willfully apply it- thus affirming and reproducing it. Method believes in its promise to deliver credible, authentic, and trustworthy research. That is, a well-trained

> qualitative research is already presupposed to be recognizable through practices such as "immersion in the field," "triangulation," "member checking," "reflexive journaling," and so on. (p. 671).

In the context of this study, the aim is to describe and re-describe the social concepts of gender and race. Therefore, it is important to explore ontological multiplicities and remain open to the diversity of emergent collectives of both human and nonhuman actors in actor-networks. However, these terms are grounded in conventional humanist qualitative methodology where the human subject is privileged. Typically, social science research methods and practices include interviews and observations, which are dependent on the human subject (St. Pierre, 2016). Furthermore, concepts associated with social science research such as data, research design, data analysis, measurement, researcher, and data representation are also grounded in the humanist subject. St. Pierre (2016) argues that these normalized concepts and practices "condition a study in advance and tie it to the strata":

> Concepts and practices are invented in encounters of events 'in the context of the problem whose conditions they determine' and so cannot be determined in advance… We read and read and read until its concepts overtake us and help us *lay out a plane* that enables lines of flight to what we have not yet been able to think and live. How we *do* this different kind of inquiry is not at all clear, but I doubt it resembles conventional social science research. (p. 122)

Here, St. Pierre (2016) introduces the Deleuzian concept of *lines of flight* to make an argument for how qualitative research can be done differently. In Deleuze and Guattari (1987), *lines of flight* can be conceptualized as a discovery that is not grounded in human agency, but in assemblages of relations. According to Bazzul and Kayumova (2016), *lines of flight* "carry the promise of new possibilities and new connections" and "engage with other multiplicities…capable of giving birth to new lines of flight" (p. 288). DeLanda (2016) defines *lines of flight* as movement, thinking, or action that moves away from the apparent or actual toward the virtual, multiple, or what is yet possible. In other words, *lines of flight* take flight towards something *new*. What *new* thing that this dissertation is trying to accomplish is to keep the social flat in order to *re*-assemble it. Latour (2005) says:

> It's rather straightforward to assemble, invoke, convoke, mobilize, and explain the social. Practitioners of social science know how painful, costly, arduous, and utterly puzzling it is. The "easy" social is the one already bundled together, while the "difficult" social is the new one that has yet to appear in stitching together elements that don't pertain to the usual repertoire. Depending on which tracer we decide to follow we will embark on very different sorts of travels…. I am not only saying that existing maps are incomplete, but that they designate territories with such different shapes that they don't even overlap! It is not even clear if they pertain to the same Earth. The job now before us is no longer to go to different places in the same country – less crowded sites, less trodden paths – but to generate an altogether different landscape so we can travel through it. Needless to say, it is not going to speed up our trips: 'slowciology it was…. 'slowciology' it will remain. (p. 165)

In terms of this study, the "easy social" would be to recognize gender or race as they have already been black-boxed and bundled together. The "difficult social" would be look for the new that hasn't been bundled or assembled together. The question the researcher of this study asks is what *could* gender and race be, and not what already *are* gender and race. Here, the researcher acknowledges that the human subject *can* be privileged. However, she aims to challenge the way social science inquiry has been done and *enact* the notion of symmetry such that *things* (i.e., objects and nonhuman entities) that were typically on the periphery of conventional inquiry are recognized and brought to foreground; in this way, the notion that actor-networks are shaped by the power of *things* as Bruno Latour argues can be accomplished. Furthermore, the researcher does not completely disregard research methods such as immersion in the field, triangulation, member-checking, interviews, data, etc. What she aims to accomplish is to *not* add components of research methods that are based on other theoretical constructions. When and if these techniques are needed, they can be added back. However, in order to take flight towards something *new*, the researcher of this study begins with the least restrictive way of doing this study to allow *things* from the less trodden paths to be seen.

The dogmatic image of method entails a universal presumption that there is the separation between the subject (researcher) and an object of knowledge with "the researcher endowed with *a priori,* voluntary skills to seek-and-find" a solution to research problems (Jackson, 2017, p. 671). This means that problems imply having a solution that is preexistent and waiting to be discovered and unearthed. However, from an ANT perspective, ANT scholars are less interested in the subject/object dualism, but more interested in the relation that is *sensed*, rather than understood. This argument further supports the notion that pre-determined practices and normalized methods are not very useful, especially in a study like this. There is no "problem" or "solution" that exists outside of the relations among the actors. A researcher would not know what these relations are going to look like until she looks at them. Therefore, ways to examine these relations cannot be determined in advance, as St. Pierre (2016) previously stated.

Lastly, through normative methods, we erase the *things* we did to make our research look like the truth. In this sense, normative methods are black-boxed and become the monolithic entity with the big M. The connections, associations, and heterogeneous entities that were assembled to produce it become obscured. In this vein, through methods, we, as researchers, are erased and do not become part of the construction of that truth; the researcher is erased so to give research more truth and value. At the end of the day, the researcher is erased, and we become a *non*-actor. Instead, the researcher of this study argues that researchers should become part of the actor-networks that we are attempting to describe. This is why the researcher of this study chooses the very act of transformation through the process of writing about her work, instead of attempting to *represent* her work. Through the transformative act of writing, the researcher is *translated* into the actor-network as the *performing actor*.

**A case against the dogmatic image of representational thought.** In pursuing the possibility of materially informed *post*-qualitative research, the researcher of this study argues for *post-representational* thought and rejects the humanist assumptions that undergird the logic of *representation*. According to MacLure (2013), "representational thinking still regulates much of what would be considered qualitative research methodology. This needs to change" (p. 658). Using Deleuze's *Logic of Sense* to resist the logic of representation, MacLure (2013) elaborates on Deleuzian *sense*, which is:

> Non-representing, unrepresentable, "wild element" in language. Sense is important for a materialist methodology because it works as a sort of "mobius strip" between language and the world (Deleuze, 2004, p. 23). Sense "happens to bodies…", allowing them to resonate and relate, while never being reducible to

either "side" of what old duality that separates the material world from the worlds that putatively represent it. (as cited in MacLure 2013, p. 658-659)

Representational thought is hierarchical, sedentary, categorical, and judgmental: it hinders the emergence of the *new* and serves the dogmatic image of thought that renders material realities *inaccessible* behind the linguistic systems that allegedly *represent* them (Deleuze, 1994). The researcher of this study acknowledges that representation happens, and that representation, after all, is a way to structure and construct a world around us and to make stable meaning, which is precisely what becomes incompatible with the assumptions of actor-network theory. In place of hierarchical representation, central to ANT is the materially informed ontologies, which prefer a "flattened" logic where all entities in the actor-network are *entangled*. With respect to the logic of *representation,* it is impossible with language to *represent*. According to Derrida (1967/2016), there is always the separation between the signifier (language) and the signified (the thing that we want to represent) – these two will never perfectly match up. Therefore, scholars have found different ways to implicate both discourse and matter in the emergence of the world. In this study, the researcher has chosen actor-network theory with concepts borrowed from assemblage theory.

As previously mentioned, the researcher of this study takes the stance that the process of writing about her work is the transformative act rather than attempting to *represent* her work. The question that remains is: how does the researcher describe her observations and write about her study? The researcher was *always already* theorizing even before she began "data collection, data analysis, data representation," or what have you in the sense of doing research. *Something* is guiding the researcher of this study to be able to write about her work and describe her observations – that *something* is concepts and theories that St. Pierre (2016) argued would emerge from reading and re-reading the accounts of encounters and allow interesting and new *things* to be seen.

Every possible method that the researcher of this study brings significantly shapes how the researcher conducts the study as she previously argued, and what the researcher is working with. Typically, that *thing* the researcher is working with is *data*. To be able to talk and write about her work, the researcher acknowledges that the term *data* must be used. In this study, the term *data* is used carefully in a way to deterritorialize or remove the limitations that the word brings. To this end, the researcher is guided by the concept of *glowing data*. In the world of materially informed qualitative study, MacLure (2013) elaborates:

> Data cannot be seen as an inert and indifferent mass waiting to be in/formed and calibrated by our analytic acumen or our coding systems. We are no longer autonomous agents, choosing and disposing. Rather, we are obligated to acknowledge that data have their ways of making themselves intelligible to us. This can be seen, or rather felt, on occasions when one becomes especially "interested" in a piece of data – such as a sarcastic comment in kind of peculiar. Or some point in the pedestrian process of "writing up" a piece of research where something not-yet-articulated seems to take off and take over, effecting a kind of quantum leap that moves the writing/writer to somewhere unpredictable. On those occasions, agency feels distributed and undecidable, as if we have chosen something that has chosen us. (pp. 660-661).

In this study, the researcher used the concept of *glowing data*, which is an idea that helps her resist preconceived notions about what she should be seeing, or what the word *data* prevents her from seeing. In line with getting away from normative methods, *glowing data* enables the researcher to take new *lines of flight*. To this end, St. Pierre et al. (2016) advise scholars to "read and read and read and attend to the encounters in our experiences that demand our attention (p. 106). In the next section, the concept of *glowing data* is discussed.

**Thinking with Concepts and Theories: Glowing Data**

The concept of *glowing data* is theorized by MacLure (2013) in order to explore the post-qualitative possibilities of data that command attention. In this study, the researcher thinks about her observations in terms of the concept of *glowing data* and pays close attention to *things* that start to *glimmer*. Accordingly, MacLure (2010) describes *glowing data* as:

> [S]ome detail – a fieldnote fragment or video image – starts to glimmer, gathering our attention. Things both slow down and speed up at this point. On the one hand, the detail arrests the listless traverse of our attention across the surface of the screen or page that holds the data, intensifying our gaze and making us pause to burrow inside it, mining it for meaning. On the other hand, connections start to fire up: the conversation gets faster and more animated as we begin to recall other incidents and details in the project classrooms, our own childhood experiences, films or artwork that we have seen, articles that we have read. And it is worth noting in passing that there is an affective component (in the Deleuzian sense) to this emergence of the example. The shifting speeds and intensities of engagement with the example do not just prompt thought, but also generate sensations resonating in the body as well as the brain – frissons of excitement, energy, laughter, silliness. (p. 282)

The emergence of *glowing data* is not something that is under the researcher's conscious or intentional control as an analyst: it is something that arrests the researcher's gaze, makes him/her pause, and wonder. Were there encounters that were shocking, perplexing, interesting to the researcher's thought? How did the researcher *sense* these encounters that were unrecognizable, resisting analysis, and refusing to render up meaning? In the context of this study, the researcher paid close attention to *glowing data* while observing actor-networks. Furthermore, the researcher described *glowing data,* as she was looking for and identifying the potentials of actors/actants in the actor-network to be activated. In other words, the researcher was looking for the capacities of actors/actants to be and actualized where normally these capacities would not have been actualized or would have been actualized in different ways. The researcher's goal was to not simply recognize the already-assembled and already-made "easy social," but the ways in which entities re-assembled the "difficult social" differently and to examine the conditions under which these assemblages occurred. This study looked for different types of assemblages, different types of actor-networks. The researcher did not assume to know ahead of time what types of actions would catalyze these capacities to be actualized in the actor-network; therefore, the researcher could not say ahead of time that she was looking for X using method Y. The "difficult social" may be actualized, but not always in the same *plane of immanence*, which Deleuze and Guattari (1987) define as an extensive continuum of movement, forces, speeds, and intensities of the virtual that has yet to become actual. This is why *glowing data* is the best way to *describe* the conditions under which something new is produced, and actor-networks are assembled and created.

In the context of this study, an example of glowing datum can be about an observation of objects that can create reality. For example, the school bell or a clock in the classroom changes physical spaces. In the case of the school bell, a classroom space becomes territorialized and re-territorialized at the beginning and at the end of a class period; as the bell is struck, it mobilizes students and teachers. Most obvious change is the movement of students into the class and out of the hallway and vice versa. At the beginning of the class, students and teachers might be getting ready to start an activity, a lecture, etc. At the end of the class, they might be finishing up an experiment, lining up at the door to exit the classroom space, talking amongst each other, etc. Similarly, in the case of a clock on the wall of a classroom, being close to the start or end of a class period changes the classroom space accordingly. Particularly with a clock, the concept of time becomes materialized into something that can organize students into, for instance, practitioners of disciplined members of the school by being on time to class and not being tardy.

In the next section, the process of *doing* field observation, *reading* and *re-reading* field observation and texts, *writing* about and *creating glowing data*, and *talking with* (i.e., interviewing) students and teachers is discussed in detail. Also included in the section is information about the demographics of the school site at which the study was conducted.

## Process of Doing an ANT Study: Methods

### Context of the Study

The researcher's study required a context in which she could examine day-to-day interactions of actants/actors and their performances in the science classroom. Therefore, this study was conducted at a public science, technology, engineering, and mathematics (STEM) school in the Southeastern region of the United States. The STEM school was recognized by the state as an exemplary high performing school based on overall academic excellence and performance on various measures. The school heavily emphasizes high academic achievement of their students in STEM. For example, the STEM school's overall SAT score was well above the district, state, and national averages. The school's overall score on the school district-implemented writing assessment is well above the reported average scores of the district.

Advanced Placement (AP) courses are taken by 70% of the students at the school, which is 48% higher than the reported statistics of the district overall. Of the students who take AP courses, 84% take the AP exams and the pass rate among the test takers is 96% with a score of 3 or higher. The school's pass rate is 66% higher than the reported statistics of the district overall. The graduation rate of the students at the STEM school is 100%; however, this excludes students who transfer out of the STEM school and return to their zoned or home schools before reaching senior year. The percentage of students graduating from the STEM school and entering a 4-year college is 91%, as compared to 67% in the district overall. At the STEM school 34% of the students are on free and reduced lunch. Students' average attendance is at 98%, which indicates that students do not miss school days. This high performing STEM school was considered an ideal site to conduct this study because of the unique characteristics of the school's science-learning environment. When the researcher visited the school, she was shocked to see the scale (i.e., size and the number of physical lab spaces available to students), design (i.e. the layout of the dish trays, the black lab tables, the sink, the gas/air lines, the chemical cabinets, etc.) of their science laboratories, and the availability of the latest laboratory equipment (i.e., gel apparatus in a high school classroom). The laboratories looked just like what the researcher had seen only *after* she had entered a large-research institution/university. The school provides a highly technologically advanced STEM learning environment that is unparalleled when compared to other public schools in the area. Given that a central tenet of actor-network theory is to foreground the *power of things* that hold together actor-networks, this school provided an ideal context to examine the actor-network of the science classroom and to examine the conditions under which gender and race became actualized and how these *things* shaped students' science identity categories related to gender and race.

The school's admission policy plays an integral part in creating a unique school culture. Parents of 8th grade students who become eligible can submit their children's names to a lottery system through which students are admitted to the school. Because the admission to the school is by lottery and the school moves students as cohorts, students must be admitted to the school as a freshman. As of 2017, the school requires 8th grade students to have completed and passed Algebra or higher with a grade of 85% or higher. Students, who are taking mathematics classes, such as pre-Algebra or introduction to Algebra/Geometry, are ineligible for admission. As entering freshmen, the 9th grade students take pre-calculus. By the time, students are in 10th grade, they can choose to either be on AP Calculus AB or BC track; the difference is the scope of the materials covered in each track. The school provides the students with a plan of study that has been modeled after the STEM major courses at the university level to prepare them for STEM-related careers. Taking advantage of the resources at the school, all juniors and graduating seniors must complete three semesters of internships in a STEM-related field. To graduate, students must complete twenty-six Carnegie credits which is three credits more than what is required by their neighboring public schools. Students are required to take science all four years along with three years of engineering. In addition, students are required to complete two years of internship in any of the STEM fields.

The student demographic data published for 2017-2018 includes 44% Asian, 23% African American, 20% White, 10% Hispanic or Latino, and 3% multiracial. The ratio between boys to girls is 60 to 40, which was represented in the majority of the classroom levels in the AP Biology courses that were central to this study.

**Observing the Advanced Placement Level Biology Course**

Ryu (2015a) indicated that advanced placement (AP) science classes are understudied because the students enrolled in these classes are generally considered to be gifted or high achieving students who are on track to attend a four-year university. To better understand the conditions under which gender and race become actualized in the actor-network of school science, the AP biology course was an ideal choice because the ratio between boys and girls was 60 to 40. The school's overall ratio between boys and girls was reflected best at the AP biology level. Within the curriculum set by the school, students are required to take AP biology. Moving beyond 10$^{th}$ grade, the school statistics demonstrate that there is a skewed representation of girls to boys in higher-level physics in that fewer girls take advanced physics and opt for other science electives. The problem to be explored here in this dissertation is not to prescribe the problem X such as the obviously observed underrepresentation of girls or minority girls in these higher-level classes. Again, the aim of this ANT study is to challenge and describe the "difficult social." For these reasons, AP Biology was chosen as the focal point of this study. Also, the recommendations of the principal and inputs from the chair and the teachers from the school's science department played a role in gaining insights into the science courses offered at the school and the decision process in choosing which courses to observe. For instance, Genetics was being piloted on a remote-learning platform in a large lecture-hall style room and thus would not have been an ideal course to observe. Furthermore, listening to their feedback and suggestions was an important part of building a rapport with the teachers and the key players (i.e., principal and science department chair) at the school. Doing so was important in rapport building process so that the researcher would have access to inquire about their experiences teaching and working with the particular student populations at this school.

### Student Population Selection

Being true to the assumptions of ANT, all actors and entities are important in the actor-network. Although the initial focus of this ANT study was on deeply investigating and understanding gender and race/ethnic inequities in school science from Asian American girls' perspectives, the researcher acknowledged the importance of other students as actors who may or may not interact with the Asian/Asian American girls in the actor-network. Guided by the concept of *glowing data*, students who became involved in these encounters were selected for in-depth observations and follow-up interviews and conversations. If and when it became necessary to identify the race and/or ethnic groups of the students, the terms, *race* and *ethnic/ethnicity* in the study were adapted from Carlone and Johnson (2007)'s study: *ethnicity* is referred to as systems of meaning sharing among a group and *race* is referred to what students at first glance "look like" (p. 1193).

During a full school day, four sections or blocks of AP biology were taught by two White female teachers who had 6-10 years of teaching experience. One female teacher (Molly) taught three of the four sections of AP biology, while the other female teacher (Barbara) taught one of the four sections of AP biology that the researcher observed. The researcher went to school each morning and observed all four sections of the AP Biology class, which consisted of lecture and laboratory components. Each section of AP biology had 25 students enrolled in the course.

### Ethical Considerations and Consent Process

Participant observation was conducted in such a way that the researcher was not a disruption to the normal activity in the classroom. Following the guidelines of the Family Educational Rights and Privacy Act (FERPA), the researcher only used pseudonyms and no identifiable and personal information about the human participants were disclosed. The researcher prepared a recruitment letter to provide the details of the study, which was sent to the principal and teachers. Initially, consent from the principal and teachers were obtained. During the consent process, the principal's letter of support and the researcher's letter-to-parent about the study along with permission forms for parents and their children were sent home. 100% of the students in all four blocks of AP biology returned the consent forms agreeing to participate in the study.

**Participant Observation: Field Observations and Field Notes**

The researcher observed 10th grade Advanced Placement (AP) biology courses from 8AM to 3PM every Monday through Friday. The duration of the field observation was for three academic months in Fall semester, 2017. The researcher sat in designated locations in the classrooms and took field notes and observations. To begin, she had her research question that was initially guiding her classroom and laboratory observations: how do the capacities of gender and race become actualized in a high school biology classroom? The collection of data entailed the researcher's field notes and observations, which included what she saw, heard, and sensed, as she observed the interactions of her actors (students, teacher, objects) in the AP biology classroom. She not only described the encounters and interactions that were happening in the classroom, but also noted direct quotes that were spoken by the students and teachers. She paid close attention to the way *things* were laid out in the classroom as well as the way students were sitting, standing, moving around, rolling in their rolling chairs, walking, writing, slouching over their desks and anything that described the way her human actors used their bodies. Therefore, also included in the observations were detailed descriptions of the physical classroom space such as the way chairs, desks, laboratory equipment, white board, etc. were placed, used, manipulated and moved around the classroom. Her field notes and observations included thoughts and questions that she wanted to ask students and teachers, and/or descriptions of perplexing, or shocking moments that she observed, experienced, and sensed. Lastly, the researcher included theoretical musings since she was *always already* thinking with concepts and theories. Mainly for the purpose of *describing* what went into the field observations, Table 1 provides a list of *entry points* that the researcher initially observed.

Table 1. List of *entry points* for field observations

| **Bigger Things** | **More Detailed and Smaller Things** |
|---|---|
| Description of encounters | Where and What:<br>• Lab or lecture<br>• Group work or individual<br>Summary of key actors/actants:<br>• Humans<br>• Nonhumans |
| Physical behavior & gestures | Appearance:<br>• Clothes, backpacks, shoes, etc.<br>• Gender, or race/ethnicity<br>Senses:<br>• Face expressions or anything that is seen<br>• Sounds<br>• Texture of things<br>• Smells or taste |

| | |
|---|---|
| | Actions:<br>• What human actors are doing and with whom (other humans) and/or with what (objects/ nonhumans)<br>Space and Proximity:<br>• Layout of things and bodies during an activity or encounter (can be pictorial)<br>• Proximity of actors to one another<br>• Arrangement details of things in the classroom space<br>Movement and Traffic:<br>• Entering and leaving a space<br>• Time spent at a particulate site or an encounter |
| Verbal behavior & gestures | Communications and Quotes<br>Verbal triggers that stand out<br>Summaries of conversations |
| Researcher | Researcher’s Thoughts and Response<br>Questions<br>Senses and Impressions |
| Theoretical musings | Theories and Concepts to Think with and about Observations |

When it was necessary, the researcher's field notes also included hand-drawn pictures of the layouts of the classroom and physical location of activities, as well as interesting encounters and interactions among actors. Pictures helped the researcher focus on where certain types of activities, people, and things interacted in the classroom space (Mack, Woodsong, MacQueen, Guest, & Namey, 2005).

**Iterative Data Collection and Analysis: Reading, Re-Reading, and Writing**

At the end of each day, the researcher read and re-read her notes in order to *trace* and focus on factors that influenced the actions of the actors and shaped the encounters that she observed. The process of reading and re-reading field notes and field observational texts naturally entailed *writing* and *describing* the *glowing data* that were shocking, interesting, chaotic, and perplexing to the researcher. As she read through her observational notes, she described the encounters in detail, which included translating her shorthand, abbreviations, and at times symbols into descriptions of the encounters. Recreating field notes and texts into working interpretive documents was part of both creation of data and data analysis in this study (Denzin & Lincoln, 1998). The goal of this transformative act of reading and writing was to describe the conditions under which the actualization of the capacities of *gender* and *race* was fully realized in the actor-network of a science classroom.

Guided by the assumptions of new empirical inquiry, this study did not follow a linear model of doing research, which is an argument that many qualitative researchers would agree on (Jackson & Mazzei, 2012). It also follows that the collection of data and data analysis in this study was enacted through a reading and writing process that was iterative in nature. The following figure summarizes the reading and writing process used to generate and analyze *glowing data*.

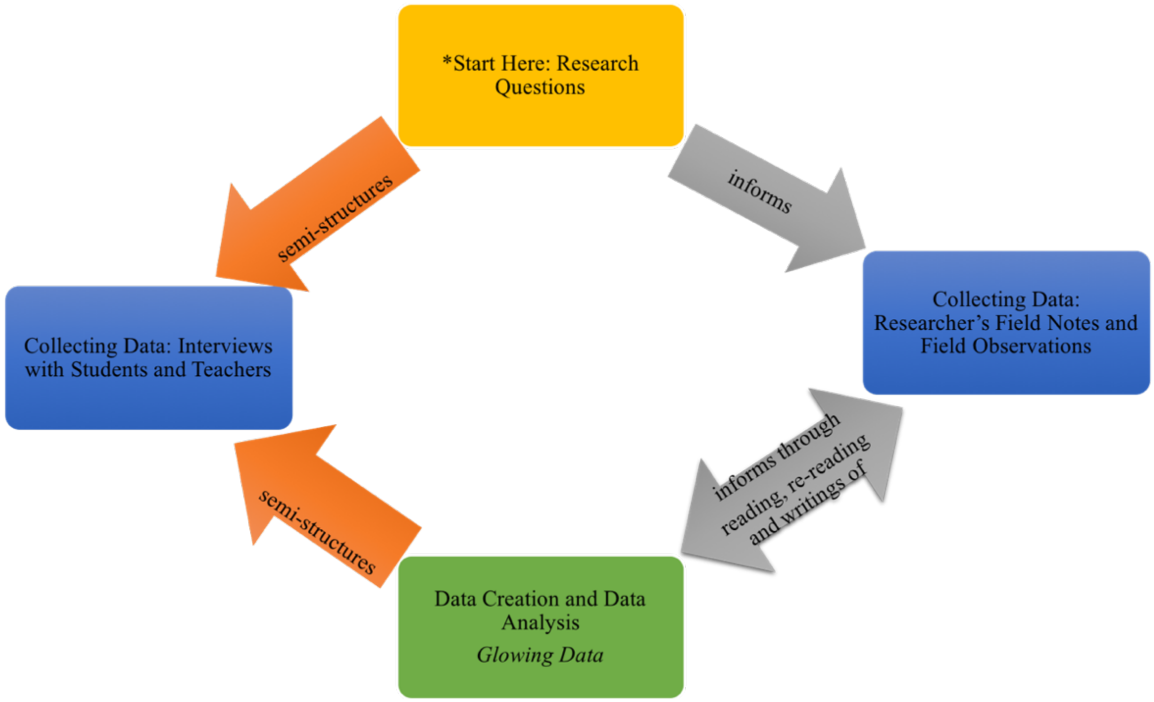


Figure 1. Iterative process of collecting and analyzing data.

In summary, the researcher's field observations and data collection informed analysis, and vice versa, where data creation and analysis occurred simultaneously through the researcher's description and writing of *glowing data*.

**Talking with Students and Teachers: Interviews**

During field observations, the researcher focused her field notes on encounters that were perplexing, puzzling, and interesting and sometimes shocking. Because her human actors were able to chat, discuss, and share their experiences with the researcher, students and teachers who were involved in the particular encounters of interest to the researcher were interviewed.

In this study, semi-structured interviews were conducted. In the interviews with the students, the researcher asked two general, opening questions: 1) tell me about how you learned about this school and why you chose this school and 2) tell me about your experiences so far in AP Biology. These two opening questions were followed by probing questions that were phrased as, "can you tell me more about…" or "could you elaborate on what you just said about…” And then, the researcher transitioned into asking students specifically about an interesting encounter that she observed by asking, “tell me about when...” The third question was followed up by questions that arose during the researcher’s field observations about interesting encounters that were observed.

In the interviews with the teachers, the researcher asked two general, opening questions: 1) how many years have you been a science teacher and 2) can you tell me a little bit about your background? Then the researcher transitioned into a conversation about interesting encounters that she had observed in their science classrooms, followed by probing questions when necessary. Interviews with teachers and students were conducted similar to having a conversation about their experiences in teaching and learning science. In addition, many of the conversations and chats occurred informally in the hallways, as students were walking with the researcher, or as students were hanging out during the in-between time of activities or laboratory experiments. As a participant observer in the class, the researcher was able to hold many chats with the students during class activities when group work and collaborations were allowed by the teacher. The researcher also ate lunch with the teachers or would stop to talk with the teachers during the passing periods. Many informal conversations occurred in the teacher’s lounge.

Following Roulston (2010)’s advice, the researcher should ensure that she does not approach interviewing from neo-positivistic ideas. These include the notion of a “skillful” interview, asking “good” questions, minimizing “bias” and “researcher influences” through a neutral role (Roulston, 2010, p. 52). According to Norman Denzin, a postmodern interview is conceptualized as a “vehicle for producing performance texts and performance ethnographies about self and society, rather than a method for gathering information” (as cited in Roulston, 2010, p. 63). Denzin further posits that the “interview subject has no essential self, but provides

– in relationship with a particular interviewer – various non-unitary performances of selves" (as cited in Roulston, 2010, p. 63). This particular approach to interviewing aligns more with the tenets of ANT by not necessarily privileging the human subject. In terms of practice, however, the researcher's questions or behavior during the interviews did not necessarily change. This is because this study still tended to explore the aspects of the AP biology classroom on the human axis, despite the researcher's every effort to address the nonhuman actors. What did change is the treatment of interview as contexts that provided useful information or insights into students' experiences to which the researcher would not otherwise have access. For example, the knowledge that came out of students' interviews about some girls strongly disliking biology would not have become knowable to the researcher by simply tracing the ontological work in the classroom alone. Also, the researcher's aim in this study was not necessarily to seek an account of the truth or truth of claims based on the observations of the encounters and interactions in the classroom; therefore, she did not treat the interviews as a method of triangulation or member-checking in this study. However, it helped when the concerns of the students and the teachers aligned with the concerns of the researcher in these interviews. It also helped when *things* that the researcher was hoping to see came up in the interview or were seen in multiple interactions. For example, in chapter 4, the interview data generated through a conversation with a student named Aisha demonstrated the alignment of the concerns about gender roles in the laboratory space; Aisha's perspective of her experience matched with the perspective of the researcher.

In light of the aim of this study to describe how gender and race were actualized in the science classroom, the goal of conducting an interview was not about giving more legitimacy to the truth of claims with respect to students' gender and race categories of their science identity, per se. Rather, the more important goal of the interviews was to make "accessible the multiple intersections of material context that collude in productive formations of meaning (Kuntz & Presnall, 2012, p. 732). In this sense, Kuntz and Presnall (2012) re-conceptualize interview as *intraview* to express the embodied act of *becoming with knowing*. This notion of "emergently relational ways of knowing" aligns with the aim of new empirical inquiry in that research practice should reject the notion of a spectator's stance of the interviewer in interviews (Kuntz & Presnall, 2012, p. 741). In terms of practice during interviews, however, enacting relational ways of knowing was challenging despite the researcher's effort to conduct them differently. This was because the majority of the encounters about which the researcher interviewed the students and teachers occurred where the researcher remained as an actant and not as a performing actor. This makes sense because of her role as the participant observer who for the most part remained as an observer rather than a participant or a member of the AP biology class.

Lastly, the researcher referred to Roulston (2010)'s chapter "Doing Interview Research" in order to facilitate the interview process from the consent process to transcription. Consent from students and their parents as well as teachers was obtained. The interviews with students were conducted in a classroom space designated by the chair of the science department and scheduled outside of their class time. With the teachers, interviews were conducted outside of their class time and during the time and day when it was most convenient for them. The scheduling depended on the availability for all of the participants. Three recorders (iPhone, a recording software on the computer, and a hand-held recorder) were used to record the interviews and the participants were informed that the interviews were being recorded. The participants were also informed that they could stop the interview at any given time, if they wished to do so. When the researcher transcribed the interviews, she focused on transcribing the words as accurately as possible. She used her discretion to transcribe pauses, sighs, or any significant breaks during the interview. All recordings of the interviews were stored in the file cabinet of the researcher's home office and destroyed upon the completion of the study. The following chapter highlights the descriptions and analysis of the ***glowing data.***

# CHAPTER 4

# GLOWING DATA

The purpose of this section is to provide accounts of glowing data that allow for the tracing of the actualization of gender and race. Latour (2005) argued that a good account *performs* "the social in the precise sense that some of the participants in the action–through the controversial agency of the author–will be *assembled* in such a way that they can be *collected* together" (p. 138). To be accounted for, actants must enter into accounts and produce a *trace* that can offer information to the observer and have a visible effect on other actors.

Qualitative studies call for a researcher's reflexivity under the assumption that reality is socially constructed, and that knowledge is context-based and historically situated (Mauthner & Doucet, 2003). Reflexivity demands a critical self-examination from the researcher to interrogate his or her interpretation from which construction of empirical data, interpretations and reflections follow (Alvesson & Skoldberg, 2009). However, Latour (2005) highlighted that, "most of what social scientists call 'reflexivity' is just a way of asking totally irrelevant questions to people who ask other questions for which the analyst does not have the slightest answer! Reflexivity is not a birthright you transport with you…! You and your informants have different concerns-when they intersect it's a miracle. And miracles, in case you don't know, are rare" (p. 151). Latour (2005) challenges the notion of *reflexivity* and argued that:

> Too often, social scientists- and especially critical sociologists- behave as if they were "critical", "reflexive", and "distanced" enquirers meeting a "naïve", "uncritical", and "un-reflexive" actor. But what they too often mean is that they

> translate the many expressions of their informants into their own vocabulary of social forces. The analyst simply repeats what the social world is already made of; actors simply ignore the fact that they have been mentioned in the analyst's account. (p. 57)

He further added that the participants were actors *before* any researcher came in with his or her *explanation*.

Therefore, the accounts provided should not be taken solely as the researcher's reflection on or interpretations of the interactions. This is not to say that writing of these accounts excluded any form of interpretations or reflections. The aim of the accounts was to provide detailed descriptions of interactions by *tracing the actors* that became visible and show the observer information about them. To this end, the researcher of this study provides several accounts of encounters or interactions that stood out or *glimmered* in the form of seven sets of glowing data. In the accounts, the researcher intentionally used the first-person pronoun. Lastly, within a set of glowing data, the two asterisks (**) are used to separate the smaller accounts within the set.

Briefly here, the researcher explains why gender and race are treated separately in the following glowing data. Recall that one of the theoretical underpinnings of this study is approaching the notion of intersectionality of identity categories such as gender and race in a slightly different way. The researcher understands that any one of the identity categories *alone* would not define a person; however, this study operates under the notion of actor-networks or assemblages. This is where the use of the words *gender or race* that appear to *separate* them as different categories imposes a limitation. It is critical to recall that the concepts of *gender* and *race* in this study are *always already* understood as being relational, or effects of relations that emerge among the actors. Therefore, this study treats the notion of intersectionality differently; in other words, the researcher does not necessarily look for the conventional sense of intersections of these two identity categories; instead, she looks for glimmering moments of where these socials become actualized. In that sense, gender and race were actualized in very different ways in this study. Therefore, in terms of writing about the glowing data, separating gender and race allowed the researcher to discuss and show these differences. For example, objects seemed to catalyze the actualization of gender. Race was more often discursively performed in the science classroom than gender and the nature of the discussion of race seemed to be more sanitized than gender -- one of the many differences in the way gender and race became actualized. Briefly, seven sets of glowing data are summarized by their titles:

Gender:

1. You need to be called out
2. Girls shall do *things* for others
    2.1. Who shall cut the DNA pieces?
    2.2. Who shall color?
    2.3. Who shall paint?
3. Not everything is always bad or good – on dress code

Race:

4. Well, that's a plus
5. Sanitized way of discussing race is to embed the discussion as part of the curriculum
    5.1. Asian earwax
    5.2. Let's both talk about x-rays, physics, and having brown parents
    5.3. There are only you and I who have blue eyes!

5.4. Let me tell you who you are going to be

6. Conversations surrounding race take lines of flight that appeared to be unexpected, demanding quick attention of the observer
   6.1. Examples of unexpected outbursts
   6.2. Sit down, brown person!
   6.3. It's just a video or a word on an iPhone
7. When some *things* do not seem to show or become visible: On not obvious interactions or observations of Asian American girls

**Part 1: Gender Glowing Interactions**

**Glowing Interaction #1: "You Need to Be Called Out!"**

Molly (the teacher) runs her laboratory section of the AP Biology class with a set of routines. Her routine of content delivery, review of lab protocol, and inclusion of a hands-on experiment is produced time after time — for each lab. This particular lab session on cellular respiration was no exception. With only a few minutes left until the bell rang, Molly called for the attention of her students and reminded them, "7 minutes! Start cleaning up, everyone."

Seconds prior to Molly's instruction, all students were working towards the completion of their science experiment. The agreement among the students towards achieving equitable participation was observed through the actions of turn-taking that were maintained throughout the duration of the experiment. Molly never explicitly instructed her students that they had to take turns. Turn-taking was something that the students chose to do for themselves. Students talked with each other to divide the tasks and asked one another if anyone preferred a specific task. These types of conversations were no different during this particular lab experiment.

The student bodies were evenly distributed around the laboratory table and the physical site of the experiment, which was also where a laptop was located. The school laptop was connected to the pressure probe and was used by the students to collect graphical data as the pressure inside the pressure flasks fluctuated. Students took turns in sharing responsibilities and tasks required to complete each step of their lab protocol. The established pattern and interactions of student bodies during the laboratory experiment were maintained and stabilized — for the time being.

I was standing next to the group that included Aisha and Lee. Aisha is an African American female student and Lee is an East Asian male student. I noticed that the beakers, pipettes, and various lab equipment they used during the experiment were thrown in the sink. Dirty paper towels, melting ice cubes, spilled water, etc. were scattered messily around the lab table.

I heard Molly, the teacher, give a verbal instruction to "clean up the experiment." The teacher's instruction was said out loud and heard by the students. The moment the teacher's words were sent out to the class, those very words acted as if they had the ability to exert force on the students. To comply with the verbal instructions, the student bodies, including Aisha and Lee, began to mobilize and move around the site of the experiment and around the laboratory sink. There were four long rows of black, epoxy resin laboratory tables with one sink per row. Each sink functioned as a place of producing and re-producing a specific role: washing the beakers and lab tools.

The very moment at which Molly's verbal instruction was introduced to "clean up," the equilibrium of the laboratory was disturbed. The very act of "cleaning up" became an assemblage of sociocultural norms and assumptions of "doing the dishes" — a domestic role generally assumed by the women in a household. In that instance, the pattern of relations between the student bodies were re-problematized; the "clean up" event began to create patterns of relations that were generally typified by gender in the laboratory space.

I noticed Lee sauntering away from the laboratory sink towards the door. A sense of tension was evident between Aisha and Lee who were in the same laboratory group, as a gender struggle over who was going to "do the dishes" materialized around the sink. The sink stood out from the backdrop of the numerous laboratory equipment, cabinets, drawers, etc., and imposed itself as a catalyst to array the physical bodies around it according to sociocultural norms.

Lee (the male body) sensing this struggle moved away from the sink and walked towards the door, which in itself worked as the barrier that territorialized the physical spaces between the lab space and the social space (i.e., the hall way that allowed playful socialization among friends). Aisha (the female body), upon noticing Lee who was standing closer to the door, shouted out, "Lee, you need to be called out and exposed. You thought I was supposed to be doing the dishes. Come back here." Aisha's voice and her words "doing the dishes" pierced through my ears. On the margin of my notepad, I wrote in capital letters, SINK and underlined Aisha's words.

Lee sheepishly yet quickly walked back towards the sink and exchanged words of banter and laughter with Aisha. Aisha moved aside from the sink to make room for Lee and re-established the pattern of equal participation. The established pattern of relations for equitable participation was re-imposed around the sink, a site where the assumptions of gender roles were contested by Aisha, and the asymmetric relations constituted according to gender were de-stabilized and rejected in that very laboratory space.

Repeatedly, I observed that the act of conducting an experiment ended with the act of saving the results of the experimental graphs on the laptop. When the graphs were saved, the laptop was closed shut. Once the students were finished with their experiments, they picked up their laptops and walked towards the door, out of the lab and into the hallway where the chatters that were not related to school tasks were permitted among friends. In the hallway, the seating area was wide and open with a large panel window allowing sunlight to come through. By contrast, in the lab, the four long, epoxy resin tables limited available space to move about the room. Students had to stand, as there were no chairs in the lab. However, in the hallway, students could sit around the available round tables that looked like coffee tables that you would see at coffee shops, or polka dot design lounge chairs that you would see in hotel lobbies and engage in activities that were not related to the conduction of an experiment. With the laptop packed up and shut, the lab bench was no longer a site of doing a science activity.

Molly's clean-up instructions had transformed into Aisha's words of "doing-the-dishes." The physical object, the laboratory sink, became the catalyst that actualized gender in that very moment. The door from the lab to the hallway functioned as a physical barrier to territorialize between a social space and a science activity space. The laptop also played a role in territorializing between the two spaces at the even more local and minute scale on the lab bench; however, Latour would say that sometimes an actant could be weak and end up as a mere intermediary, or a placeholder. The sink, as a mediator, performed more than just a mean or a tool to reproduce by convention the social construction of gender. The sink actualized the elements of what gender *could* be in that very particular, local interaction.

In my conversation with Aisha I asked her about my observation of this particular interaction towards the end of the lab experiment. She explained,

> "I remember that day. Lee was just strolling around doing nothing. I felt like, look, the least he could do was help me clean up whether he wanted to or not. As a female and as a minority in this school, I feel like at some point some of the boys do think it's acceptable to do certain things. Maybe it's the person that I am, but I'm going to say, 'No, that's not acceptable. It's not right.' People become harsh with me because I call people out. I'm just trying to, as a person, as a human being, help other people improve. Even if that means I have to call you out and tell you that you need to clean up. Lee and the boys were just strolling around and having a little fun when we were doing the cleaning up. What's he going to do the next time something happens and somebody else is cleaning it up, but you are not doing anything. Maybe it will incline you to be like, 'maybe I should go and help out.' It's just that simple stuff like that."

Glowing interaction #1 was an account whereby the assumptions of gender roles were contested, and the asymmetric relations constituted according to gender were de-stabilized and rejected in that very laboratory space. More than likely, the original concerns of Aisha as well as her classmates were focused on completing their lab experiments. It was not until the very end of cleaning up the experiment that Aisha felt something that was "not acceptable." Though Aisha did not use specific words such as gender or inequities etc., she made the distinction between the "the boys who were strolling around" and the "we" who were cleaning up. Aisha's words demonstrated the disturbance of the equilibrium that Aisha *felt.* She was an equal participant in the lab experiment to her male partner in lab until she became someone who was associated with sociocultural norms and thus positioned as the female body who was supposed to be *doing the dishes*.

If the sink actualized *gender*, then the glass panel of the cabinet doors that were above each lab station demonstrated a different interaction. There were storage spaces above each lab station with a clear, glass panel door. Someone had glued down a square piece of Velcro and a dry erase marker was stuck on it. During lab activities, students often used this space. John, Madeline and Daniela were working in the same group. Daniela, a Hispanic female student, was writing notes and doing calculations on the board. As Daniela was doing her mathematic calculations on the cabinet door, it became the focus of the group's discussion. John, a White male student, wanted to add additional notes. Daniel handed over the marker, so John could add his notes. Unlike the interactions at the sink, the cabinet door served as a site of turn-taking collaboration. Students took the initiatives in writing out their calculations and adding their own thoughts to the discussion. In other words, all students, regardless of gender, were active participants in the science activity. There was a more equitable contribution from both genders compared to the interactions at the sink at which the boys tried to avoid doing the dishes rather than sharing the workload. Thus, the cabinet door played a different role than the sink.

**A Set of Glowing Interactions #2: "Girls Shall Do *Things* for Others"**

**Who shall cut the DNA pieces?** When I walk into Barbara's class, the first thing I look for are the teaching materials that she prepares for her class. On this particular day, there were three stacks of papers: 1) pink handouts with several rows of four nitrogenous DNA bases, 2) white handouts with rows of four nitrogenous RNA bases, and 3) another stack of handouts with polymerases and other enzymes that make the transcription process work. As indicated by Barbara's handouts, today's science activity was going to focus on the transcription process of the Central Dogma. As per usual, Barbara delivered content on the transcription process at the beginning of class. She stood in front of the class and used the smart board to demonstrate how all the enzymes and the nitrogenous bases worked together to make RNA in a cell.

I looked closely at the pink handouts with DNA pieces that contained Adenine (A), Guanine (G), Cytosine (C), and Thymine (T) and the white handouts with the RNA pieces that contained A, G, C and Uracil (U). For the purpose of demonstrating transcription and linking the bases, the bases assumed a symbolic shape that looked like rectangular puzzle pieces with one side with an "out" end and an "in" end on the opposite side as shown below. DNA bases are on the left and RNA bases are on the right:

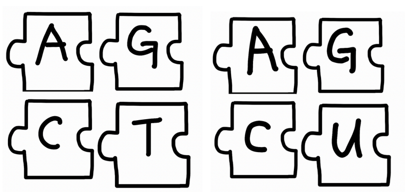


Figure 2: DNA and RNA Pieces

It looked to me as though all the small pieces from the three handouts needed to be cut before students could use them in the hands-on activity. Barbara's lecture was nearing its end. As she was wrapping up her lecture, she walked over to the table, picked up the stacks of papers, and passed them out to each row of students.

Barbara instructed her whole class, "Everyone, I want you to listen, while you cut out the pieces." Then, she took a seat on her special teacher-chair and began to tell a story. My gaze followed what students started to do as soon as Barbara told them to "listen and cut." Students began to reach for the plastic pencil box that was placed on their desks. There was one pencil box for every two students. Four or five students sat at each row. The pencil boxes contained school supplies such as scotch tape, rulers, scissors, glue, pencils, erasers, etc. Students were reaching for the pencil box to take out the scissors to cut out the pieces.

In between Barbara's pauses during her storytelling, I could hear the sound of paper cutting, "snip, snip, ssss." Then, I noticed Yvonne, an African American female student, reaching for Ravi's pieces and began to cut out his DNA pieces. I scanned the rest of the class and I saw that Jane, a White female student, was cutting out Han's DNA pieces. All the while, Ravi, a South Asian male student, was walking around the class from one group to the other, socializing and talking to his classmates, while Han, an East Asian male student was giggling over something with another classmate.

Barbara was an observant teacher, the type of teacher who did not seem to miss a beat, and nearly nothing went unnoticed in her class. She did not miss the interactions between Ravi and Yvonne and between Jane and Han. Barbara asked Jane and Yvonne why they were cutting the pieces for the boys. Jane, a White female student said, "it gives me an excuse to do something!" Barbara in her usual sarcastic yet playful manner, responded, "That's horrible. This will follow you to your adulthood and you will be folding laundry and doing dishes for your man because men can do that. They can do that to you. I have a friend who can never go to her kids' school events because she says, 'my husband can't watch the kids. He won't know what to do.' When you say your husband is going to babysit my kids tonight, they are his kids too. That's called being a dad! I kind of blame the boys' mothers' ideology here because you learn what you see at home."

When she finished her monologue, Barbara looked over at me with disbelief showing on her face and continued, "Ladies, I'd never marry someone who can't be a dad. We got to make changes here; starting now. Ravi and Lee – go cut your own pieces."

Cutting out the DNA pieces only took an additional 15 minutes and students finished quickly. Then, Barbara transitioned to the hands-on activity and demonstrated how DNA and

RNA bases aligned with their special pair. Students had to line up the correct bases to create the newly synthesized strands based on the pink template strand. As students were working on this activity, they began to realize that all hands were needed to coordinate this action of "pairing up the bases." It was a lot of hands-on, manual work that required one person placing the DNA base to create a template DNA strand, while another student lined up the RNA base and taped the two bases down together. In groups of 2 or 3, students took turns lining up the bases, tearing a piece of tape to tape down the bases onto the template DNA strand, and repeating the procedure until they reached the end of the template strand and completed the transcription process. No one was left out of the activity or was sitting idle during the activity. All students were huddled around where they had to place their template strand on the table and students completed the activity.

I took a moment to compare the two activities. Once the activity on demonstrating the DNA transcription process started, everyone was engaged and participating. There was no distinction between the tasks that girls were doing and the tasks that boys were doing during the science activity. However, the design of the activity necessitated the cutting of the DNA pieces as preparatory tasks and this preparatory work almost got away with being gendered, until the teacher brought the gendering of the activity to the forefront of the class discussion. Jane and Yvonne could have gotten away with cutting the DNA pieces for their boy partners; the boys could have gotten away with socializing, while their girl partners were doing prep work for them. However, Barbara explicitly called out the gendering of the activity and brought it to the attention of the class. In other words, the teacher's comments transformed the activity. She explained what Jane and Yvonne were doing for their male partners by articulating and drawing on a strong analogy of specific domestic responsibilities that a husband and a wife generally share in a household. Based on Jane's comment and Barbara's verbal instructions, cutting the paper pieces was not as meaningful as the science learning task itself. It was necessary to cut out the pieces, but the more meaningful and engaging part of the activity was carrying out the transcription process. In the later part of the activity, everybody had to be involved; however, when there were not many "meaningful" *things* to do other than mindlessly cutting the DNA pieces, gendering of the activity became possible.

** (part of glowing interactions set #2)

**Who shall color?** In my conversations with Barbara, she told me that she intentionally breaks up her lecture with storytelling so that students can take a mental break. During a lesson on waves, Barbara lectured for about an hour using wave diagrams. As usual, Barbara gave the students a break from listening to her lecture. She began telling a story on her special teacher-chair and students were given a task of coloring the absorption spectra with coloring pencils.

As she was telling one of her stories, students began to color. After about 10 minutes, Barbara got up from her special teacher chair, went to her computer, and projected a new diagram to pick up where she had left off in her lecture. Jane raised her hand, "Ms. Barbara, I am not done coloring yet. Can you give us 2 more minutes?" Barbara inquired, "Why aren't you done coloring?" And, Jane said, "I was coloring for Han." Barbara responded, "Whoa, I didn't know Han had a secretary here doing his bidding." As Barbara walked over to Jane's desk, she announced, "if you do this – girls, if you do this, we are perpetuating the stereotype of girls and boys." Ravi shouted out, "smart is the new sexy." Barbara responded, "Yes, I have a lot of hot girls in here and everyone is warned – we are a bunch of hot mess!" The class laughed but Barbara, in a firm tone stated, "Alright, I am waiting for our secretary to finish, but ladies, let the boys color their own coloring books." Jane with a big smile responded, "I'm done, Ms. Barbara!" Then, Barbara resumed with her lecture.

Just as I saw in the previous interaction during the DNA paper-cutting activity, Barbara explicitly called out what Jane was doing. What Jane was doing for Han could have remained in the background, but her actions to do *things* for her male partner became highlighted and brought to the foreground of the interactions in the class. Jane was not merely coloring for Han, but Barbara's words emphasized that Jane's actions were like that of a female secretary doing secretarial tasks. Here is an example of where *something,* an action, a word, an object, really anything (in this case Barbara's words) allows for one assemblage to transform into another following a line of flight that is quick, sudden and yet transformative. In terms of the line of flight in this particular moment in the classroom, Barbara's words brought Jane's actions to the forefront and they were transformed from being something normalized to something that should be resisted, instead. The DNA paper-cutting activity and the coloring activity showed that tasks that were viewed as less important to the actual science learning seemed to get shifted to female students. Tasks like cutting and coloring were not required to learn science. As the teacher pointed out, when a female student did these tasks for the boys, she was acting like a secretary, and she should not be.

****** (part of glowing interactions set #2)

**Who shall paint?** On the day when Barbara was teaching a unit on plants, students were conducting a leaf impression lab. Students filed neatly into the microscope lab and each took a seat at the microscope. Each student had his or her own microscope to use. The activity entailed observing and identifying stomata under the microscope. In order to examine a section of the leaf, Barbara instructed students to paint 1cm in width of the plant surface with the clear nail polish that was provided for the students. I could sense, saw and heard girls' excitement. Girls jokingly asked Barbara if they could paint their nails with the nail polish, but Barbara said no.

Barbara demonstrated how the nail polish could be used to create an impression of the leaf. The day before, Barbara had asked students to bring their own leaves so that they could compare different types of leaves. Barbara also prepared a standard leaf impression for everyone to see. Barbara said, "If you have used nail polish before, then you know that you need to wipe some off when you first dip so that you don't get it all over your nails!" Some of the girls yelled, "Cho has the best nails!" Cho, held up her bright orange nail extensions for the class to see. In the midst of the excitement, Cho and the girls sitting nearby dipped the end of the nail polish brush into the bottle, effortlessly wiped one side of the brush that flattened the clump of nail polish clinging onto the brush and, in a swift swiping-motion, began to paint the leaf. By contrast, there were boys who seemed to struggle with putting the nail polish on the leaf. I did not observe any girls experiencing difficulty in completing this task.

I was sitting near Lucas and Emma. Lucas was trying to paint the leaf as his torso and his face were leaning closely over his leaf, concentrating very hard to paint the tiny 1cm square. His hand was shaky as he was focused on placing the tip of the nail polish brush on the leaf. As Barbara predicted, clunky nail polish spilled over the leaf and onto the desk. Lucas continued to stay hunched over the leaf; the end of his nose was getting closer and closer to the leaf, the more he concentrated on the swiping motion that seemed to be effortless for Emma. Emma exclaimed, "Here! Let me!" Lucas said, "I know how to do this." Emma said, "I don't think you do!" Lucas responded, "Emma, I can do this. I know how to paint my nails" with a smile.

There might be high school boys who are familiar with using nail polish to paint their nails, but it might be a more common practice among their female peers. In this class, it was my observation that the girls were more comfortable with the task of using the nail polish and were more familiar with how to use nail polish properly (i.e., dipping the brush and then wiping the side). This appeared to reflect socialization based on gender. The majority of the girls in the class had either experience with applying polish to their own nails or had socialized with other girls who wore nail polish. Nail polish was part of their experience, which was significantly more common among the girls and not necessarily shared by the boys in the class. This is not to say that all girls or no boys will have had the experience; however, by the nature of how students are gendered, it influences the likelihood of them having such experiences that were relevant to this specific task of painting the leaf with nail polish.

**Glowing interaction #3: Not Everything is Always Bad or Good – On Dress Code**

There were three physical spaces where students could go during their AP Bio class: 1) the regular science classroom with the occasional trip to the project room, 2) the laboratory, and 3) the microscope lab. The microscope lab was technically designated as a lab space, but I observed that there was a different set of expectations for each of these three physical spaces. The dress code was not enforced in the classroom, project room, or the microscope lab. There were chairs to sit on in the classroom and the microscope lab, unlike the laboratory. In the lab, there were no chairs and dress codes were strictly enforced.

The dress code for the laboratory was made very clear to all students and was reinforced throughout the semester for safety reasons. The dress code that was enforced during students' laboratory sessions followed the standard practice by scientists and what was generally accepted as personal protective equipment and appropriate lab attire that I had to also follow when I was working in a higher education institution or a lab setting. An institution's appropriate lab attire would be specified by a list of what was allowed and not allowed to wear in a lab for safety precautions. For example, generally a list goes like this: long hair must be tied back and kept away from the eyes. Loose clothing items such as scarves and jewelry were not allowed. Baseball caps or other headgear were not allowed with the exception for religious reasons, but religious head coverings must be kept far back on the head so that vision is not impaired and there is no interference with protective eyewear. Shirts and tops must cover upper torso and long pants must be worn to cover the wearer to the ankle. Lastly, completely enclosed shoes must be worn.

From the beginning of the semester, Cho's outfits stood out from the rest of the students. She often wore short skirts with form fitting tops, while most students wore jeans and sweaters, or often sported their school t-shirts. One day, Cho walked into class in an outfit that one would wear to the beach: halter top and short shorts all designed into a one-suit outfit. Barbara said to Cho, "Cho! Come on! You know what I'm talking about, right?" Cho, as she walked by said, "Yes."

I cannot say if there were other dialogues between the teacher and Cho about the way she dresses. However, the way Cho dressed stood out among her peers from the first day of school. In later accounts, during a lab experiment involving Cho and her classmate Ravi, Ravi told Cho that she was like the kinky aunt in the family. Cho sported her *girly* style of fashion daily, at least up until this particular interaction with the teacher. The next day, Cho began wearing clothes that were fully covered up. After that, I would often see her wear long, grey sweat pants with hooded grey sweaters, or black t-shirts with a long gray sweater. Though I saw her sporting her own unique styles time to time, her way of dressing changed, and this change was significantly noticeable.

Safety concerns related to how one dresses in a lab are real and dress codes must be enforced to prevent exposures to hazardous agents and physical injury. Bodies must be covered up with appropriate clothing that function as an extra layer of protection against spills and splashes of hazardous materials. Cho's interaction highlighted the importance of covering up for the lab. For safety reasons, one could not walk into a lab wearing attire that seemed more suitable for a day at the beach. A teacher must enforce the appropriate lab attire to make sure that students do not get hurt. Thus, enforcing a dress code is not necessarily a good or a bad thing; it just is necessary. However, from my perspective, Barbara's enforcing of the dress code was transformed to strict policing of the female body and thus did not change the fact that dress code enforcement happened more commonly to girls than boys. This interaction also emphasized that the issue of dress code is not simple; in other words, it is not a matter of coming up with an intervention to start policing the male bodies more or just as much as the female bodies. Some of my observations in the classroom do not necessarily transition into an intervention or finding a solution. This example of enforcing dress code is one of those examples where gender indeed shapes the science classroom. As previously mentioned earlier, students' experience with science is *situated* in the practices and norms of *school science* as they are produced and re-produced in the science classroom. This account of enforcing a gendered dress code in laboratory reflected a culture of science that might position girls as unfit members of science, and thereby exclude them through othering. Not only did the teacher have a conversation with the class about an attire that was not appropriate within a laboratory setting (tank tops, long hairs, skirts, etc.) but also these examples of clothes were pointed out more commonly in girls than the boys in the class. Through these interactions, a gendered idea of the appropriate garments for a school science lab was established, and thereby producing and reproducing a pattern of practices and norms that were projected onto the perception of science, and not *just school science*. These cultural practices were shaped and impacted by the situated nature of actions, interactions and social relations among students, teachers, and also objects in the lab (i.e., bodies needed to be protected from dangerous chemicals), which in Cho's case impacted who she could be in science classes – Cho was not allowed to be the girly girl as represented in her style of fashion.

From a practical teacher perspective, I am not claiming that these examples of gender are bad or good. However, it is important to acknowledge these conditions under which gender can be actualized in science classes. Barbara's criticism of Cho's outfit drastically changed her clothing choices. Cho's style literally transformed overnight after hearing Barbara's criticism. She went from wearing ultra-feminine and revealing clothes to very masculine, loose-fitting clothes as a direct result of Barbara's comments. This example showed that when individuals walk into a science classroom, they cannot remain neutral. Gender influences the interactions. When teachers teach their students, they might not recognize the impact that their words and actions could have on the students. Thus, we need to account for this so that we are not marginalizing students who might not perform standard gender roles. Briefly here, the term standard is context-dependent. In a science laboratory, there are ways of expressing gender that are policed and not allowed (or at least not encouraged due to safety concerns). There are certain types of clothes that would make Cho a girly girl, which is shaped by social expectations by the students at the school. If she desires to fit in with these expectations she is limited in her ability to do so by her science class which does not allow her to express her gender this way. This form of identity comes, in part, from her desire to express a particular gender in a particular way. By standard, the researcher does not mean *correct*. At this school, there are common ways in which students express their gender. Because of the dress code students' ability to express their gender in this way was limited (more commonly for female students than male students in this example). This example suggests that being girly was considered inappropriate in the science classroom as it did not reflect the dress code norms in this context.

## Part 2: Race Glowing Interactions

### Glowing Interaction #4: "Well, That's a Plus!"

Barbara was getting ready to teach a lesson on genetics. As usual, Barbara spent about ten minutes delivering content. She began the lesson on how to read a genetics pedigree diagram. She projected a diagram of a family pedigree on her smartboard. As she was referring to the pedigree diagram, she stood in the center, front spot of the classroom, right below the sound system. During the lecture portion of the class, students were focused on taking notes either on their laptops or their notebooks. Students hardly spoke as they were too busy typing or writing down notes. They might have been listening to Barbara, but their eyes were fixated on their laptop screens, as the majority of the students were typing faster than I ever could in order to write down everything Barbara was saying verbatim. The students who were taking notes in their notebooks were looking down, busily scribbling away from left to right. They would occasionally look up from their notebook whenever Barbara would refer to something on the diagram.

As noted previously, Barbara had a routine of breaking up her lecture with storytelling. After an intensely focused twenty minutes of content delivery, Barbara stopped and started to tell a story. Her story-telling time always started with her taking a seat on her special teacher-chair that looked different from the students' chairs. Her teacher chair was as tall as the height of a bar stool and had a padded cushion with a mesh backing. In contrast, the students' chairs were not cushioned and had a hard-plastic backing. Though the students' chairs had four wheels on the bottom, their chairs did not go as high as Barbara's chair. Barbara usually parked her chair against the back wall of the classroom. When it was time for storytelling, Barbara would walk to the back of the room, grab her chair, roll it to the middle of the class and sit on it. Taking this as a cue, students would stop their note-taking and look up from their laptops or notebooks.

Barbara explained, "We get our chromosomes from Mom and Dad and that is why we look like our parents." I noticed that this particular topic sparked an interest, demonstrated via multiple shout-outs from the female students in the class. One female student said, "my hair is just like my mother's" while another female student said, "my skin color is fair like my mom's, but my dad's skin color is yellow!" Another female student said, "my eyes are green because of my mom and dad."

Barbara continued to lead the conversation about how offspring were produced and discussed how marriage was necessary, or not (she added), to produce offspring. She provided an example of infertility among married couples and how a couple could not have babies because of a type of DNA mutation. She shared her personal experience with in vitro fertilization and began to tell the class about her children who were carried by a surrogate who was Puerto Rican. Then, she shared with the class how her parents had asked if their grandchildren would speak Spanish. As the students broke out in light-hearted laughter, Barbara rhetorically responded, "No, of course, my children won't speak Spanish! It's like what my old boss experienced who was Korean but was adopted by a white couple. Every time she goes out, people speak Korean to her!" Barbara's voice faded out from my hearing and I overheard a female student ask Lucas, "Lucas, are you Hispanic?" Lucas responded, "yes, but that doesn't mean I speak Spanish. My mom always told me to learn Spanish, but it's too hard to learn and then when you come to high school you have to take a class on it!" This conversation also faded, and I overheard a random shouting of words in Korean by two non-Korean male students. Ravi, a South Asian male student, started yelling inappropriate words out loud in Korean, "Gae-Ssaet-Kki (S.O.B.)! Ggo-chu (weiner)!" while Dinh, a Southeast Asian male student, said out loud, "An-young (hello)! Babo (idiot)!" But, they quickly settled down on their own, and, they, too faded into the background noise of the classroom.

Here, I was following lines of flight as presented in the classroom. One moment, Barbara was talking about genetics to the whole class, which led to a smaller conversation between Lucas and his classmate. Then, my head jerked towards the sound of Ravi shouting out inappropriate words in Korean and Dinh playfully saying Korean words that had no relevance to the course. The discussion that the teacher Barbara brought up about the race of her surrogate acted as a launching point in a line of flight to normalize the discussions of race that might normally be excluded from the classrooms. However, bringing up this topic allowed the students who were interested to be able to talk about these issues in relation to the science content on genetic mutations (later interactions describe issues such as infertility, test tube babies, etc.). In the context of the curriculum, this particular discussion on race became an ok-topic to bring to the forefront of the classroom discussions as well as interactions – for the time being. Other interactions that took off in lines of flight were the dialogue around language. Race does not form a direct causal relationship with language. However, language can be influenced by race. For instance, Lucas, a Hispanic student, does not speak Spanish but other students assumed that he could. Barbara's old boss did not speak Korean, but others assumed that she was Korean and could speak the language. Examples such as this highlighted how language is often assumed to have come from one's race, but it clearly does not have to be part of one's race. Barbara's parents asking if their grandchildren would speak Spanish demonstrated the complex relationship between language and race that are perhaps presumed too quickly and too hastily. Also, Ravi and Dinh could not have said the same words in English without experiencing a very different response from the teacher. If a student yelled out words such as bastard, penis, idiot, I would imagine a very different response from a teacher. I wrote next to Ravi and Dinh, "Looks weirdly satisfied." Language can be empowering in a strange way. Ravi and Dinh seemed quite pleased that they *could* shout these words out without suffering a normal consequence when one shouts out inappropriate words in class.

All the while, Barbara briskly walked over to her filing cabinet and pulled out a photo. The size of the picture was about 4 inches by 3 inches and it was a black and white photo of 4-5 embryos in a clear, round petri dish. As she passed the picture around the class, Barbara began to explain that shared genetic material between relatives could be telling evidence.

I could sense that the entire class was focused on Barbara, as the noise level went down, and I could hear the students' breathing while they listened to Barbara. Barbara continued with her story explaining that her children were once embryos in a petri dish. She explained that she took the pictures under a microscope and told the class how adorable she thought the embryos were. Marcus, an African American male student shouted out, "They are good looking embryos!"

A group of female students sitting to my right was whispering and appeared confused. One girl looked at the classmate sitting next to her and shrugged her shoulders, as if that other student had asked her a question that she could not answer. Meanwhile, Barbara continued to explain that during in vitro fertilization the two embryos that "took up" became her children. Barbara described in detail the process of in vitro fertilization. In vitro fertilization required harvesting the male's sperm and the female's eggs to fertilize the egg in vitro. Then, she re-emphasized that two out of the four embryos from that petri dish "took up." One student asked, "Whose are the other two?" Barbara replied, "I don't know whose they are, or where they went, but I know those other two aren't mine!"

Zola, an African American female student, who was among the girls who looked confused, raised her hand and asked how Barbara was able to get the pictures. Barbara responded matter-of-factly, "under the microscope! You take the fertilized embryos and look at them under the microscope and you can take a picture." That answer seemed to have satisfied the group of girls who appeared to be confused.

Another female student asked, but I heard uncertainty in her voice by how she asked her question in a very timid and quiet way, "Is calling someone a test tube baby a rude thing?" Barbara replied, "It's not if you don't mean it that way, but I'm not the queen of political correctness." Another female student raised her hand but quickly put it down. Barbara saw the girl and encouraged her, "Go ahead. What did you want to ask me? I'm okay with sharing this experience. It's okay – ask me what you want to ask me." The female student, in a very soft voice, asked why Barbara did not want the baby to grow in her. That's when Barbara explained that she lacked the proper protein that facilitated the attachment of the embryo to the uterus due to a DNA mutation. Using the concept of cell cycling, which was a topic being taught that day, Barbara elaborated that communication for the embryo's attachment must occur. However, the proper protein was needed, but Barbara explained, "I somehow didn't have the protein. There was a mutation, and so I had my children carried by my friend."

Zola said innocently, "That's cool that you have someone you can just call up and say, 'hey can you carry my baby?" To her comment, the class in union shouted, "Zola! Stop!" A female student sarcastically said, “And…. we are done.” Zola light-heartedly responded, “I’m trying to make light of the situation!” Two male students said to Zola, “You really don’t have ways with your words. Zola, sometimes it’s too much.” Zola defensively replied, “Well, it wasn’t for her.”

As an effort to smooth over the moment, Barbara added, “Well, my children don’t look like me. They don’t have my eyes or my hair color, except that they *are* white!” And immediately, Zola shouts out, “Well, that’s a plus!” Barbara, in disbelief, shouted, “No, it’s not!” I heard a collective expression of horrified gasps. Another female student shouted out across the room breaking the silence, “Zola, stop talking.” Looking exasperated, Barbara moved onto the next class activity.

The interactions between Zola and Barbara demonstrated a moment of transition. The discussion on race in the context of science (i.e., topic of race in the context of in vitro fertilization) was okay but it became no longer okay when the conversations became personal not only to the teacher but to the girls, and potentially to the rest of the class. According to Barbara’s description of her experience with in vitro fertilization using her eggs and her husband’s sperms, and the fact that her children did not look like her could mean that Barbara most likely had a gestational carrier whose genetic materials cannot be passed onto her children. By contrast, a traditional surrogate can pass her own genetic materials through her own egg and the father’s sperm are fertilized with the surrogate mother’s egg. The fertilized embryo is then carried to term by the surrogate mother. Provided that Barbara specified how her eggs were used, her children should look like her. From my perspective, there were some inconsistencies in terms of science (more than likely, Barbara was using a more commonly used term, surrogate, for the ease of the classroom discussion). However, this interaction demonstrated a way in which science specifically allowed these topics on race to come up in class and be relevant to science content on genetics, birthing, etc.

This particular topic on race as it relates to the scientific process of in vitro fertilization and the biology of birthing would not be possible to discuss openly in other classes (non-science classes). Barbara's exaggerated outburst that the only way that her children resembled her was that they were white, warrants, to a certain degree, Zola's response. Barbara said that her children did not look anything like her (i.e., negative) *except* that they were White. It appeared as though being White was the only thing that was *present* (i.e., positive) in her children that could be related back to her. This is one way that Zola's response could be understood, which, in fact, Zola claimed was her original meaning behind her comment. However, the rest of the interactions showed me that Zola's comment was perceived very differently. Coupled with Barbara's parents' comments about whether their grandchildren would speak Spanish or not, Zola's response to Barbara strongly points to the complexities of race. Zola's comment about how being white was a plus became a catalyst for the tensions observed in the classroom. The interactions among Zola, the teacher and the rest of Zola's classmates highlighted a contentious issue. The spoken comment that looking white can indeed be advantageous runs counter to the assumption that all races are equal. This interaction seems especially relevant because of the school environment that I observed at this school. The culture of the school overall emphasized how *everyone* at this school was special, extraordinary and can succeed.

Barbara settled down the class for the next hands-on activity on DNA recombination. The activity involved counting the number of recombinant crossovers in Sordaria, a type of fungus. Dinh asked, "Ms. Barbara, what is a good number to count?" Barbara answered, "That's not the point of this activity. There isn't a good number. What you are asking is like asking ‘what’s a good hair *length*?’” To this, Zola perked up yet again, and said, “blonde!” Once again, her classmates all turned to her showing expressions of disbelief and amazement, and one female student iterated, “Zola, did you just say *blonde*?” The female student was rolling her eyes and shaking her head.

“Saved by the bell,” I wrote in my note. The class bell rang, and Barbara dismissed the class. Students started to file out of the classroom. I packed up my things and I made my way to my next classroom observation. That was when I overheard Zola and her group of girlfriends talking, “I think it’s sad. I think she was sad about it. Something about that process is sad and that’s why I was trying to make light of the situation!”

Here, I think it is relevant to describe Zola and the type of student she is from my observations. Zola identifies herself as African American. On several occasions I noticed that she had to prove herself to her classmates. I observed her interactions with two other female students during a lab experiment that was particularly challenging for most students due to the complicated lab protocol. Even though Zola was the only one who understood the procedure well, the two other classmates quickly dismissed her suggestions on every step of the lab protocol.

In my conversation with Zola about that particular lab experience, I learned that she often conducted study sessions where more than twenty students would attend. She was an A student, but she told me that she was often “put down” in class by her classmates when she raised her hand to answer the teacher’s question, or when she tried to contribute to the class discussion. From my frequent conversations with her, she revealed to me:

> Last year, I had straight A’s in all my classes. That’s really hard to do. I think only fifty kids did that. The problem is that in the beginning people were

> doubting me. They didn't really talk to me. I don't know if it's because I'm black or if they just don't want to talk to me, they didn't have a good day, or maybe their grandma died. I have no idea. Then, as soon as they figured out I was actually intelligent by some sort of means, people started treating me differently. I don't know what intelligence is and I don't know how people define intelligence. I define it as having some kind of strong common sense in you. I don't know if it was because of the breakfast thing. But I went to the freshmen honor's breakfast thing. You can if you got straight A's. Now, that's where the 80% of my Asian friends are coming from. If I wasn't in that, I probably would be sad."

During my conversation with Zola, I asked her about my observation of the conversations that she had after the genetics lesson. Zola responded,

> Let me explain. I explained this to so many people already. Basically, I was saying some children don't even look like their parents. So, the children looked like her, which is what she said. Ms. Barbara is White, because people will say what they are. The baby couldn't come from Ms. Barbara, or at least, didn't feel like they did… Anyways, when she said that her children looked like her, I said that's a plus that at least the children look like you, as in, at least you have someone that looks exactly like *you*. Maybe she could have found a surrogate who was even more Hispanic or have a different appearance, but her children are White *like* her. Okay. That's what I meant.

Zola's response was interesting to me; it was as if I was reading her response written on a "Mobius strip" that transitioned from her "original" interpretation of her own comment to the interpretation perceived by her classmates on *race*. Barbara had explained how her children did not look like her, but Zola was starting to equate *appearance* and looking like someone in terms of race. Ms. Barbara is White. Her children are White. Therefore, from Zola's perspective, in the presence of negative evidence (i.e., children not taking after Barbara), being *white* was a plus (or a positive) because *that, being white,* was what allowed them to look like Barbara. From Zola's perspective, being of the same race as someone else meant that you both look alike even though the physical facial features of each person may be completely dissimilar. However, from my perspective, her response during my conversation with her was her way of trying to explain what seemed to have upset her classmates and her teacher. Her comment about the children's whiteness being a good thing carries a different interpretation when I consider Zola's other comment about being *blonde*. I remembered specifically that Dinh asked what a good hair *length* was and did not ask about hair *color*. However, Zola shouted out *blonde* and Zola's comment that being white was a *plus* could mean something else than what she was trying to *explain*, rather; and, this was precisely how the rest of her classmates and Barbara perceived her comment and thus responded accordingly by silencing her.

**A Set of Glowing Interactions #5: Sanitized Way of Discussing Race is to Embed the Discussion as Part of the Curriculum**

**Asian earwax.** During the same genetics lesson as described above, there were also discussions about earwax. Barbara said, "earwax is gross. My earwax is gross. Your earwax is gross. Asian people tend to have crumbly, dry earwax, while non-Asian people tend to have sticky, yellow earwax. My husband has sticky gross ear wax, and that's the end of our ear wax discussion because they are gross."

The discussion was about Asian earwax versus other earwaxes. Although this interaction focused on something about being Asian, it did not really deal with anything about being Asian that was particularly impactful. The dryness of Asian earwax was a tangential way to bring race into the discussion; however, the topic was not dangerous nor was it highly politicized. The Asian earwax as an example was simple; and nobody was going to argue about the dryness of Asian earwax.

Similarly, discussions where race became relevant were often embedded in the science curriculum and, in doing so, these discussions were often presented to the students in a *sanitized* way. The topic of race that came up in the context of earwax was highly policed and it was acceptable for topics such as Asian earwax to be discussed because it was part of the science curriculum. It was a way to demonstrate how biology worked and how genes worked to produce different types of earwax. This interaction did not have enough force to impact students' experience in the science classroom, or their racial identity -- for the time being. This interaction was not necessarily an actualization of race as part of a student's identity but a form of actualizing a version of race that was safe and sanitized. Notwithstanding, Barbara made the discussion acceptable to be had in the class, but it soon became a springboard, or a jumping off point for talking about the appearance of her children, which led to a significant actualization of race and thereby catalyzing a meaningful discussion on race.

****** (part of glowing interactions set #5)

**Let's both talk about x-rays, physics, and having brown parents.** In Barbara's class, the topic of DNA mutations was being discussed. This topic brought up a lively class discussion about microwaves, x-rays at dental offices, and tanning beds, and how those different types of waves could cause mutations in human bodies.

Barbara began the discussion by sharing her experience with the class, again through storytelling. Barbara said, "Don't get x rays every time you go to the dentist office." Zola raised her hand and shared with the class how she had researched the amount of radiation that one received from flying for two hours and found that it was equivalent to two years of radiation exposure. Then, another female student started to have a small side-chat with friends about skin cancer from the sun. Overhearing this conversation, Barbara joked that the students at this school did not need to use tanning beds because they did not have the problem of not having enough pigment. To this, Priya, an Indian American female student, added, "My physics teacher used to always say that she was the only white person in the room. And, my friend is Black, and she used to also always say that she was the darkest one in the whole class! We had to do a project in that class, and during a group presentation, there was one group that was composed of all Asian students and they called themselves the 'Asian gang.'

In the same class period, Priya and Ravi talked about how Brown parents have certain characteristics. Ravi said, "Brown parents are particular about weird rules. My mom told me not to stand in front of a microwave because of radiation, or not to watch TV so close." Han responded, "But she was right! You are not supposed to watch TV up close."

These short, quick, back-to-back conversations during which students highlighted their own skin tone are examples of student-led discussions that were mostly safe without the tensions noted in previous accounts on race. Though short, this interaction revealed even the smallest ways by which race could show up in science classes. Priya and Ravi were ascribing their skin tone to the particular ways that *things* were done such as having rules about not standing in front of a microwave or not watching TV up close. Most importantly, students as well as the teachers were aware of the fact that the school's student population was mostly Asian/Asian American.

As previously mentioned, interview data were treated as being able to provide context. Interview data from the students in this study provided further insights into how students think about race and ethnicities. During an interview with Esther, an East Asian female student, she explained how the school lunchroom was organized into groups. Esther said:

> If you haven't noticed, people group themselves by their ethnicities. It's more like their pride of their culture that makes them. If they looked a little more Asian, like, they go with the Asian groups. I saw a lot of people who looked more Americanized. So, they went with American groups.

I asked Esther what she meant by American. She replied:

> You know, American as in White. White goes with the White and it's usually the skin color. Unless they are Black, then they go with the Black. Look at me (as she was pointing to her hand), I'm yellow! (laughter).

In another interview with Lu, an East Asian female student, she said something similar:

> I don't know why it's super bad at our school, but kids just click together based on tight friendship groups, like their ethnicity. It's super annoying for me because I don't really like that. The super tight groups are the Asian kids. Don't you come from an Asian family, too, Ms. Jeong?

Priya, Indian American female student, said:

> Usually, there is a table of us, Indian, or Indian Americans. And then, there is a table ahead of us that would be all Asians. Sometimes it's not but probably the same ethnic groups kind of tend to be friends with each other.

And, Dinh, Southeast Asian male student, said:

> A lot of the South Asian people hang out together, and Koreans usually hang out together, too. That's just the way they are because they have similar interests, I'm sure. Because sometimes, I like to mix, so one of us goes over there if we have something to say. It would be the same if they have something to say, they would come over to us.

Typically, the discussion of skin tone or skin color would not be acceptable in other settings. What Esther said about her skin tone being yellow is considered politically incorrect in present day. I was shocked as she pointed to her hand and told me that she was yellow. The word yellow was almost as bad as the word *oriental* which is no longer an acceptable term to describe an individual belonging to a particular ethnic group. However, using the science curriculum as a launching point, race and skin tone were allowed to be discussed in the science classroom, as when Priya openly talked about her physics class and what her White physics teacher said about being the only white person in the classroom.

Because interview data were used to gain insights into contexts outside of the science classroom, what students said about grouping by ethnicities and their perceptions of how "bad" these groupings were at this school were not a significant part of the discussion in this study. However, examples of such grouping would reveal territorialization and de-territorialization of communities among students based on skin tone or ethnicities. In a different context, the lunchroom would be an interesting physical space to study how race would be actualized by tracing how these associations are formed, maintained, and broken-up. What Dinh said could become an interesting example of de-territorialization and re-territorialization.

** (part of glowing interactions set #5)

**There are only you and I who have blue eyes!** Lauren, a White female student in Molly's AP biology class shared similar observations about students and teachers alike, noticing race in the classroom.

This interaction occurred during one of the laboratory experiments. Lauren and her group were finishing up an experiment. They had finished earlier than most of the other students. Lauren and her friends started to talk about going to the school dance and needing to buy tickets. Lauren was avidly sharing with her friends how she did not want to assume that her guy friend (her date for the dance) would buy her ticket because then "that would be assuming gender roles." Lauren asked Jose, "Jose, I like having options. If I let my date buy my ticket, then does that mean that I am dating him?" Molly, listening in on this conversation nearby, said to Lauren, "Lauren, you tell him that you bought your own ticket and tell him that you are excited about the dance and just go! Take control!" Molly did a fist pump demonstrating empowerment. Molly elaborated, "Tell him you bought your ticket." Lauren said, "My date doesn't call or text back. But, I guess that's a small type of drama compared to other schools where a 9th grader gets pregnant or there's a fight in the bathroom, or a drug bust." Her friends chimed in and agreed that the students at this school were all nerds and the biggest drama they had to deal with was getting good grades. Then, all of a sudden, Lauren pointed out, "Hey, everyone here is black-haired or black eyed, except me and Ms. Molly!" Here, the sudden jump from the discussion about how bad other schools were to the discussion about how students at this school looked like (i.e., their physical appearance) was fairly significant from my perspective. From interviewing Lauren, I knew that she attended a middle school that did not have high populations of Asian/Asian American students. Every student I spoke with referred to what they called their home school, which was the school that they would have attended if they did not obtain admission to this STEM school. Lauren mentioned that her home school was a school known to attract students who wanted to play football in college and thus attracted kids who were not interested in academics. So, she said her friends who attend her home school had to deal with these students who were not disciplined. Knowing this context and understanding what Lauren was referring to when she said other schools had worse drama, this transition, as sudden and brief as it was, was an actualization of race. What followed after Lauren's comment was Quinton's response. Quinton, an African American male student responded, "You can't have black eyes! That's not genetically possible. Right, Ms. Molly? You can't have black yes!" Molly responded, "Yes, you can have black eyes, purple eyes – it's rare, but you can." Following this discussion on eye color, the conversations began to fade and then stopped as students started to pack up their things, waiting for the class bell.

The next day was a regular day of lecture. Molly had prepared a lesson on chromosomes and genes. For about twenty minutes, Molly was delivering a lecture on wildtypes versus mutant genes. John, a White male student, raised his hand and asked, "How do you make wildtype flies mate with the mutant flies when they look like *that*?" pointing to the short-winged, red-eyed mutant *Drosophila* flies. In response, Molly began to describe the process of culturing the flies together in a flask with a food source in order to force cross breeding to occur between the wildtype and the mutants. John said, "Isn't it messed up to force the wildtype to mate with the gross looking mutant flies?" Esther, an East Asian female student, turned around and faced John, "John, are you saying different is gross? I get you, John. I see what you are saying." John said, "No, all I am saying is that there is a good difference and a bad difference. *That* looks like a bad difference." And Ali, a South Asian male student shouted out saying, "We all know the right difference is White!"

Several days later, Molly's class moved onto a unit on biochemistry and chemical compounds. Lauren had a question about formaldehyde. Molly explained that formaldehyde was a compound that caused cancer and was used on dead bodies to preserve them. Lauren asked, "Why does it matter if it causes cancer if the bodies are already dead?" Molly explained that, "Well, if my job is to bond these bodies then I would be exposed to the chemical and I would be at risk." To this comment, Bill, a White male student, quickly responded, "If you are Mexican, then you get that kind of job!" He was laughing out loud causing other students to look up from what they were doing. Molly indignantly said, "I have family members who were morticians!" as she was pointing to herself. Without having any transparent connections, Billy disregarded this discussion and continued to bring up a completely different topic, "We should be doing an experiment on gerbils by putting oxygen via IV to their vein. Why can't we do that?" Molly simply had an expression of disbelief and did not respond to Billy. Lauren said, "If I were your teacher, I'd be sending you to a counselor right now. But then again, they would be just like, 'Oh it's Bill.'"

** (part of glowing interactions set #5)

**Let me tell you who you are going to be.** The following interaction was during a lab in Barbara's class. As usual, I was walking around observing the activities and listening in on the students' conversations. I was standing behind Zola's group who was about to finish up their lab experiments and I had been observing the tension and struggles between Zola and the rest of her group (this interaction was described in the context of introducing Zola during glowing interaction #4). Ravi's group was working on their experiment on the lab table directly across from where I was standing. I noticed that Ravi's group was also finishing up the experiment. As Cho and Jane were cleaning up the experiments, Ravi began to impose a very specific racial identity onto each of his classmates, *unprompted*. To Jane, a White female student, Ravi stated, "Jane, you are like the Mom. You take care of everyone." To Cho, a Vietnamese American female student, Ravi said "Cho, you are like the kinky aunt. Cho, pull up your shirt, girl. I'm doing this for you. Pull up your shirt" as he pulled *back* Cho's shirt so that it was not hanging off her shoulders. To Han, a Chinese male student, Ravi commented, "You are like that cousin who is super genius and is just out there." To Thomas, a White male student, Ravi said "You are just smart." To himself, Ravi shouted, "And, I am brown! And there are only three pairs of blue eyes and blonds in this class and the rest of us are brown! Haha!"

Here, the goal of these accounts is to show, instead of tell. However, at the end of each set of glowing data, sometimes it is useful to provide some account of commentary about how to think of these interactions in light of my overall study and how these social constructs of gender and race are being shown to actualize in each of these accounts. In this particular set of interactions #5, the topic of race began from curricular materials, but these experiences moved quickly away from the curriculum. A lot of *things* about race might not be ok to say out loud. However, some *things* about race emerged from the curriculum where students were allowed to say them out loud and no one seemed to stop them.

The last account where Ravi imposed identities onto his peers came out of nowhere; it was sudden, and I could not pin point where this conversation began. As such, this account provides a transition to the next set of glowing interactions #6 that include interactions that emerged in the classroom in an unexpected manner.

**A Set of Glowing Interactions #6: Conversations Surrounding Race Take Lines of Flight That Appeared to be Unexpected, Demanding Quick Attention of the Observer**

The actualization of race worked very differently than how gender was actualized in the classroom. For instance, in glowing data on gender, the interactions seemed obvious and apparent that an observer could see gender being actualized (i.e., sink). In glowing data on race, these interactions seemed more like explosions of unexpected and unanticipated outbursts, which often took off in different directions from where they had started (i.e., the science curriculum). The next set of interactions contains examples of unexpected outbursts of conversations revolving around race. Race was discursively performed and was presented in a very explicit and direct manner. These discursive actualizations of race often emerged from the interactions among students in a manner such that other students could internalize these conversations. The majority of these interactions were spontaneous. As the listener who was trying to follow one interaction from the other, I felt that these interactions had no particular origins or directions. In this sense, students jumped from one topic to another and it was difficult to define a starting place from where these conversations even began or how, or why. The lines of flight by which these discursive performances of race followed were sudden, quick, hopping from one node to another and even making it hard to follow at times. Therefore, the accounts provided in the set #6 do not necessarily have reasonable transitions in between each account to show the unexpected nature of how the actualization of race emerged in the science classroom.

** (part of glowing interactions set #6)

**Examples of unexpected outbursts.** Sometimes conversations on race were unexpected. In the case with Elif, a Muslim female student, she was talking with her friend, who came into class and sat next to her, about people being racist and the way she was treated before coming to the school because of her religion. Elif looked up and saw that Molly was interested in the conversation, and said, “Ms. Molly, I am a survivor!” Molly responded with a smile.

The bell rang, and students took their seats. That day was an easy day for the students, since Molly instructed them to finish up the worksheet that they had started during the previous class. As students started to work in groups, Vikram, Aisha and surrounding students began to compare each other to grocery stores. Aisha, an African American female student, pointed to Lee, a Korean American male student and said, “You are a Walmart.” Vikram, an Indian American male student said, “There’s 1.3 billion Indian people in the world, and my people are good at yoga, so I’m a Sam’s club. Lee, you are a Costco, because there are tons of Asians at Costco. Haha!” Aisha says, “Then I’m a Walgreen. My people have been here forever.” Overhearing this conversation, Ali, a Pakistani American male student, who was sitting on the opposite side of the class shouted, “Black Muslim women have it the worst. I feel for the Black Muslim women. Yeah, that’s right! Minorities can get on the team too. White supremacy!” Then, Lauren says, “Well, then, patriarchy!”

****** (part of glowing interactions set #6)

**Sit down, brown person!** During one of Barbara’s class, her sound system was not working, and her speakers were making funny noises. Barbara asked the class, “Trouble shooting tips?” And students tried to offer tips. Dinh, an East Asian male student shouted to Thomas, “Bro, go help her!” Both Thomas and Ravi got up at the same time to help Barbara but Dinh shouted at Ravi, “Sit down, Brown person. It’s always the White people that get to help and not Brown people.” Ravi laughed and sat back down.

I looked up from my field observation notebook, looked at Dinh and Ravi, and then looked over at Barbara and Thomas as he was hovering over her computer to trouble shoot the sound system. Barbara and Thomas were focusing their attention on fixing the sound system, but there was a non-response from Barbara to these unexpected outbursts from Dinh to Ravi. Though Dinh's quip sounded humorous and Ravi responded to it with a light laughter, these unchecked outbursts was yet another example of how quick and suddenly race could be actualized in the classroom.

** (part of glowing interactions set #6)

**It's just a video or a word on an iPhone.** Ali and Bill have had an unexpected outburst in class about race. Bill openly talked about being racist and had earlier stated, "I don't care if you are brown, white, or purple. I am racist even against white people." Ali joked and said to Bill, "Are you being racist because of my religion?"

One day, Ali walked into the classroom shouting, "I am a big Brown boy, and no one is going to mess with my stuff." This interaction was observed by Molly who noticed that Ali did not seem to care that his backpack was left in the hallway during a fire drill. Ali said, "You see, Ms. Molly, I told you that my bag would be still here." Molly said, "That's one of the nice things about this school. If you had left your bag at another school, it would've been stolen already." Ali said, "It's not the school, Ms. Molly. People know that's my bag and you'd be stupid to mess with a 6 feet tall big brown boy."

Turning her attention from Ali to the rest of her class, Molly had her students settle down after the fire drill. As a result of the fire drill, the class routine was disrupted. Students could not seem to concentrate. So, instead of carrying on with her lecture Molly gave students a choice of either updating their lab notebook or finishing a worksheet. Bill and Ali were out of their seats and were standing in the back of the classroom. They were watching a video clip that was posted to social media and sharing a headphone to watch the video on Ali's phone. The two boys were giggling, as they were watching the video, while they were standing behind, inches away from Quinton, an African American male student. Ali made a comment as he was watching the video clip exclaiming, “The idiot who is protesting his freedom of speech in front of his yard is Black!” Ali then laughed when the man set himself on fire in the video.

On a different occasion, Ali and Bill googled on Ali’s phone an inappropriate word in Vietnamese that was meant to be degrading. Ali and Bill were acting disruptively, being loud, joking and laughing, as they were looking at the word on the phone. Tugba, a West Asian female student, wanted to concentrate on the lesson on cell signaling. However, Ali and Bill who were sitting in front of her, were distracting, and Molly, the teacher, did nothing to curb their behavior at this time.

Tugba told Bill, “Bill, we are trying to talk about the foundation of cell signaling. You are being a distraction.” Ali turned around and in a very caustic tone exclaimed, “Tugba, this is none of your business. What do you care?” Tugba and the friends around her became very quiet.

As the cell signaling lesson continued, Bill started to say, “Vietnam kills Vietnam; Korea kills Korea; China kills China. Can we just blame China for everything? Blame China since they’ve been angry at the rest of the world. They took over Korea. They took over everything.” Ali giggled as Bill made these statements. Grace and Yumi, the two Korean female students who were sitting in front of them looked uncomfortable, but Grace turned around and gave Bill a frowning look and returned to focus on taking notes.

Bill and Ali’s goofing off continued and Bill said a bad word out loud in Vietnamese, “Poong…”. And Molly said, “Don’t say that. That’s a very bad and ugly word.” Bill responded, “But, it’s also the name of a city in Vietnam!” Bill turned to Vu, “Why do Vietnamese hate

Japanese?" Vu, a Vietnamese American male student, replied in a quiet voice, "because of colonization." Bill squawked, "That's it? But that was hundreds of years ago! Geesh!"

It appears that there are two ways to differentiate between the types of interactions where race became actualized. For the most part, race was discursively performed. However, one such interaction was where race came up in a sanitized manner when the discussion was embedded in the science curriculum. Anything that might make anyone feel bad, concerned, or uncomfortable was removed. Instead, race was presented through examples in the school curriculum. For example, it was acceptable to bring up Asian earwax versus White earwax because these discussions were embedded in the curriculum. Race was directly connected to a science topic rather than discussed as a societal issue, which made the controversial implications of race more palatable for both the students and the teacher. By contrast, a lot of *things* about race that were spoken out loud in glowing data #6 felt explicit and direct, and made the students around the speaker(s) uncomfortable. Unlike the issues in relation to race that emerged from the curriculum, students' outbursts were checked and policed when the comments began to appear inappropriate.

**Glowing Interaction #7: When Some *Things* Do Not Seem to Show or Become Visible: On not *Obvious* Interactions or Observations of Asian American Girls**

Yumi and Gracie, Korean female students, were the focus of my observations in Molly's class. However, day after day, my observations of them were the same. They were quiet. They were always on task. They finished work early. They also seemed to be doing well in class. In laboratory experiments, Gracie and Yumi were often paired up with other studious students. They were efficient in carrying out lab experiments. They seemed to always turn in their homework fully completed, but I never heard them speak in class other than a few words here and there when they were working in peer groups.

Esther was more vocal about her Korean heritage. She would sing nursery rhymes in Korean out loud, unprompted, in class and during lab, which happened often enough that classmates sitting next to and around her seemed to have learned to ignore her. She would play Korean computer games on her laptop during class. She would count out loud in Korean. When Esther was in the same lab group with Yumi, they had to share their graphs with each other. During group work time, Esther said to Yumi "I will send you my graph" in Korean. However, Yumi turned away from Esther and did not respond to Esther. A few minutes later, Yumi discussed the lab findings with Esther in English. Esther seemed more comfortable with speaking in Korean than Yumi, even though Yumi was a Korean immigrant who came to the States when she was a young child. By contrast, Esther came from a bilingual family background; her parents both spoke English and Korean and Esther could not distinguish which language she had learned first.

Whenever the topic of K-pop (Korean pop songs) came up among her classmates, Esther loved talking about it. She especially liked to discuss it with Lauren, a White female student who was into Manga and K-pop. However, Gracie and Yumi never participated in the conversation. As a matter of fact, they turned away when these conversations came up. During a lab experiment, Bill's group was testing the effect of different types of music on living specimens. Bill's group tried different types of songs such as jazz, country, and k-pop music. When Lauren turned up the volume on the k-pop music, Bill said, "I won't deface myself with the likes of that music." Ignoring Bill, Lauren asked the teacher, "Ms. Molly, do you know K-pop? I think it's great" and other students around Lauren agreed how popular K-pop culture was at this school, including Esther. However, Yumi and Gracie, who were standing right behind the group of students, did not join in on the conversation.

During Molly's lectures, Yumi and Gracie were always very quiet. However, during my conversation with Gracie she revealed that she was not quiet in other classes. Rather, she noted that she was very talkative in her other classes. One of the few times I saw Gracie speak more than a few words was when she was avidly talking with another officer about planning the school dance. Gracie elaborated on her experiences being on the student council:

> [Student council] is a lot of fun because every month, we do an event. We are planning the Spring Dance. Last year, I also got to go to prom just to serve food. On top of that, there were just a bunch of smaller events and it was a lot of fun and I wanted to continue doing it again.

In my conversation with Bill, he pointed out that Gracie held a high-ranking officer's position in the student government and was probably the smartest girl in Ms. Molly's class. When I asked Bill why I had not seen any students interact with Gracie, Bill smiled and said, "That's because we communicate virtually on G-Chat. Also, we text each other a lot." Bill continued, "Gracie is the first person we all go to for help. She knows everything." By contrast, in my conversation with Gracie, she revealed to me, "I am the last one to get my materials, or the last one to get into the lab." I was surprised to hear her response because Gracie and her group were always on task and never seemed to have any struggles during lab. In fact, when Yumi's group was struggling with a lab that was particularly challenging for all students, Gracie's group finished first and Gracie walked through the steps of the experiment with Yumi's group so that they could finish on time.

It was during my conversations with Gracie, Yumi, and Esther that it became apparent that even though they were always attentive in class and were on task during lab experiments, they each had unique struggles in AP biology. Gracie revealed her challenges with listening in her AP Bio class:

> "Also, I am not good at listening to verbal instructions. Ms. Molly would say things and give instructions, but I won't listen until the very last step and then, I'm like, 'oh no, what's going on?' I will just read over the print outs and be like, 'I guess this is it.' I don't know if it has to do with me being tired. Usually, when Ms. Molly gives me verbal instructions, I just can't focus. [laughs]. I am definitely quieter in Bio, but I am vocal in other classes. I don't know why… I just am."

In my conversation with Esther, she told me that even though her father is a White American, she's always felt disadvantaged with speaking and reading in English, because she didn't consider herself a native English speaker. Esther was having a hard time reading the large volume of texts for AP Biology. Esther revealed to me:

> "Biology has been very tough for me because it's hard. I don't grasp and understand the concepts because, as I tell everyone, and it's not an excuse, but I am not a normal kid who grew up in America and who reads the textbook and gets it. I have to read the book twice more than that normal child. I have to read it three or four times more to understand what's actually going on."

Though I observed day after day Yumi diligently taking notes on her laptop during Molly's lectures, Yumi revealed to me that she was failing AP Biology.

> I'm usually always tired. That's the difference from middle school. I'm a lot more tired and kind of check out. I'm really bad at time management, too. I should make up for what I didn't get in class, but I don't do that because I don't know how to manage my time and how to make time to study. I don't know if you know, but a lot of my Korean peers, they go to Hak-won, Korean tutoring, because the math they do is so advanced. It was like nothing I have seen before. But, my peers, since that's what they have been doing the whole time, it occurred more naturally for them and Korean teachers assigned more homework. I can't necessarily get through all of it. Reading is hard for me, so reading in bio takes a really long time. English is my second language even though I've been living here a long time. Reading just doesn't come naturally and it's a big issue. So, I don't read the chapters; it just leaves my brain and I don't retain a lot.

When I asked Yumi and Esther if they had plans to seek tutorial help, they both said they would not seek help because that would be embarrassing. Although Yumi, Gracie, and Esther fit the description of a good science student, they were struggling tremendously in the AP biology class. Gracie, who was maintaining a relatively high grade in AP biology, preferred to pursue business as her future career. Esther explicitly stated her hatred for science and Yumi said she had lost interest in science because "science seemed to be only about random facts."

In terms of the Korean American girls, tools such as G-chat made it possible for these students to be engaged in ways that were not obvious to the researcher at first. These interactions occurred in this virtual space such as G-chat that were not obvious to the observer. For instance, I would never have known that Gracie was the go-to person in the AP biology class and that her peers perceived her as the good science student. Her peers' perception of her was different from her own perception, or her own science identity, which she discussed during the interview. Nonetheless, what I learned through the interview became a critical part of understanding the classroom dynamics even if these interactions were not easily accessible to me as the outsider.

Esther's interaction around K-pop showed me that not everyone liked all parts of her/his identity. Gracie and Yumi did not want to discuss K-pop or talk in Korean. By contrast, Esther was open about her Korean-part of her identity. She sang, talked, and did things in Korean in class. This contrast between Esther and the other two Korean American girls served to best demonstrate that dealing with the identity of students who might not like some aspects of it is indeed complex. Every other account was about a loud exclamation such as wanting to be blonde or white, or vocalizing an announcement that one was brown. The interactions involving Gracie or Yumi were the opposite; they tried to avoid any topic that drew attention to their Korean-ness of their identity, and perhaps hoped that it would go away. Here, a sense of tension was evident when students' identity did not match their *expected* identity. In the case with Gracie and Yumi, their experiences with learning science was impacted by the imposed stereotype, the model minority, as they had to look like "good" students; this prevented them from seeking tutorial help even when they were struggling in AP biology.

In the case of set #6, race was actualized through discursive performance. Often these conversations were direct, and they were not sanitized like in the earlier accounts that emerged from the science curriculum. These explicit and direct conversations or unexpected outbursts at times caused students to feel uncomfortable. Previous studies have shown that these comments could potentially be internalized by the students who might be the target of those racialized comments. Even though the discussion of race and gender is often uncomfortable topics to discuss, it is critical that educators immediately address negative racial stereotypes as they arise.

In summary, I borrow from the words of Deleuze to describe the state of students who were often in *milieus* where all the different components of assemblage were passing through, as they learned science, which are further discussed in Chapter 5. As such, these components of science learning, race and gender were inseparable as shown in these observations.

CHAPTER 5

DISCUSSION AND CONCLUSION

This chapter discusses the three salient claims that stood out from the findings of this study in the context of answering the research question: how do the capacities of gender and race become actualized in a high school biology classroom? The three claims are:

1. Objects and things matter in the actualization of gender
2. The actualization of gender and race follow lines of flight that are unpredictable
3. Gender and race matter in the science classroom because some of these discussions would not necessarily be allowed in other classroom spaces

Then, the three claims are followed by the discussion of *boundary objects* with respect to gender and race in the science classrooms.

**Objects and Things Matter in the Actualization of Gender**

This study made a contribution to introducing theories of new materialism in the context of how objects can catalyze the actualization of students' identity categories in the science classroom. Latour (2005) argued:

> 'material infrastructure' that would 'determine' social relations like in the Marxian types of materialism; as a 'mirror' simply 'reflecting' social distinctions like in the critical sociologies of Pierre Bourdieu; or as a backdrop for the stage on which human social actors play the main roles like in Erving Goffman's interactionist accounts. None of those entries of objects in the collective are wrong, naturally, but they are only primitive ways of packaging the bundle of ties

> that make up the collective. None of them are sufficient to describe the many entanglements of humans and non-humans. (p. 84)

As the review of literature in chapter 2 showed, studies that theorize the role or power of objects or *things* in exploring gender and race in science education have been rare. In terms of new materialism, scholars such as Jane Bennett (2010) and Karen Barad (2007) have discussed the ways in which both human and *things* are entangled at the intersections of materiality, ontology, and subjectivity. In Bennett's (2010) work, she theorized encounters where materials as actants become an important part of creating what she calls *action text*. In other words, she posited that physical things and objects become *vibrant matter* as they resonate with potential to incite other actors to *do things*. The intersection of these moments or encounters is where humans and nonhumans "slip-slide" into each other, while both humans and *things* have the capacity of agency to transform one another (Jane Bennett, 2010, p. 4). Accordingly, one of the salient philosophical assumptions of actor-network theory is that all entities, both humans and nonhumans, matter in their continuous material exchanges in producing the social. In this study, the sets of glowing data particularly on gender demonstrated this. In the account involving Aisha, Lee, and the sink, the role of the sink demonstrated what Jane Bennett (2010) calls *vibrant matter*. Lee's male body moved away from the sink as the sink became a site of producing a gender role often associated with the female body. All the while, Aisha spoke out and called out Lee for his action. In other words, both Lee's male body and Aisha's body responded to the sink, which Jane Bennett (2010) refers to as creating "powerful affects that can boost or dwindle the power of others (p. 3). Although for a brief moment, the gender role was imposed upon Aisha, as the female body who was supposed to be doing the dishes, she felt she *could* speak out and call out Lee for his action.

Karen Barad (2007) discussed the notion of entangled agencies where *things* and human exist in a state of mutual constitution, or *intra-action.* This particular notion of *intra-action* by Barad (2007) provided an idea of what actants *could become*. In other words, Barad (2007) posited that through this intra-action, *things* and human are no longer the same as they were when they were alone; instead, they have become something different, as they are fused together. In the sets of glowing data on gender, students created narratives through their interactions with the classroom materials in the science classroom. Within these intra-actions, both the students (especially the girls, Aisha, Jane and Yvonne) and the objects became something different. These narratives could be unspoken as these actions and practices could have never been brought to the forefront of everything that was happening in that science classroom space. However, these narratives could also be spoken out loud, and brought to the forefront, as seen through Aisha's words about doing the dishes and Barbara's words about the girls playing secretaries for the boys. In all three accounts of the glowing data on gender, the object and the students could not be separate, but became entities that constituted a mutually new construct of what gender could be and what students could become possible in that very moment. What could become possible was that girls took up the role of a secretary, often associated as a female profession, and it became possible that girls would cut out the pieces or color the papers for the boys, while the boys went off to socialize. Here, the glowing data on gender demonstrated a material-discursive process of *becoming* during which the objects and students equally played a vital role in the production of what gender could be in that very specific moment. The process was both material and discursive because the actions of the actors alone were not the only aspect to which the researcher paid attention. Yes, the actants were entangled in intra-actions, but students and the teacher were already always using other discourses available to them in the classroom -

language, beliefs, relationships, etc. The researcher claims that the objects were the catalyst in actualizing the capacities of gender in each of these accounts; however, more often than not, the spoken words of the human actors helped make the actualization *visible*. Here is where the researcher also claims that this study builds on and extends the works of scholars who do identity work by examining discourses in the classroom. It is not just the discourse that matters but also the *things*, as these objects, which functioned as a catalyst, helped actualize these identity categories.

**The Actualization of Gender and Race Follow Lines of Flight That Are Unpredictable**

Recall the Deleuzian notion of line of flight denotes the possibility of escape by which an action, a word, or an object, etc. allows for a moment when change or transformation can happen (Deleuze & Guattari, 1987). For instance, in the previous argument, objects catalyzed such transformative moments in the case of the actualization of gender. The laboratory sink, the paper-cutting or coloring actions, and the nail polish painting all created lines of flight that were quick and sudden so that a science learning activity transformed into a gendered activity. Furthermore, these moments were transformative; during the paper-cutting account, Barbara's words brought Jane's actions to the forefront. In other words, Barbara's words made visible the moment when the science activity became a gendered activity. This moment was transformative in the sense that the paper-cutting activity, when it was in the backdrop of the class, was something that was acceptable, and perhaps even normalized (i.e., normalized in the sense that it was considered okay to cut the papers for boys). However, as soon as Barbara's words were spoken out loud, that activity became something that should be resisted (i.e., it was no longer acceptable to act like secretaries for the boys). This transformative moment was especially demonstrated in the laboratory sink account. Aisha resisted the imposed expectations of gender norms associated with being the female body. In another example, the resistance was not specific to the girls; they were not the only ones resisting gender norms! During the nail polish painting activity, Emma and the majority of the girls took a larger share of the classroom activity as the skill of nail painting was something familiar to them and was associated as being the girls' social activity. However, Lucas resisted the imposition of this norm when he told Emma that he, too, knew how to use the nail polish.

In terms of race, there were specific ways in which the actualization of race showed up in this study. However, these accounts demonstrated the unpredictable nature of when race could be actualized. The glowing data on race were largely followed lines of flight that: 1) originated from the science curriculum, 2) that initially originated from the science curriculum or a science learning activity, but quickly and suddenly became racialized, or 3) originated via unexpected outbursts which appeared to have little relevance to the science curriculum or a science learning activity. Within these interactions, some of the content of the conversations around race were sanitized, thereby removing potentially controversial aspects of race. By contrast, some of these interactions were more direct. In this sense, the actualization of race that originated from the science curriculum tended to be more sanitized. Therefore, these interactions were dealt with differently by the teachers. In the account involving the discussion of Asian ear wax, the discussion originated from specific science content on genetics. This account dealt with *something* about being Asian, but really *nothing* about being Asian at the same time. The discussion was stripped of anything that could become controversial and stayed grounded within the discussion of the genetics lesson at hand. The teacher, Barbara, used humor by making everyone's ear wax gross to ensure that the comparison of Asian ear wax to other types of ear wax remained *neutral* in the sense that she was saying *something* about *everyone's* earwax even though she was making a distinction between Asian versus other ear waxes. Similarly, the class discussion on x-rays and microwaves provided a context in which race was able to show up. Despite the brevity of this particular account on microwaves, it showed how quickly different discussions on race could emerge. From the moment the teacher Barbara introduced the harmful effects of x-rays to Ravi's comment on having brown parents, race came up in three different ways which originated from science content but took off in a line of flight away from the science curriculum; in this sense, race was actualized discursively *away* from the science curriculum or at the *periphery* of a science learning activity at hand. Small conversations on skin cancer from the sun emerged first, since the topic was closest to the science content on UV-rays and other harmful rays; however, the conversation took off very quickly towards a discussion of how the students at the school would not need to use tanning beds since there was no problem of not having enough pigment. Here, the context of this school, with a high population of Asian Americans, provided an understanding of this comment from the teacher. Sensing this, Priya further took off in a line of flight that transformed this moment; the discussion was no longer about the x-rays, UV rays, etc. Priya blurted out that most of her peers in her physics class were Asians and that her physics teacher noted that she was only one who was white in the classroom. Then, following a different line of flight, Priya turned to Ravi and joined him on the discussion of having brown parents who were "weird about microwaves," thus leading the conversation back to their science lesson.

An example of the actualization of race showed up during the protein mutation lesson that took off in a line of flight from being neutral at first to *something* that was no longer neutral; this transition again, happened very quickly. Race was introduced when Barbara mentioned that her surrogate was of a different race than she was. This introduction acted as a line of flight to normalize these types of discussions of race within the science content *for the time being*, until it quickly became no longer appropriate to discuss race. At first, the teacher sensed the hesitant mood of her students and explicitly let them know that she was comfortable discussing this experience, and that she was okay not being the most political correct person in the room. The interactions, especially the back-and-forth conversations between Barbara and the students, were humorous and light-hearted (i.e., they are good looking embryos!) and remained grounded in science content (i.e., elaboration on how in-vitro fertilization worked), until Zola's comments that came at lightning speed. Zola's rapid response that being white was a plus and that a good hair *length* (not color) was being blonde was nothing anyone could have predicted; however, two of her consecutive responses pointed to the transformative moment where being politically correct mattered and thus her comments were no longer acceptable. Sensing this, her classmates effectively silenced Zola from further saying things out loud about that topic on race. On the other hand, similar shout outs occurred in Molly's class. During the lesson on chromosomal mutation, Ali shouted out, "the right difference is white!" Here lies the difference in how Barbara and Molly chose to deal with these outbursts. With Zola, Barbara responded to her comment directly saying that it was *not* a plus to be white; she exclaimed, "No it's not!" while allowing that comment to become socially unacceptable. On the other hand, Molly did not directly address Ali's comment but returned to re-focusing the conversation to the lesson at hand. However, in another instance, Molly also drew personal connections to a student's comment, thereby making it unacceptable. This was demonstrated when Bill made a comment that Mexicans were the ones who become morticians and, as Molly pointed to herself, she told him that she had family members who worked as morticians. The moment Molly addressed Bill's comment in the context of her personal life, the discussion quickly and abruptly was dropped, and Bill took off in other directions by talking about experimenting on gerbils, to which another classmate of his, Lauren, verbalized that Bill was not a “normal” student and that he needed to be sent to a counselor.

The actualization of race sometimes took off in a direction away from the science curriculum, occurring at the periphery of the science curriculum. What exactly catalyzed these encounters cannot be certain. In the account involving Lauren during one of the lab experiments, the conversation started out as social, small-talk while the students were wrapping up the experiment. As Lauren was sharing one of her social dilemmas about attending the school dance with her date, she juxtaposed her worries with other more “serious” problems at other schools such as drug-busts and teenage pregnancies. Then, she turned the tide of the conversation by shouting out that there were only two pairs of blue eyes and blondes in the class, which included herself and the teacher Molly. Lauren could have been alluding to the fact that those other social problems did not exist because her school had a very different student body, such as a high population of Asian students or that a majority of students attending the school strived to live up to high academic expectations. A similar encounter happened during Barbara’s lab experiment session when Ravi chose to define his classmates. Ravi chose those stereotypes based on the race of his classmates; what can be known is that *race* was on his mind as he exclaimed at the end that he was brown and that there were only three pairs of blue eyes and blonds in the class. What catalyzed that particular transition in Ravi’s train of thoughts cannot be known; however, the discussion of race always followed a line of flight that was unpredictable and unexpected. These conversations existed at the periphery of the science activity or the curriculum.

The actualization of race originating via unexpected outbursts, which appeared to have little relevance to the science curriculum or a science learning activity, were harder to predict.

For example, I could not have predicted or expected that at the beginning of one class, Elif would decide to share with Molly that she was a survivor of racism. This conversation took less than a minute before the bell signaled the start of the class. Then, in the middle of unorganized activity in the class (i.e., downtime), students decided to categorize each other as grocery stores, followed by Ali's comment that Black Muslim women had it the worst. Students on several occasions decidedly brought up white supremacy and patriarchy. For instance, when Barbara needed trouble-shooting help with her computer equipment, Ravi and Thomas both stood up to help; however, Dinh shouted to Ravi that brown people did not get to help, that it was the role of white people to help others. Ravi sat back down laughing, as if he were acknowledging Dinh's remark. From the glowing data presented so far, humor played an important role in diffusing these situations. Even in the case with Zola's comment, she made her comments in a half-hearted humorous way and the discussion started out with many jokes. Undergirding these accounts was always a tone of "ha-ha. Let us not get offended!" The researcher cannot claim that the use of humor was either a bad or a good thing; however, humor was observed as effective at diffusing tensions and worked well as a classroom management skill for both Barbara and Molly.

In terms of the actualization of race that was less than neutral, meaning it seemed to have an uncomfortable effect on others, the actualization came about in the most unpredictable manner and explicit and direct words *about* race were spoken out loud. Their effects were shown through gesture, facial expressions, or the non-compliant attitudes of students. When the discussion of race emerged in this manner, the race identity category was often brought to the forefront for students. For example, Ali's response to his bag not getting stolen (in a different situation, as in at other schools, it would have been at other schools) was because everyone knew that he was a big brown boy, and no one was going to mess with his backpack. When Bill started to shout out that Asian countries killed their own, he turned to his classmate and asked about Vietnam because Vu was Vietnamese American. When the discussion on K-pop (Korean pop songs) was less than friendly, and Bill said that he would never degrade himself by listening to K-pop, the Korean girls did not participate in the conversation, but rather chose to distance themselves from it. The way in which the teacher responded to these encounters varied. One explicit way used to address the abrasive nature of these comments was when the teacher, Molly, asked whoever began the conversation if something "ugly" was being said out loud. When Molly brought to the forefront of the conversation the ugliness of the comments, students often played them off as being a joke. For instance, when Bill looked up a bad word in Vietnamese and tried to distract the rest of the class with it, Molly immediately said that the word was an ugly word and directed Bill not to say the word. Bill then turned to Vu and in a joking tone asked why Vietnamese people hated China. In other moments, Molly would not catch these smaller interactions. For example, when Ali was being mean to Tugba for asking Ali and Bill to stop the distraction of using their phone to look up the ugly word, Molly did not see this smaller interaction and Tugba and her friend became very quiet. When Bill and Ali once again looked up a video clip that was circulating on social media and made a comment about the black person as the idiot, they were standing behind the only African American student in the class. Molly was at the front of the class and did not see these interactions. The researcher makes no claims that the teacher should always know everything that is happening in the class – this is impossible. However, these encounters showed how unpredictable the actualization of race could occur in different contexts and how each student involved in the discussion differently negotiated, managed or refused to be part of the interaction. Thus, these sets of glowing data on race do not aim to serve as an exhaustive list but serve to demonstrate different conditions under which race can be actualized.

**Gender and Race Matter in the Science Classroom Because Some of These Discussions Would Not Necessarily Be Allowed in Other Classroom Spaces**

The science classroom was what provided the context as well as content-specific launching point by which the discussion of race and gender could become actualized. Would the discussion of in-vitro fertilization likely happen in arts, music, social studies, history, etc. classes? Other classes might have other contexts that would be different. For instance, the topic of race and gender would likely come up in a class like social studies. However, the kind of interaction entangled with the laboratory sink could never happen anywhere else but in a science classroom. The researcher acknowledges that the science classroom sometimes provided *peripheral* contexts and discussions that emerged in these contexts sometimes had nothing to do with school science. However, race and gender mattered in the science classrooms, and these identity categories could never be separated from students' science learning experiences. What this study did was to get the researcher to think more deeply about these minute interactions by which gender and race become actualized.

Two notable boundary objects emerged from the glowing data: 1) dress code for gender and 2) skin for race. The notion behind boundary objects focuses on *things* that could *act* to police the actor-network. In this sense, boundary objects can trigger or create expectations for the membership of the networks. In the context of this study, *boundary objects* can create expectations for students' race or gender and likely determine how students' identity categories should further be negotiated.

In terms of gender, clothes and the dress code acted as an identifier and served to signal the appropriate response from different members of the network. Different objects (i.e., length of pants, style of the shirts, the way in which hair was tidied up, etc.) were discussed in order to enforce the dress code. The regulation of these boundary objects was connected to the *code* (i.e., code of conduct to territorialize what is and what is not acceptable in the actor-network) that acted to police students' forms of expression. This *coding* or act of policing was seen in the interaction with Cho.

In terms of race, the boundary object was the skin itself. Skin acted to structure the responses of student and teacher to each other (i.e., students' comments about being brown, or their teacher was the only white person in the classroom) and set up the *possibility* of certain expectations for different students. This was especially interesting on several occasions. In the case with Lucas, others assumed that he spoke Spanish because he looked Hispanic. Another interesting case was with Zola when she wondered if she was not being taken seriously because she was Black. Daniela is a Hispanic female student in Barbara's class. The interactions that were observed involving Daniela did not have enough "energy" to be included in the glowing data. However, in the researcher's conversation with her, she revealed that people were often surprised to find that she was Hispanic because she looked White. Daniela said, "I know I don't look Hispanic, but I am." One of the interactions involving Daniela and Han was interesting when their classmates expressed surprise to find that Daniela was up against Han in the district-wide science competition. Han was usually perceived by everyone to be *the* smartest student in Barbara's AP biology class. Zola made a point to announce to the class that Daniela was *also* one of the three finalists. In the case of Daniela, her appearance had set up different responses from her peers and teacher in different contexts.

Aside from identifying boundary objects, Daniela's coming-out as a smart science person in the classroom was even more interesting given that her gender identity was highlighted more than her race identity. Despite the initial surprise factor, upon learning that Daniela was in competition against Han, Barbara and her peers shouted words of support, encouraging her to beat out the boys and win. The comment about beating out the boys and winning was interesting because it was as if girls had to work hard, if not harder, to be the top student in science. When the competition was against the boys, Daniela's girl identity was celebrated while her racial identity fell to the background; it did not matter in that moment whether she looked White or Hispanic. Lastly, students kept commenting about blue eyes and blondes being rare and these came up in three different places by three different students when race was discursively performed. The fact that this same comment showed up in three different places helped identify skin as the boundary object. *Some* narratives about skin tone and the color of eyes could be passed on from one actor-network of science classrooms to another. For example, in the interviews, I learned that many students had a strong tendency to group themselves by their ethnicities beyond the science classrooms and even in the lunchroom. Esther pointed at her hand and said," Look at me. I'm yellow" during her interview and further elaborated on the particular ways by which students grouped themselves and sat at lunch tables. This is not to claim that the researcher is stratifying different racial groups based on skin. The conversations that emerged from students interviews as well as observed interactions in the science classrooms about skin and eye colors are interesting and important to discuss because *some* narratives about race are being passed on through the boundary object of skin from the actor-network of the science classrooms to another actor-network of the lunchroom. This is *something* that students have noticed and were open to point out. However, the researcher acknowledges that this needs to be further probed; exploring the question of what meaning and what sort of narratives could be passed on and transmitted will require great effort if the researcher were to examine them through ontological work in her future studies.

## Conclusion and Scholarly Contributions

Looking at the local interactions allowed the line of flights to escape from black-boxing the constructs of gender and race. According to Prentice and Miller (2007), groups of individuals are essentialized when they are viewed as having unchangeable essence that is some kind of inherited *property* that determines who they are or they can be. Furthermore, essentialism presumes that a particular group of people is fixed in membership and thus is separate from others. In light of the discussion on race, this fixed membership is demonstrated by the evolution of race categories in the United States and scholars have argued that such essentializing of groups of people has been one foundation of oppression. In terms of gender, Fournier (2014) highlights the unrealized potentials for re-thinking gender by applying the Deleuzian concept of lines of flight; here, he emphasizes the power of gender dysphoria when "a supposedly familiar landscape is blurred by the transposition of gender-signifying marks from one *milieu* to another, when the socially determined coordinates of familiarity-identity-gender no longer add up to a legible (legitimate) pattern, when materiality itself escape the frame of representation, because this frame is built on gender binarism" (p. 121). Briefly, the Deleuzian concept of *milieu* denotes the status of being in the *middle* (Deleuze & Guattari, 1987). To be in the *middle* or *milieu* is existing in the status of chaos, which is composed of many *middles*, which are neither units nor dimensions, but rather directions in *motion*. Therefore, to be in *milieus* in the context of gender binarism is to be in motion, following line of flight that allows one to escape from the essentialized representation of what it means to be male versus female.

With that said, this study contributes to the emerging scholarly works on *post-identity*. Namely, the researcher would agree with past works on identity that race and gender do not exist as monolithic entities or simply as attributes of individuals. Rather, race and gender can be actualized either through discursive practices or materiality catalyzed by physical objects that are assembled in different ways to fashion encounters and events between bodies. Therefore, Puar (2011) urged scholars to understand identity categories as ontological work that is generated as *effects* of relations and *shaped* through practices. By not imposing these social constructs as something that was monolithic, deterministic, and stable, the researcher was able to focus on the local interactions and empirically observe and document the nodes of negotiations. In doing so, even the smallest interactions mattered because *someone* is negotiating and positioning his or her identity or is being positioned because of his or her perceived identity in the science classroom. Herein lies the truth to what Bruno Latour said about how *the local is all that matters*. Scholars have not paid enough attention to *how* these associations, connections, and nodes were navigated and negotiated by the students. This state of *milieus* that is chaotic, exhausting, and at times intrusive, constitutes our youths' every day experiences with school science in relation to their identity categories. We know from literature that students *internalize* their experiences in relation to their identity formation, especially their racial identity (Banks & Stephens, 2018; Pyke, 2004; Pyke & Dang, 2003; Pyke & Johnson, 2003; Stevenson, 1995; Tatum, 1992). Thus, bringing the perspective back to the local interactions helped the researcher of this study document not only the conditions under which gender and race were actualized but the *actuality* of what students *do* and *act* in response to those conditions.

In terms of studying identity categories such as race and gender in science education, the entry-points of many studies begin with what gender and race *are.* Similarly, this study began with an idea that gender and race are social constructions but furthered the exploration into what gender and race *could be* and how those identity categories were actualized (or not) in ways that could potentially shape students' science learning experiences. The question remains is, did these encounters reveal a science classroom environment that was less than equitable for girls (for instance, was the classroom environment inequitable in the case of the Asian/Asian American girls)? They might or might not have, considering the limitations of this study. What *can* be said based on these encounters is that using theories from new materialism and emerging concepts from post-identity works offers new possibilities and insights for future research and practice in science teacher education, especially when a scholar aims to push back against the black-boxes of Gender and Race with the big G and the big R.

## Implications

This study holds implications for teacher practice. As demonstrated by the glowing data, a teacher needs to be ready for the actualizations of gender and race in places that are often unpredictable. The unpredictable nature of these *things* complicates teaching strategies needed to address these concerns in class. Though the teachers' classroom management styles were not the focus of this dissertation, the most common approach used by both Barbara and Molly was the use of humor to diffuse the situation. Given the context of what the researcher knows about these teachers, humor was used effectively because both teachers were veteran teachers who were highly aware of gender and race issues. Therefore, a practical take-away message for teachers is the importance of awareness and mindfulness which denotes paying attention in a particular way and being present in the moment (Kabat-Zinn, 1994). By looking at the examples in this study, teachers can see how unpredictable the discussion of race can be and how small the actualization of gender can be so that it can easily be missed. However, both teachers paid attention to these smaller details and brought them to the forefront of students' attention to be addressed.

## A Double-Edged Sword: Limitations and Contributions

The way this study was conducted has both limitations and contributions to methodology. Bruno Latour (2005) emphasized the importance of looking at the day-to-day and minute practices. These local and minute interactions and small nodes of negotiations are often missed by scholars, as researchers tend to look for the deterministic socials. However, as small as these encounters may seem, these minute interactions reveal the day-to-day experiences that students have with school science, thereby making visible any controversies, resistance, and negotiations that may be occurring.

In terms of contributions to methodology, looking for that *something* (i.e., object, or *things*) to catalyze the actualization of gender or race has its limitations, especially with race that was often performed discursively. Therefore, scholars need to account for the discursive-material nature of this type of research and re-envision what glowing data might look like to *show* the more precise moment when *things* become transformative to catalyze the actualization of gender or race.

Lastly, in terms of policy, this type of *ethnomethodology* research that examines the day-to-day practices in any settings may appear to be not as useful for impacting policy changes. Roth (2005) highlighted:

> As an analytic method, ethnomethodology has many outstanding qualities. The critique is but one example that shows how this form of analysis can yield insights novel to our discipline. It is an excellent method for describing how the world as we know it arises from the situated actions and operations of ordinary people

> (students, scientists). It does, however, as the critique exemplifies, function much more poorly as a guide for rethinking and remaking the world: The critique is consistent with the argument that ethnomethodology cannot change the world.… In the form used in the critique, ethnomethodology is loyal to the local and to the particularities of everyday life and, therefore, fails to move beyond the everyday and make connections with the macro-level of society, imposing an ideological description on the situations and people it studies…. (p. 195)

In response to the critiques of ethnomethodology and by proxy ANT studies, not all is lost. Drawing on DeLanda's notion of upward and downward causality, the emergent property of a macro-social structure is *immanent* to the relations of its actors that compose it. Therefore, in the context of this study, the emergent property of the school is immanent to the relations of its students, teachers, and the *things* that compose it. The point of showing these smaller examples of how gender and race could be is so that anyone who reads these accounts can begin to re-think students' identity categories and be open to new ways of thinking about them, thereby learning to address them differently. These are indeed smaller changes, but as these smaller changes begin to occur from one classroom to another, the school's identity, or *emergent property,* will emerge. Therefore, the researcher is hopeful that one day, slowly but surely, the science education community and stakeholders alike can begin to think about gender and race issues in science education differently, thereby impacting policy on equity, diversity, etc.

## Future Research Directions

Based on the glowing data provided in this study, the researcher could not claim that the intersectionality of students' identity categories (i.e., gender and race) showed up. This is because in all of the glowing data, one particular identity category, either gender or race, was brought to the forefront of students' identities, while the other categories remained in the backdrop, were invisible or were not yet actualized. In other words, the actualization of one identity category was more prominent and based on the encounters observed in this study the researcher cannot make the claim that intersectionality of different identity categories became visible. In the existing body of literature on identity in science education, many scholars have called for the intersectionality of identity categories, as an individual cannot solely be defined by race, gender, class, etc. alone (Crenshaw, 1989; Scantlebury & Baker, 2007). One of the most prominent scholars doing identity work from a critical feminist perspective in science education, Brickhouse (2001), also called for intersections as one's identity is never single or stable and an individual can be a part of many different communities and take on multiple social identities. As such, when scholars aim to understand how students construct themselves as girls, their membership in a particular racial or ethnic group, and other overlapping identities must be considered. However, provided that this study put heavy emphasis on the nature of the multiplicities of one's ontology, the notion of intersectionality would still not be able to account for all the different ways in which gender and race could become actualized. According to Day (2016), intersectionality does not help resolve the problem of perpetuating an essentialist category with one specific meaning. For example, "the category of race itself is deeply problematized because intersectionality relies on these basic categories as tools for constructing 'intersecting' identities" (p. 125). Dess, Marecek, and Bell (2018) acknowledged that at each stage of research from feminist theory to critical race theory, new insights have helped scholars to re-think gender and race and how research could be done to better understand the lived experiences of individuals. At some point in history, it was a reasonable notion to distinguish between sex and gender and make causal statements with respect to sex-related differences.

Similarly, it was reasonable to attribute race as a causal factor to the differences seen in individuals. However, research is in motion and is moving beyond a simple dichotomy of gender binarism, or essentialist categories of race, and is instead letting go of the single-axis manner of studying social identity. Therefore, Dess et al. (2018) argued that *doing* intersectionality work seems quaint. With that said, the researcher of this study extends the scholarly work of previous generations and thus puts forth a new understanding of identity categories and theorizes them as *subjectivities in motion*. However, there is nothing *new* under the sun. In 1993, Kathy E. Ferguson, theorized the notion of *mobile subjectivities*, which denotes the idea of maintaining agency without relying on a stable locus of one particular identity category; in her work, Ferguson provides an empirical example of a businesswoman who negotiates diverse social relations in day-to-day activities while being on the move and as she takes on multiple subject positions and embodiments. Coupling Ferguson's notion of *mobile subjectivities* and the emerging scholarship in new materialism, the future direction of this study will continue to re-think questions of identity categories. Furthermore, the researcher hopes to extend her new understanding to further re-conceptualize notions of a subject's multiplicities, agency, and power as effects of relations within the context of school science and science education.

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