Investigating Student Science Identity in a Middle School Social Studies Classroom

Hazel Cashman
University of Maine, hazel.cashman@maine.edu

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INVESTIGATING STUDENT SCIENCE IDENTITY IN A MIDDLE SCHOOL SOCIAL STUDIES CLASSROOM

By
Hazel Cashman
B.S. Bates College, 2018
M.S.T. University of Maine, 2022

A THESIS
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Advisory Committee:

Elizabeth Hufnagel, Associate Professor of Science Education, Advisor
Darren Ranco, Associate Professor of Anthropology
Tammy Mills, Assistant Professor of Curriculum, Assessment and Instruction
Franziska Peterson, Assistant Professor of Mathematics Education
Much science identity researchers theorize identity as a process of authoring and re-authoring oneself while being recognized by others, and therefore theorize science identity as negotiated (for example, see Avraamidou, 2019 and Calabrese-Barton et al., 2013). It is widely accepted that recognition by others shapes students’ negotiations of science identity (Carlone and Johnson, 2007). Few studies, however, have focused heavily on the role that students’ self-recognition plays in the science identity negotiation process. A large body of research also exists on students’ ideas about science (see Lederman, 1992), yet that research has not frequently intersected with research on student science identity (Avraamidou and Schwartz, 2021) and often fails to probe students’ ideas about science for much nuance. This thesis project addresses these two identified gaps in the current science identity research literature.

The goals of this research were to explore and describe how sixth grade students negotiated their science identities through descriptions of: 1) their engagement in science and 2) their own ideas about science. Ethnographic interviews were conducted with ten 6th grade students from a middle school in a semi-rural state in the Northeastern US. The interviews were intentionally conducted in a social studies classroom during an integrated science and social studies unit, in order to capture students’ science identity negotiations in a unique and expanded science learning setting. Two components of students’ identity negotiations from the interviews were analyzed: how students authored science selves, and how
students recognized (or didn’t recognize) those science selves. The interaction between students’ conceptualizations of science and their science identity negotiations was also analyzed.

Analysis of the interview data showed that these 6th grade students have multifaceted conceptualizations of science composed of both inclusive (broad) and exclusive (narrow) sets of ideas. The complexity seen in students’ conceptualizations of science illustrates that students construct their understandings of science as they do their science identities: from the many experiences they have with science in the different figured worlds they inhabit.

Despite authoring a diverse range of science selves via descriptions of their own engagement with science and scientific thinking both in school and outside of school, seven of the ten total students did not recognize themselves as scientists. This lack of self-recognition was primarily due to the fact that students drew from their own lived experiences (both in school and outside of school) when authoring science selves, but students made their self-recognition contingent entirely on their narrow and exclusive ideas about science. This thesis project therefore contributes to an understanding of the ways in which students’ ideas about science shape their negotiation of science identities, by influencing the ways they recognize themselves as scientific (or not). These findings have implications for both science identity research and science teaching.
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CHAPTER 1
INTRODUCTION

In this chapter I will present an introduction to this thesis project via a description of how I came to be involved in this research, followed by an overview of the project’s goals. The chapter concludes with a summary of why attending to students’ negotiations of science identity is an important and valuable pursuit.

How I Was Drawn to This Research

As a researcher who is also currently engaged in the science teaching certification process, through teacher education at a western academic institution, I am constantly asking myself: “what do I believe is the real purpose of science education?” and “how can I teach to that purpose?” I entered my graduate studies knowing that I wanted to do research on what happens when the “definition” of science, as presented in the discourse of classrooms, is expanded. This thesis project emerged from that interest.

During my undergraduate studies I had the joy of working with a mentor who challenged me to think about the sociocultural and sociohistorical implications of scientific research. Learning about Indigenous archaeology from this mentor, the (then) only Indigenous professor at my college, I traveled in her company to conduct fundamentally community-driven archaeological research. This research was propelled by an Indigenous community’s desire to tell history as it had actually happened, not as painted by previous extractive scientific studies. The perspectives of those involved in that work began to make it clear to me that science has the potential to do great damage, and also the potential to do great justice. My question then became: how do I bring that understanding with me, and work to operationalize it, through the rest of my science education? As a result, continual attendance to Indigenous perspectives, critical review of my work, and connection with and sharing of science with stakeholder communities all became priorities for me.

While engaged in my own thesis project at my undergraduate institution, I realized that research, for me, only felt productive if shared with others purposefully. This led me to shift my focus from research to science education, where my first experience was at a decolonial Indigenous history and
culture museum. My experience there pushed me to consider how to make complex and interwoven colonial and scientific histories accessible to wide audiences. I moved from there into the field of experiential education with a desire to continue interrogating how I thought about science, now asking myself: “why is science useful?” and “how do I embody my understanding of science (as inherently connected to culture, politics, and social justice) in the ways I interact with students?” Working as an experiential educator in various settings, I came to appreciate that each student’s engagement with science is different; each student will take different things away from hands-on science experiences. Each student brings their full self to science. How, then, to teach science in a way that brings as much creative diversity to the students as they bring to their learning of it? Through these initial experiences as a science educator, I came to understand that science should complement and honor the unique histories and identities of each student who encounters it.

This trajectory, and that which I’ve followed during my graduate studies, has allowed me to articulate a vision of science education that has guided this thesis research. This vision centers on valuing every student as an intellectual individual who brings uniquely powerful assets to the classroom and community of science. For me, the purpose of science education centers on learning about how to be in good relation (Kimmerer, 2013) to the world in nested scales: beginning with one’s home place, and expanding outwards regionally and globally. I value the perspectives that Cultural Science (carr, 2019) and Traditional Ecological Knowledge bring to science education: expanding science beyond learning about the world, to include the process of growing into being a member of its systems.

I believe that the goal of science education should be to guide students to an understanding of their responsibilities as members of an ever-changing earth system. This requires that students engage in hands-on, locally relevant science, and requires that science learning bring meaning to students’ interactions with their home environments. Science education, therefore, has the responsibility of building students’ values of sustainability, reciprocity, and their capacities to make future-conscious decisions.

I began my graduate studies with these ideas not fully formed, and they still aren’t. However, in the science identity research literature I have found a community of researchers who are asking these
same kinds of questions about science and science learning. Engaging in this thesis project has made it clear that in future teaching I won’t be able to enact this vision of science and science education without attending to students’ identities; in fact, doing so is required if I am to teach science in a way that honors each unique fabric of experiences and identities every student brings to the science classroom. In response to my own questions of “what do I believe is the real purpose of science education?” and “how can I teach to that purpose?” I am now asking further questions, such as “which students’ identities are more readily recognized and accepted in science learning environments?” and “what sorts of discourses facilitate some students being able to engage in science learning with their full selves, while others are forced to compartmentalize or renegotiate their identities in order to engage in science?”

This research, therefore, grew out of a desire to push myself to enact pieces of this vision of science and science education, and in the process, continue to articulate them to myself. Creating a unique science learning environment, in partnership with a social studies teacher and with advice from a Cultural Science researcher and practitioner, allowed me to investigate how students see themselves in relation to science when engaging with it in this kind of “expanded” way, and led to an investigation of how students’ ideas about science shape the ways they articulate their own science identities. The following section will present the goals of this thesis project.

**Goals of This Research**

The goals of this research were to explore and describe how sixth grade students articulated and negotiated their science identities in the context of a science-based unit taking place in their social studies classroom. These goals emerged from the perspectives and motivations I have described above. Namely, my intention was to create a science learning context which differed in intentional ways from that of a science classroom, in order to expand students’ experiences of science beyond what they might typically encounter in school. Within that context, I aimed to explore how students articulated their science identities to me in interviews, during our shared participation in the unique science/social studies learning space. To guide my exploration of students’ science identity articulations during their interviews, I made use of the following research questions:
1. What experiences and ideas do students draw from when communicating how they conceptualize science?
2. What kinds of science selves do students author? How do they author them?
3. How do students recognize (or not recognize) themselves as scientists?
4. How do students’ conceptualizations of science shape the ways they recognize their science selves?

This thesis project was designed in collaboration with a mentor from a local Indigenous science education group and with the classroom teacher whose students were participating in the study. The goals that emerged from this collaboration were that the research be useful for middle school teachers (at the participating school and elsewhere), and provide a jumping-off point for creation of further curricula integrating science with social studies and incorporating Indigenous knowledge into science teaching.

The goals that emerged from my perspective as a researcher were entangled with these collaboratively-built goals. Through this thesis project I aimed to contribute an example of science identity research taking place at the intersection of multiple ways of knowing and doing science, and aimed to begin to explore the under-researched intersection between how students think about science and how they see themselves in relation to science. Underlying all of these goals was my own personal desire to continue to explore the questions I have articulated above. This project was therefore fundamentally shaped by my desire to enrich my own articulation of what I believe is the purpose of science education, and work towards answering, for myself, how I can teach to that purpose. The following section will address the question of why this work is valuable for both the fields of science teaching and science education research.

**The Value of This Research: Examining Who Can Belong in Science**

Disciplinary identity has become increasingly important over the last 15 years within the fields of science education and science education research. In 2017 the *Journal of the Learning Sciences* published an issue on disciplinary identity, the introductory article of which emphasized that investigating disciplinary identity formation is important because it helps educators (1) understand how science intersects with the many other identities of their students, and (2) create science learning experiences that deepen students’ senses of belonging in science by engaging them in learning that is relevant to their
many identities (Bell et al., 2017). Since the 2000s, the body of work on student science identity has been rapidly growing. Researchers have investigated many different aspects of student science identity, particularly among students with marginalized identities, towards the goal of understanding how to make science learning experiences relevant to students of all backgrounds.

Clearly, research on student science identity has great value for addressing questions of equity and access in science education, and for addressing conceptualizations of science learning. I would add, based on the findings from this thesis project, that science identity research also has the potential to address the importance of understanding how students think about science. Studying student science identity allows researchers to ask questions that push science education towards honoring students’ diverse ideas about science, and towards presenting science as a fundamentally cultural, creative, and individual pursuit. In short, studies of identity negotiation in science learning allow for conceptualization and exploration of science as one way of knowing the world that is shaped, each time it is done, by the unique identities of those doing it. The following sections will summarize the value that studies of student science identity have in addressing these important ideas.

**Conceptualize Learning as Identity Negotiation**

Firstly, it is important to acknowledge that attending to student science identity allows exploration of learning as the process of identity negotiation. Lucy Avraamidou (2020) argues that a “more radical goal” of science identity research, which takes science identity as an ontological approach to learning, is to assert that science identity “is what makes science learning both necessary and possible” (p. 326). As articulated by Wenger (1998), “learning transforms who we are and what we can do, it is an experience of identity” (p. 215). Understanding the process of learning as the process of identity negotiation promotes a vision of students as whole people, and, I think, provides the necessary foundation for such questions as: “how can science be taught in ways that honor the diverse identities of those learning and doing it?”
Critically Examine Who Can Belong in Science

Of course, science identity provides an extremely valuable construct for examination of processes of being and belonging in science (Avraamidou, 2020). In fact, Avraamidou (2020) argues that the wider implications of science identity research are to promote equity and justice, by investigating questions of truth, knowledge, and power; how they are defined and enacted in science, and who has access to them. Indeed, it is well accepted that school and school science (as influenced by larger sociopolitical discourses) provide and instill cultural models of who can be seen as a scientist (Wade-Jaimes and Schwartz, 2019). This study is therefore framed by the understanding that science is a culturally-mediated process (Brickhouse, 2000) and school science constitutes a subculture of Western Modern Science (WMS) (Aikenhead, 1996). (See Chapter 2 for a discussion of how the construct of WMS is used to frame this research.) Understanding how science and science education inform and participate in cultural production and conflict (Lemke, 2001) is incredibly important if we want to teach science equitably, and studying the ways in which students negotiate science identities is one way in which to approach this work.

It is well known that achieving membership in school science is more challenging for students with marginalized identities (Brickhouse & Potter, 2001; Carlone et al., 2014). Yet, when students have science identities to draw on they are more likely to participate successfully in the subculture of school science (Aikenhead, 1996). Investigating student science identity can therefore inform mitigation of the well-documented decrease in student enjoyment of science from elementary to middle school (Carlone et al., 2014). In this way, studying students’ negotiations and articulations of science identity offers a path for moving away from science teaching as cultural assimilation, towards science teaching centered around the question: “how do we help students retain identities desirable in their home communities while supporting them in the (sometimes hazardous) border crossing (Aikenhead, 1996) that is necessary to get access to school science?”
Expand Conceptualizations of Science Education and of Science

Clearly, school science achievement should not be (and is not) the sole motivation for science identity research. In fact, studies of science identity, because they help us understand processes of student authorship and agency in science learning, can inform science teaching that is meaningful for all students by focusing on science for informed lifelong decision-making (Tan & Calabrese Barton, 2007). Part of this involves making students’ ideas about science salient in order to make connections between students’ science learning experiences and their abilities to negotiate meaningful science identities that integrate with their other many identities. It has been shown that students view science as classroom-based, indicating a lack of connection between students’ own lived experiences and those in which they are learning school science (Tugurian and Carrier, 2017). Science identity research has an important role to play in informing teaching to expand connections between students’ lived experiences and their time learning science in school, therefore increasing the ability for students to negotiate science identities congruent with their many other identities.

So why conduct my investigation of students’ science identities in a middle school social studies classroom? We know that linking disciplines through common themes offers students more chances to make creative connections, and therefore enhances learning (Nuthall, 1999). Much research has been done on integration of STEM (through engineering and design) and some work exists on integration of art and science, or literacy and science, yet little research exists on integration of science and social studies in a middle school setting. This appears to be indicative of the continued resistance to expand conceptualizations of science beyond those spheres of influence articulated by WMS. Creating an integrated science and social studies learning environment in which to conduct my investigations of students’ science identity negotiations was done purposefully, to begin to enact a vision of science education that is truly expansive. It is important to acknowledge the value that creatively imagined science learning experiences have in creating space for all students to constructively negotiate science identities. As J. L. Lemke powerfully argues in his paper titled “Articulating communities: Sociocultural perspectives on science education,” science education should be focused on expanding the tools available
for diverse audiences to “come to understand, appreciate, and criticize science as a human activity, a social institution, a specialized culture,” and one of many legitimate ways of making sense of the world (2001, p. 307). I believe that through creation of such science learning environments like the one in this thesis project, we can begin to expand students’ conceptualizations about what counts as science, and therefore open up space for negotiation of a wide range of science identities.

This thesis project therefore provided an opportunity for me to dig deeper into an important intersection, one which has been underexplored in science identity research. Investigating the interactions between students’ ideas about science and the ways in which they articulated their science identities allowed me to bring together what I see as the two main contributions (and responsibilities) of science identity research: 1) to make salient the accumulations of experiences and ideas which function to shape students’ belonging in science, and 2) make salient the ways in which the culture of science (namely, WMS) continues to shape the politics of being and belonging in science. In the following chapter, I will provide an overview of the science identity research literature which shaped my research.
CHAPTER 2
CONCEPTUAL FRAMEWORK

Part 1: Science

Conceptualizations of Science in the Literature

In this section, I will present the ways of knowing and doing science which have, over time, shaped my own conceptualization of science and therefore shaped the way I approached the concept of science in this thesis project.

**Western Modern Science (WMS)**

Western Modern Science (WMS) constitutes one way of knowing the world, and is indeed a subculture in itself (Aikenhead, 1996). Most science education in the United States today continues to be informed by the epistemology, ideals, processes, and products of WMS. WMS has its roots in Greek philosophy, which favored abstract generalizations over practical knowledge (Aikenhead & Michell, 2011). These roots center on notions of Cartesian dualism, reductionism, and positivism. Its objectivist epistemology prioritizes asking “how?” towards evidence and explanations of phenomena in the physical world (Aikenhead & Ogawa, 2007), and functions to de-center humanism and relationships. In WMS there is an emphasis on classification and universally applicable theories grounded in empirical evidence and replicable procedure. Tools and technology have vastly expanded the scale of observation so that observations can be made directly or indirectly (i.e. via models) at both the micro and macro scales (Aikenhead & Michell, 2011; Stephens, 2000). WMS emphasizes disciplinarity and specialization, and the importance of the written record. While WMS is increasingly acknowledging its own pluralism, heterogeneity, and cultural situatedness, the subculture of school science today continues to generally center on non-humanistic, positivist science (Aikenhead and Ogawa, 2007).

**Indigenous Science**

Indigenous knowledge asserts the resilience and self-reliance of Indigenous peoples, emphasizes the importance of Indigenous educational philosophies, and in doing so fills “the ethical and knowledge gaps in Eurocentric education, research, and scholarship” (Battiste, 2002). Aikenhead and Ogawa (2007)
assert that one of the key differences between western ontologies and Indigenous ontologies is the
difference between knowledge as a destination or object to be attained (in WMS) and knowledge as a
journey toward wisdom, or a “coming to know” (in Indigenous science). To denote this difference, they
prefer the term “Indigenous ways of living in nature,” instead of the term “Indigenous knowledge.” Many
more terms are used by other scholars, and each term’s use differs with these scholars’ orientations and
identities. Some of these terms include Traditional Ecological Knowledge, (or TEK) Traditional
Knowledge (TK, or Tkn), (Bartlett et al., 2012) Native Science, Cultural Science (CS) (carr, 2019) and
Indigenous knowledge (IK).

Fundamentally, Indigenous sciences are the “coming to know” processes born from participation
within nature’s relationships, that produce ways of understanding, experiencing, and feeling the world
(Cajete, 1999). Sciences is plural here because each Indigenous science is strongly rooted to and mutually
lived in place (Hatcher et al., 2009). Indigenous ways of living in nature are relational, mysterious, place-
based, dynamic, systematically empirical, internally consistent, self-validating, (Cajete, 1999) rational,
contextual and experiential-- in contrast to many western sciences (Hatcher et al., 2009). Learning in
Indigenous knowledge systems is participatory and constructive, and at its center is the concept of
wisdom-in-action; the process of coming to understanding and knowing (Aikenhead & Ogawa, 2007;
Cajete, 1999). Indigenous knowledges are “fully integrated into the whole of life and being” and therefore
can’t be separated into disciplinary bins (Cajete, 1999).

**Integrative Science: Indigenous and Western Science as Equal Partners**

Integrative science refers to science that weaves together Cultural Science (CS) and Western
Modern Science (WMS) (Bartlett et al., 2012). Critically, this is done by bringing both paradigms to the
table as equally significant, distinct, and whole-- and emphasizing a co-learning approach (Iwama et al.,
2009). One framework used in such integration is Two-Eyed Seeing, which Albert Marshall (Mi’kmaw)
has articulated as “learning to see from one eye with the strengths of Indigenous knowledges and ways of
knowing, and from the other eye with the strengths of Western knowledges and ways of knowing, and to
using both these eyes together, for the benefit of all” (Bartlett et al., 2012). Crucial to this process is the
understanding that both IK and WMS are based in culture, rational thinking, and empirical approaches, and involve the dynamic evolution of wisdom-in-action (IK) and quantifiable knowledge (WMS) (Aikenhead & Ogawa, 2007). By drawing from the overlapping strengths of both ways of knowing, and by weaving back and forth between each, researchers and practitioners can develop a “wider, deeper, and more generative field of view,” (Bartlett et al., 2012; Iwama et al., 2009). It has been shown that such an approach, when used in science teaching, enhances the learning of both Native and non-Native students (carr, 2019).

How Students’ Conceptualizations of Science Have Been Studied

In this section, I will discuss how student’s ideas about science have been studied by science education researchers. As with student science identity, much work has been done to understand students’ ideas about science among populations of varying ages between elementary school and college. Largely, this work constitutes its own field of science education research, and there has not been much work at the intersection of students’ understandings of science and their negotiation of science identities. Work on students’ understandings of the nature of science (NOS), therefore, has largely remained disconnected from STEM identity research. (See Lederman’s (1992) literature review for a summary of this NOS work spanning the 1950s through the 1990s.) In this section I will give a brief overview of the NOS literature, and then discuss the research that has been done at the intersection of students’ understandings of science and their development of science identities.

The field of research on students’ understandings of NOS largely has used standardized instruments to gather information on students’ ideas about science and scientists. These instruments have included Likert-style questionnaires, semantic differential scales, and interest inventories (Osborne et al., 2003). Since the development of the Draw a Scientist Test (DAST) by David Wade Chambers in 1983, that test has been used extensively to continue to gather information on students’ understandings of science and scientists across age groups and contexts. One commonly used addition to the DAST is the DAST-C (Draw a Scientist Checklist), developed by Finson et al. (1995). The DAST-C is a checklist used to assess DAST drawings; each item on the checklist is a stereotypic characteristic known to exist in
students’ images of scientists. The more of the items on the checklist present in a student’s drawing, the more stereotypical their image of a scientist.

Work using the DAST and its variations has generally shown that students hold “stereotypical” images of scientists. In short, students think of scientists as primarily white, older to middle-aged men, wearing lab coats and working alone in labs, with specialized equipment (Barman, 1997). The DAST continues to be used today; however, numerous shortcomings of the test have been identified which have been shown to unintentionally promote stereotypical depictions of scientists (Barman, 1997; Palmer, 1997). These include the lack of explicit instructions it provides to students, and the implicit instruction for students to draw “a” (one) scientist (thereby encouraging them to depict only one set of ideas about scientists). While the DAST continues to be used because of its simplicity and ease-of-use, well-documented critiques of the test (and other simple instruments like it) emphasize that these sorts of tools do not allow researchers to capture the nuance in students’ understandings of and ideas about science and scientists. Notably, however, use of the DAST has shown that students’ ideas about science and scientists are influenced by the cultures of which they are a part (Farland-Smith, 2009).

Some researchers have modified the DAST by adding an interview component or by adjusting the number and type of drawings that students produce while taking the test, to try to address some of the DAST’s observed shortcomings. One example of such work is that of Barman et al. (1997) who conducted interviews with 117 fifth grade students (of a range of socioeconomic and racial backgrounds) from the midwestern and southwestern United States. During the interviews, students were asked to draw both images of scientists and images of themselves doing science, and then explain their images. The researchers analyzed students’ images of scientists using the DAST-C, and this analysis along with that of the students’ interview responses showed that these students shared many of the stereotypical ideas about scientists identified in other studies, and notably, that most of the students did not see a connection between the science they learn in school and their everyday lives.

Another example of such work is that of Scherz and Oren (2006) who investigated the ideas of students from six eighth and ninth grade classes at schools in the United States, primarily serving
heterogeneous, middle and lower middle socioeconomic sectors. These researchers asked the students to
draw a scientific and a technological workplace. Analysis of the drawings was supported with interviews,
where selected students interpreted their drawings. Scherz and Oren’s findings agree with much of the
other DAST work: they found that the students in their sample had similarly stereotypical images of
scientists and their workplaces. They concluded that traditional school science instruction “fails to
introduce students to the scientific and technological environments in the real world or to the
professionals that work there” (p. 982).

Donna Farland-Smith (2009) compared American and Chinese students’ images of scientists
using the Enhanced Draw a Scientist Test (E-DAST). Farland-Smith emphasized that a single drawing
might not capture the full range of a student’s views about scientists, and that students’ drawings should
be examined in more detail than that which the DAST-C allows. Farland-Smith therefore used multiple
drawings and a new scoring mechanism (the DAST Rubric) to evaluate 225 fourth and fifth grade
students’ images of scientists. Findings from the analysis of the E-DAST results showed that American
students tended to associate chemicals and beakers with science, while Chinese students associated robots
and inventions with science. Interestingly, only American students drew teams of scientists, and more
female scientists were drawn by American students than by Chinese students. Farland-Smith concluded
from this work that students’ ideas about who can be a scientist, where scientists work, and what
scientists do are influenced not only by the personal images they hold of scientists, but by their culture
and the science they engage in in school. Therefore, students’ ideas about the roles of scientists can “be
directly influenced by the classroom, since each classroom is a culture of its own” (p. 35).

Although there is much research, like that described above, which makes use of the DAST, it
remains true that little qualitative work seems to have been done to understand students’ ideas about
science via other means, such as through in-depth interviews. Notably, Palmer (1997) found that when
students’ ideas about science were explored through a specialized set of interview questions, developed
specifically to illuminate students’ ideas not shown via the DAST, more nuance in middle school
students’ understandings of scientists was made salient. Additionally, there remains an even greater need
for further qualitative research into students’ ideas about science from a perspective that takes into account individual students’ identities (Archer et al., 2010). Wade-Jaimes and Schwartz (2019) echo this call, emphasizing that “a much needed area of research is exploring the connection between NOS conceptions and science identity development” (p. 703).

One example of research that explores the intersection of students’ science identities and their images of science and scientists is that of Zimmerman (2012). Zimmerman followed the at-home science activities of one student, Penelope, from fourth to seventh grade. Using the “when is science” approach (McDermott and Webber, 1998), which examines the ways in which people’s meanings for the word “science” are developed from their everyday experiences and the social recognitions they receive, Zimmerman considered how Penelope’s at-home experiences (namely, caring for her pets) overlapped scientific practices. One finding from Zimmerman’s work was that as Penelope began to feel like her experiences in school science were diverging from the kinds of work that scientists really do (which she explained, partially, as building and using complex models), she also began to discursively distance herself from school science. However, through being able to incorporate aspects of her at-home experience into school science (via learning about animals), Penelope continued to access school science in personally relevant ways. Zimmerman argues that the “when is science” perspective, which requires an understanding of science grounded in students’ own intentions and experiences, is important to incorporate into studies at the intersection of students’ ideas about science and their negotiations of science identities because students develop science identities when they engage in practices that value and make use of their everyday experiences. More such research is needed to continue to investigate the ways in which students’ ideas about science and their negotiations of science identity are intertwined.

How I Conceptualize Science

I am approaching my study of science identity from the understanding that science is a culturally-mediated process, (Brickhouse et al., 2000) and indeed constitutes a subculture in itself (Aikenhead, 1996). I acknowledge that my understanding of science is shaped by the culture of which I am a part, as a young, white, female graduate student who has studied both science and science education at western
academic institutions in the United States. I conceptualize science as all of the ways of thinking, acting, and being that are involved in being an active and curious participant of one’s world. This conceptualization of science is built from my experience engaging with Western Modern Science as both a science student and science educator, as well as my learning about Indigenous Knowledge and Cultural Science through interaction with Indigenous scientists and their writing. My conceptualization of science has grown from a recognition of similarities between both of these ways of knowing the world.

At the heart of science, for me, are the processes of asking questions based on observation of and interaction with the world, and the processes of investigating those questions through either “formal” or “informal” processes of data collection and analysis. In my conceptualization of science, “data” is not defined by the procedure with which it is collected, by the way it is recorded and codified, or by the distinction of qualitative/quantitative. Data is defined by its function— to investigate a question—and could therefore be anything from a memory of a conversation to a running logbook of daily maximum temperature of the sidewalk in front of one’s house, to an electropherogram. I do not define methods of scientific inquiry by standardized procedures or the use of specialized tools or equipment but instead by their function: to act as the means of investigation itself. My conceptualization of science therefore includes all kinds of observations; for example, those made in one’s neighborhood park using their own eyes, or made via an autonomous underwater vehicle and transmitted back from the depths of the ocean. It includes all kinds of measurement and data collection; for example, taking a photo of the same patch of Earth every day, or taking a deep breath each morning and mentally noting the smell, or instructing a satellite to detect the intensity of incoming radiation every second. And it includes all kinds of data analysis; for example, complex statistical analysis or a process of annual story-sharing.
Part 2: Identity

Identity as Sociocultural and Negotiated

In this section, I will present the conceptualizations of and approaches to studying identity and science identity which have influenced my own conceptualization of science identity, to ground this thesis project’s conceptual framework in the science identity research literature.

Sociocultural Views of Identity and Identity Negotiation

Identity is often framed in the education research literature as the study of what kind of person students or teachers want to be in both the present context, and/or in particular future contexts (Gee, 2000). Many researchers have undertaken studies of science identity from a sociocultural view; much of this work is influenced by the early work of Gee (2000) who argued that to be a particular kind of person we must act, participate in discourses, think, and value in ways that make who we are and what we are doing visible to others. This thesis project is situated within the science identity research literature that takes this kind of sociocultural view of identity.

Carlone et al. (2015) articulate a theory of identity shared by many current science identity researchers: that identity is “a process of identifying (or not)” and not “a reified achievement” (p. 1527). They and other researchers have shifted the focus towards identity work, and center their conceptualizations of identity on the understanding that identity is formed in practice with others, in ways that are shaped by and shape the norms of a given setting and larger sociopolitical/sociohistorical structures at overlapping timescales (Carlone et al., 2015; Lemke, 2001). Indeed, Calabrese-Barton et al. (2013) conceptualize identity work as the “ongoing effort to continuously refigure oneself” within and against local norms and larger sociocultural narratives (p. 41-42). This thesis project is situated within the science identity research literature that conceptualizes the process of identity negotiation as identity work as these researchers have articulated it.

Identity is Made and Remade Through Discourse. One of the characteristics of a sociocultural conceptualization of identity is the understanding that identity is continually made and remade through
discursive interactions. A discursive view of identity holds that “language can be conceptualized as an active resource for identity construction” (Brown et al., 2005, p. 783). Brown, Reveles, and Kelly (2005) put forth a framework for discursive identity in the science learning context. They argue that students’ identities are negotiated through discourse; discourse is a signal of cultural membership because it includes histories, assumptions, and cultural knowledge, and can therefore signal identity through interactional exchanges. Identity is therefore negotiated through ongoing mutual interpretation. Membership in discourse communities hinges on how students position themselves in relation to knowledge, discourse practices, and others, and on how those acts of positioning are recognized by others. Brown et al. (2005) take a sociocultural view of identity and acknowledge, too, that the manifestation of identity through social interactions does not happen independently of broader sociohistorical contexts, but in fact shapes and is shaped by them. I too conceptualize identity as made and remade through discourse; in this thesis project the discourse was bounded to that of students’ interviews.

Identity Both Shapes and is Shaped by Larger Social Structures. A central question in studies of science identity among those researchers who take a sociocultural view of identity is the extent to which individual agency and macro-level structures (e.g. the sociopolitical meanings carried by/ascribed to cultures and ethnicities) influence identity negotiation. Identity researchers approach this question using many different theoretical frameworks. All identity researchers who take a sociocultural view of identity attend to, in some way, the ways that cultural meanings arising from everyday actions are both produced by and reflect/counter larger social structures (Eisenhart & Finkel, 1998). Conceptualizing identity in this way draws attention to how identity negotiation is shaped by larger social structures; put concisely, it acknowledges that people are formed in practice (Carlone, 2012). Such an approach helps make salient the "co-development of the global and the local" (Carlone, 2012, p.10). Socioculturally-grounded studies of identity acknowledge that the process of coming to be (which is heavily influenced by individual agency) takes place as structure (race, class, gender, etc.) exerts its influence on local practice to enable and constrain available subject positions, all while these structures are themselves being
reproduced by everyday practice (Carlone, 2012). Shanahan et al. (2011), for example, conceptualize identity as made through both authoring and recognition, and as shaped by and shaping social structures. Attending to the ways in which the process of identity negotiation is entangled with these larger structural influences thus forces us to ask how dominant ideologies are taken up to produce particular ways of being (Carlone, 2012). This thesis project attends to this last consideration in particular, by considering the ways in which students’ science identities are shaped by their ideas about “real” science.

**Identity is Negotiated via Authoring and Recognition**

This project is situated within the science identity research literature that conceptualizes identity as continually made and remade, through processes of identity negotiation that involve both identity authoring and recognition. Here I am using the phrase “identity negotiation” to indicate that authoring science identity is a contentious process for students. Students negotiate their science identities within multiple and overlapping contexts, each with their own structures of power and privilege (Calabrese Barton et al., 2013).

**Science Identity Authoring.** Tan et al. (2013) theorize identity negotiation as consisting of two different performances of self: students’ narration and embodiment of science “identities-in-practice.” They explain that students author science selves through their accounts of "who they are in science, who they can be in the future in science," and "the pathways they describe to get there" (Tan et al., 2013 p. 6). Distinguishing between these narrated “identities-in-practice” and embodied identities-in-practice, they define embodied identities-in-practice as performances of self conveyed through actions and interactions with the tools and discourse of a specific context or figured world (Tan et al., 2013). In my analysis of students’ interview data, I investigated students’ narrated identities-in-practice and described the science selves that they authored through such narrations.

Carlone and Johnson (2007) include performances of self (which they define as “social performance of relevant scientific practices-- e.g. ways of talking and using tools” (p. 1191)) as one of three key pillars in their model of science identity, the others being recognition and competence with science content. Calabrese Barton et al. (2013) use the concept of identity trajectories to extend the
influence of identity work to include both present and future. They argue that when students’ identity negotiations are recognized and supported, students view possible future science selves which accumulate layers of meaning as identity negotiation continues. All of these researchers theorize the process of science identity negotiation as involving performance of self. However, they also recognize that performance of self, alone, does not constitute identity negotiation. Recognition of these performances of self has been established as a crucial component shaping students’ negotiations of science identity.

**Recognition of Science Identity.** It is well accepted that science identity is influenced not only by a student’s personal beliefs, self-recognition, and self-perceptions, but also by the way that a student’s performance of self is recognized by their peers and by meaningful others, both scientific and non-scientific, (Carlone & Johnson, 2007; Vincent-Ruz & Schunn, 2018) and by the geopolitical context of the classroom itself. The kinds of talk, actions, and presentations that are marginalized or emphasized in the classroom therefore impact student science identity (Carlone & Johnson, 2007). In fact, in their longitudinal study of 15 successful women of color Carlone and Johnson (2007) found recognition to be the greatest predictor of future science identity (see below). More recent studies of science identity have attended to questions not only of who receives recognition, but whose recognition matters (Avraamidou, 2020).

This approach requires paying attention to how recognition functions to make science identities accessible/inaccessible, or how recognition makes border crossing (Aikenhead, 1996) more or less hazardous, to students with differing multilayered identities. Besides considering the structure of classroom discourse and the nature of its overlapping figured worlds (see Chapter 3 for a discussion of the methodological use of figured worlds in this thesis project), science identity researchers are also investigating what subject positions are available and/or valued in classrooms, to shed light on how or if student science identity negotiation aligns with these celebrated subject positions. Carlone et al. (2014) propose asking such questions as: “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?” (p. 837).
Identity is Negotiated Within Figured Worlds

In addition to theorizing identity as negotiated through the processes of authoring and recognition, I use the concept of figured worlds to theorize the ways in which students’ identity negotiations are shaped by the various contexts they inhabit. It is worth mentioning here that many science identity researchers make use of the concept of figured worlds because doing so makes salient the different ways in which collections of norms, rules, resources, practices, etc. (which have been legitimized via historical reproduction) function to shape what science is and what being a scientist looks like (Calabrese-Barton et al., 2013). Figured worlds, therefore, shape how students conceptualize what science is, and shape how they express their affiliations with it (Carlone et al., 2014).

Considerations of the influence of recognition on students’ identity negotiations are often entangled with consideration of the figured worlds in which students’ identity negotiations are taking place. In a longitudinal case study of three diverse students’ identity work from fourth- to sixth-grade school science, Carlone at al. (2014) looked for the figured worlds shaping what counted as science in a given setting, and the practices, talk, and presentations that were celebrated or marginalized by those relevant figured worlds. The study showed that more overlap between celebrated subject positions and students’ identity work made the process of science identity negotiation easier and less threatening for these diverse students. Conceptualizing identity negotiation as shaped by (and shaping) the figured worlds in which it happens requires researchers to ask not just who students are but who they are obligated to be in a given community (Carlone, 2012).

How Identity Recognition Has Been Studied

In this section, I will discuss various ways in which the role of recognition in science identity negotiation has been studied, in order to situate this thesis work within the literature on identity recognition. Notably, much research has focused on how recognition by others shapes students’ science identity negotiations, while little research has focused on the ways in which students’ own self-recognition shapes their negotiations of science identity. The body of work on recognition by others has shaped the way I approached my analysis of students’ science identities in this thesis project; therefore, I
will present a summary of that research here. I also include a discussion of the few studies that have focused on the role of self-recognition in science identity negotiation, to situate this thesis project within that small (but growing) body of research.

Studies of science identity frequently include analysis of the role of recognition, particularly recognition by others. It is widely accepted among science identity researchers that recognition (by both oneself, and by who Carlone and Johnson (2007) refer to as meaningful others) is an important component of the process of science identity negotiation. Zimmerman (2012) argues that recognition work includes how a student perceives themself, the perceptions that they want others to see, and the recognition they get from others. As such, recognition is an important analytical tool for examining how students negotiate their science identities in science learning environments.

Most researchers theorize recognition from others, on varying scales from individuals to communities to societies, as a necessary component of identity formation (Avraamidou and Schwartz, 2021). The idea of identity as negotiated through “bids for recognition” (Carlone et al., 2014) provides one example of the ways in which recognition by others has been investigated as a crucial component of identity formation. Most science identity researchers have focused more heavily on the role that recognition by others plays in shaping identity and the identity negotiation process. Some researchers, however, have explored the importance of both self-recognition and recognition by others in shaping students’ science identity negotiations. In this section I will present a review of some of the studies of recognition that have been most influential in shaping my analysis of students’ science identity negotiations in this thesis project.

Many studies of science identity focusing on the role of recognition have used the model created by Carlone and Johnson in their 2007 paper titled “Understanding the science experiences of successful women of color: Science identity as an analytic lens.” In that model, Carlone and Johnson investigated the influence of competence, performance, and recognition on the science identities of 15 successful women of color over the course of their undergraduate and graduate careers. They found recognition to play the largest role in shaping the womens’ science identities, and decomposed recognition into self-recognition
and recognition by meaningful others. They found that the women recognized themselves as science people by pinpointing certain aspects of science that aligned with other aspects of their identities. Sometimes, the women even redefined science when putting themselves in relation to it. However, recognition by meaningful others interacted most critically with the women’s racial, ethnic, and gender identities. This interaction between recognition by others and the intersecting identities of students has been explored in numerous other studies investigating the role of recognition in science identity formation.

Hughes et al. (2020) found, through their study of three middle school girls of color in a coding camp, that both personal and public recognition of competence with coding tasks/activities by their teachers served to “thicken” the students’ coding identities. Interestingly, the coding identity of one of the girls, who received frequent public recognition by the teachers, thickened more throughout the course of the study, because this public recognition led to that student being recognized as a coder by their peers. The authors proposed that perhaps the fact that this student was White-passing, and the fact that her behavior aligned with the “good White girl” identity, affected how the educators recognized her. This study provides one example of how recognition is considered in the science identity research literature; here, the authors investigated how recognition by meaningful others, in combination with the structural norms of science (and particularly the field of coding) shaped the girls’ disciplinary identities.

Calabrese-Barton et al. (2013) investigated the role of “critical identity-leveraging resources” (p. 67) in the science identity development of 40 girls over the course of sixth to eighth grade at schools across the country. They focused on the ways in which the students’ use of those resources was recognized by both peers and teachers, finding for one African American girl in their study that a certain resource (a movie she had produced in art class and shown to her science class) contributed to a shifting of her school and home figured worlds in such a way as to open up the ability for others to recognize her as a science person. The authors acknowledged the importance of peer and teacher recognition to this shifting of her identity trajectory towards one of a science person, again emphasizing the importance of recognition by meaningful others in shaping identity negotiations.
Lucy Avraamidou has made a call for intersectional studies of the role of recognition in science identity negotiation. To operationalize intersectionality in studies of science identity (Gonsalves, 2020) requires that researchers consider science identity as one of many identities held by each individual student, and acknowledge that students’ science identities are shaped by and shape those other identities. Lucy Avraamidou (2019) characterizes science identity as relational to other multiple identities such as gender identity, religious identity, and ethnic identity. She considers the integration of multiple identities at the individual, interpersonal, and collective levels of self.

Avraamidou (2020) articulates the importance of recognition to studies of identity by drawing a quote from Taylor (1992), which emphasizes that “Our identity is partly shaped by recognition or its absence… Nonrecognition or misrecognition can inflict harm, can be a form of oppression…” (p. 25). Studies of recognition are therefore important particularly in science identity research because science, as Avraamidou explains, “has traditionally been an elitist world from which certain groups are excluded” (p. 332). She argues that an intersectionality lens can allow researchers to move from personal science identity narratives (on which much science identity research has focused) toward a broader understanding of the social and political meaning of identity narratives. For Avraamidou, investigating the role of recognition in identity development through an intersectionality lens can help researchers begin to answer questions like: who is allowed in the world of science? And: who is recognized as a science person in specific contexts? She suggests that future science identity research examine how recognition differs for different individuals, based on their unique ethnic identities and individual histories.

Rodriguez et al. (2017) found that both self-recognition and recognition by meaningful others played an important role in the STEM identity development of 17 Latina undergraduate STEM majors. These researchers used Carlone and Johnson’s (2007) science identity model to investigate the role of both self and outside recognition on the students’ STEM identity development. They found that these Latina students based their self-recognition on their own understanding of STEM content and their understanding of their place within the STEM community. This focus on knowledge when making self-recognition decisions is similar to the research scientist identity seen by Carlone and Johnson among the
women in their 2007 study. Recognition from within the STEM communities at their respective universities was also found to be critical, as it functioned to either welcome them into or exclude them from the science community. This study, and those detailed above, provide notable examples of the varying ways in which researchers have investigated the importance of recognition by others in shaping the ways students negotiate their science identities. Few studies, however, have focused heavily on the role that students’ self-recognition plays in the science identity negotiation process.

One of the most prominent studies considering the role of self-recognition in science identity development was done by Zimmerman (2012), as discussed above. Zimmerman focused on the at-home science activities and hobbies of one girl (Penelope) from fourth to seventh grade, creating an account of, among other things, her self-recognition through time. Acknowledging the continued importance of recognition by others, Zimmerman noted that Penelope’s recognition work was “a complex relational negotiation” between how she viewed herself, how she was viewed by others, and how she wanted others to view her (p. 624). However, Zimmerman primarily focused on Penelope’s self-recognition and concluded from Penelope’s behavior that “recognition work is a complex negotiation between aspects of one’s self and of science” (p. 625). Interestingly, the findings showed that it wasn’t necessary for Penelope to recognize herself as scientific in order for her to participate in science in productive and relevant ways, which allowed her to gain access to “content, competencies, and artifacts” (p. 625). This is the only such study that I have been able to find that investigated the relationship between a student’s ideas about science and the ways they recognized themself as scientific/unscientific.

These studies illuminate the kinds of identities that are accepted and supported in the culture of science. Critically, focusing on recognition makes salient who the science insiders are and who the outsiders are, and what determines where the line is drawn. What this work forces us to recognize, then, is that becoming a science person is not solely a process that is within one student’s control—instead, it can very much be (particularly for students with marginalized identities) something that happens to a student (Avraamidou, 2020). This, of course, has many implications for science teaching, learning, and science identity research. However, there is remarkably little research on the impact that students’ own self-
recognition does have on their science identity development. There is therefore a need within the field of science identity research to further explore the role of self-recognition in students’ negotiations of science identity, across science learning contexts and student communities.

**How I Conceptualize Science Identity**

In this thesis project, I take a view of identity as sociocultural, discursively constructed, and intersectional. I understand identity to be fluid, dynamic, and negotiated in context. I understand identity to be negotiated (or: continuously made and remade) through participation in discourse genres, which include cultural knowledge embedded in social interactions (Brown at el., 2005). Identities are authored via presentations of self, made through interacting with others. Because identity is negotiated through discourse, the process of identity negotiation inherently involves recognition both by oneself and others. As stated by Carlone and Johnson in their foundational 2007 paper: “being ‘somebody’ requires the participation of others” (p. 1190). Identity consists of multiple components that are constantly interacting with the social context and norms of a given situation; students bring their whole selves to the construction, negotiation, and expression of their repertoire of identities-in-practice (Avraamidou, 2020; Tan & Calabrese Barton, 2009). We must therefore approach students’ expressions/negotiations of identity as those of whole selves acting within specific geopolitical environments (Avraamidou, 2020).

I conceptualize identity work as happening within layered figured worlds and structures of power (Calabrese Barton et al., 2013; Carlone and Johnson, 2007) that both shape and are shaped by identity negotiation. These structures of power act on scales ranging from individual to geopolitical. Students always negotiate their (continuously evolving) identities within the particular constraints of the overlapping figured worlds they are acting in. Therefore, identity negotiation is at the same time personally, socially, and politically constructed (Avraamidou, 2020). To attend to this complex interaction between micro (local) and macro (global) structures of power and influence, and to attempt to do justice to the complexities of each individual student and their processes of identity negotiation, I conceptualize identity as inherently intersectional. Each of us, then, has a repertoire of identities that we negotiate as our
complex, whole, selves. These identities are inherently intertwined, constantly informing each other, and hybridizing as we move through the various overlapping figured worlds we inhabit.

In this research, I hold that the process of science identity negotiation includes both authoring and recognition, and that negotiation of science identities occurs simultaneously and is intertwined with negotiations of students’ other intersecting identities. Students author science selves through both narrated and embodied performances of self. (My analysis focused on students’ narrated performances of self during their interviews.) Students recognize the science selves that they author, and these science selves are recognized by others. (My analysis focused on how students recognized their own science selves.) This recognition shapes students’ continued science identity authoring. The process of science identity negotiation is acted upon by students’ school and outside-school figured worlds. The interaction between students’ multiple identities and the layered and overlapping figured worlds in which they are being negotiated ultimately combine to configure students’ science identities-in-practice, which of course influence their identity trajectories (and are influenced by them). See Figure 1 for a representation of my initial working model of science identity negotiation, which situates the pieces of science identity negotiation considered in this study within my larger conceptualization of how identity is negotiated.

Figure 1 Initial model of science identity negotiation. The portions of the model enclosed in the orange dashed line are the components of science identity negotiation that were analyzed in this thesis project. The purpose of this figure is to place the identity components analyzed in this study in context, showing how they fit within my full conceptualization of how students negotiate their science identities.
Contributions Made by This Thesis Research

The goals of this thesis project were to explore and describe how sixth grade students articulated and negotiated their science identities in the context of a science-based unit taking place in their social studies classroom. This research goal also led me to investigate students’ conceptualizations of science, because it became clear throughout the research process that students’ ideas about science were shaping the ways they articulated their science identities. Avraamidou and Schwartz (2021) argue that investigating students’ ideas about the nature of science through the lens of science identity is needed in order to determine whether students’ ideas about science may “facilitate or hinder their development of science identity” (p. 338). They argue that if marginalized students experience science as a community steeped in the ideals of WMS, those experiences decrease the chances that those students’ other intersecting identities can ever be compatible with a developing science identity. While this study does not explicitly address the science identity negotiations of marginalized students, it does shed light on the interaction between students’ conceptualizations of what science is and who does it with their abilities to recognize themselves as scientists.

As Avraamidou and Schwartz (2021) argue, self-view is inherently a part of questions about who is allowed in science and who aspires to be a scientist. However, there is little research that deeply investigates students’ views of themselves in science. It is therefore imperative that science identity researchers keep in mind that students’ ideas about science are fundamentally intertwined with how they see themselves in relation to science.

This thesis project addresses these two identified gaps in the current science identity research literature: 1) the need for further exploration of the role of self-recognition in processes of science identity negotiation and development, and 2) the currently under-researched intersection between science identity negotiation and students’ conceptualizations of the nature of science. By exploring the ways in which these 10 sixth grade students conceptualize science and recognize themselves, this work makes a contribution to our growing understanding of the ways in which students’ conceptualizations of science shape their relationships with it.
CHAPTER 3
METHODS

Methodological Framework

Figured Worlds

The theory of figured worlds was used in this study to make salient the differing ways in which students conceptualized science and their identities in relation to it. Understanding students’ identity authoring and recognition through the lens of their school and outside-school figured worlds helped make salient the ways in which their learning about science in school and their experiences engaging with it outside of school shaped both their conceptualizations of science and the ways in which they authored and recognized their own science identities. Figured worlds were used to understand students’ identity expressions in this study because science identity authoring was conceptualized as the ways in which students described their (scientific) participation in the practices and structures of their various figured worlds (Calabrese-Barton et al., 2013). Viewing students’ identity negotiation as happening across multiple figured worlds made salient the fact that students’ authoring of science identities did differ across figured worlds. Understanding students’ identity authoring as differing across school/outside-school figured worlds lent more depth to the analysis by also making salient the multifaceted ways in which every student conceptualized science. Indeed, students’ conceptualizations of science were seen to be shaped by the unique structures of the figured worlds themselves, and these multifaceted conceptualizations of science were seen to shape the ways in which students recognized their science selves.

Hatt (2007) describes figured worlds as the forces that influence speech, behavior, and practice within social spaces; the “rules” or “guidelines” (p. 149). Holland et al. (1998) define figured worlds as socially/interactionally constructed worlds that bound how identity is negotiated by valuing particular types of people, acts, and outcomes, (or talk, actions, and presentations (Carlone et al., 2014)) which constrain the available possibilities and therefore guide individuals to act in appropriate ways.
Figured worlds are similar to Aikenhead’s (1996) subcultures; Aikenhead argues that school science is a subculture of WMS, and that it often expects students to integrate the dominant norms, values, and practices of western science into their personal worlds. From this understanding, the theory of figured worlds helped make salient the ways in which students’ conceptualizations of science were shaped by the contexts in which they engaged with it (namely, in school vs outside of school). In essence, Aikenhead argues that there is an inherent disconnect for every student between the figured worlds they inhabit outside school and those that they are forced to inhabit in the science classroom. To get access to school science, students need to engage in border crossings from their unique subcultures (here, their outside-school figured worlds) to the subculture of school science; the hazardousness of these border crossings depends on the particular intersecting identities of each student. This framing of identity negotiation as these acts of border crossing between figured worlds helped make salient the influence of learned ideas about WMS on students’ perceptions of their own ways of thinking, acting, and being in their outside-school figured worlds.

Carlone (2012) argues, similarly to Aikenhead, that who students can become (i.e., how they can negotiate their identities) in any given figured world is inseparable from who they are obligated to be by the very structure of that figured world. This idea that the valued presentations in any given figured world function to shape the ways in which students “become” helped explain the disconnects between the ways in which students authored their science identities but did not recognize them (due to the shaping of their conceptualizations of science by the ideals of WMS). In this way, the theory of figured worlds framed my understanding of the factors shaping, for the students, both what “counted” as science (Carlone et al., 2014) and the ways of thinking, acting, and being that counted as scientific.

Figured worlds were therefore used in this study to describe the sources of the various influences on students’ conceptualizations of science and on the ways in which they expressed and negotiated their science identities.
Interview Methodology

Interviews in this study were conducted ethnographically. As the researcher, I was present and actively engaged in the classroom community for a total of six weeks from April to June of 2020. (However, data collection only occurred for the five weeks for which the study had IRB approval.) This period included an initial week of observation, followed by five weeks of teaching. (The classroom teacher was present as the primary teacher for the first week, then as support for the following five weeks.) Interviews were conducted over the course of two weeks in May of 2020, about halfway through my time in the classroom. As such, I conducted the interviews positioned as a participant-observer (Spradley, 1980) in the classroom. I had a standing relationship with each student who I interviewed, and knew them (as both an observer and teacher) in the context of their classroom before conducting each interview. This positioning allowed me to draw on the knowledge of each student I developed during this time in their classroom to structure each individual interview.

All interviews were structured in such a way as to encourage students to be reflective (Simms and Shanahan, 2019). Questions were used as a way to get students talking, and were asked conversationally. As such, the order in which questions were asked, the nature of the questions, and the total number of questions asked differed from interview to interview, depending on my knowledge of each student and their responses during the interview. A unique interview guide was therefore developed for each interview. See the appendix for a list of interview questions.

Educational Setting

The Classroom

The study was conducted in a small, rural middle school in a New England state. The classroom was a sixth grade social studies classroom, led by a middle-aged, white, female teacher. This teacher had an enthusiasm for culturally responsive teaching, an easy and warm way of interacting with students, and was well-respected in her school for her innovative uses of technology in the classroom and her attentiveness to best practices in social studies teaching. She was drawn to this project because of her
desire to explore connections between social studies learning and science through the lens of human-environment interaction, and because of her interest in incorporating Indigenous knowledge and perspectives into her teaching.

The classroom climate was generally one of mutual respect between students and between students and the teacher, with a focus on respect for all ideas and contributions, an expectation of engagement, and a culture of curiosity, respectful challenging of ideas, and evidence-based explanation.

The Participants

The class of twelve students was majority white, with one self-identified Indigenous student and one other self-identified student of color. All students either lived in the town in which the middle school was situated (a town of approximately 10,000 people, home to a major research university), or in the surrounding rural areas. Many students were experienced hunters, fishers, and spent much time outdoors in the surrounding areas interacting with both the local woods and waters. Some students had deep family histories in rural New England, other students’ families had moved to the area more recently.

The students as a group were generally enthusiastic and high-energy. They showed respect for each other and each other’s ideas, but needed occasional reminders to refocus and stay productive. They enjoyed sharing aspects of their home lives with the class, and many of them shared relationships outside of the classroom. There were two main groups of friends in the class: one group of boys that shared an interest in fishing, hunting, and playing sports, (this group was generally very high-energy and tended to distract others in the class if not redirected) and one group of girls that shared interests in some social justice oriented co-curricular activities, some sports, and some other interests outside of school (this group tended to stick to themselves and generally worked well together). Students not belonging to one of these two main identifiable friend groups were also friendly with the students in these groups, but tended to interact with other students in the class who weren’t part of one of these groups. However, there was much crossover between these two friend groups and the class dynamic was generally one of respect towards all and an acknowledgement of each student’s individual strengths.
The Integrated Science and Social Studies Unit

The interviews analyzed in this study were conducted during the course of a unit that was developed specifically as a part of this research. Initial goals of the research were to create an integrated science and social studies unit that drew from both Cultural Science (CS) and Western Modern Science (WMS), and to use that unit to investigate the nature of students’ science identity expressions in the context of that purposeful integration of CS and WMS. However, as the unit was being developed it became clear that during the timeframe of the study, integration of CS and WMS to the level initially intended would be challenging to achieve. Therefore, instead of integrating CS and WMS in collaboration and relationship with a Cultural Knowledge Keeper (carr, 2019) as would have been ideal, the unit was developed in collaboration with the classroom teacher and members of a local Indigenous science education organization, using resources vetted by local Indigenous groups and tribes.

The unit was centered around one of the five themes of geography, a framework that the collaborating teacher had been using to structure a large part of their teaching throughout the year of this study. This framing allowed the unit to integrate purposefully into the existing curriculum. The unit focused specifically on human-environment interaction in the watershed of the middle school, one of the largest watersheds in the state. The river draining this watershed runs right through the town in which the middle school is situated, and provided the anchor for the unit. The unit consisted mainly of independent research done in small student groups, with the final product being a collection of student-made murals depicting the interaction between humans and the river through time. While purposeful integration of CS and WMS in the unit still remained a focus during both unit development and teaching, as my time in the classroom progressed the focus of this research shifted to investigating the relationship between students’ conceptualizations of science and their expressions of science identity. Therefore, the interviews were ultimately structured with those research interests in mind.
Data Sources

Many types of data were gathered throughout the study. However, only the interviews were ultimately chosen for analysis. Data was collected during the last five weeks of my time in the classroom, after IRB approval was obtained. These data included field memos written after each day in the classroom, video recordings of the classroom during each class period, artifacts of all student work done during the unit (written reflections, small group research notes, and final projects), interviews (including audio recordings, video recordings, written interview notes taken during each interview, and a memo made after each interview), research memos written during the analysis process, and relevant project meeting notes and recordings.

Given the timeline and scope of the project, interviews were the only data source chosen for systematic analysis. The interviews occurred during the time at which the unit was being taught. Out of the 12 total students in the class, 10 consented (and received guardian consent) to participate in interviews. These interviews were conducted over the course of two weeks in May of 2020. Each interview lasted between 20 and 30 minutes and was conducted in a small multi-purpose room connected to the classroom by two open doorways. The interviews were scheduled either during the school day when students had their advisory block, or immediately before school or after school. The interviews were recorded both with a video camera and an audio recorder (except for one interview where video was not obtained). A unique interview guide was developed for each interview, on which notes were taken during the course of each interview. Following each interview, a memo was written consisting of interesting noticings, emerging patterns across interviews, questions that should have been asked, and reflections on the affective environment and student’s body language during the interview.

All 10 interviews were transcribed; nine of the video recordings were transcribed, and one interview was transcribed from its audio recording. All initial transcription was done using Otter.ai. Transcripts were then updated manually using video (9 interviews) and audio (1 interview for which video was not obtained).
Data Analysis Methods

How I’m Bounding Science Identity

The purpose of this study was to investigate the ways in which students articulated their science identities during the interviews, which involved investigating how they conceptualized science and how those conceptualizations of science shaped the ways they expressed their science identities. As detailed in Chapter 2, I acknowledge that a student’s science identity is but one of their many intersecting identities, and therefore both informs and is informed by those other identities. I theorize identity as fluid, dynamic, and made/remade through discourse. I also acknowledge the ways in which the various figured worlds students inhabit both shape and are shaped by their expressions of identity.

The focus of this study centered on the ways in which students authored science selves through descriptions of their own ways of thinking, acting, and being in both school and outside-school figured worlds, and on the ideas about science that students communicated while authoring science selves. Therefore, I bounded my analysis of science identity to focus specifically on the processes of science identity authoring that emerged in the discourse (i.e., how students authored science selves) and on the conceptualizations of science that emerged in the discourse (i.e., how students drew different conceptualizations of science from their own ways of thinking, acting, and being in the two different figured worlds and from their learned ideas about science influenced by the paradigm of WMS). By analyzing these aspects of science identity using interviews (the discourse of which is itself a momentary creation/representation of those people involved), I inherently bounded my analysis to one snapshot of students’ ever-evolving intersectional, and multidimensional science identities.

Although my status as a participant-observer allowed me to draw on my knowledge of the students gained through time spent building relationships with them in their classroom (and therefore allowed me to take an ethnographic approach to the analysis of the interview discourse), I nevertheless analyzed their expressions of science identity only in the discourse of their interviews. In this way, I inherently bounded my analysis of their identities to the discourse of the interviews themselves and used my knowledge of each student to enrich my interpretation of that discourse. This is to say that I was not
able to (and did not aim to) conduct an analysis of all the intersecting components of each student’s identity, but focused on their expressions of science identity only as they emerged in the specific discourse environment of each interview.

By analyzing expressions of identity solely in the interviews, I also bounded my analysis of identity to the emic realm. While I recognize that science identity isn’t only comprised of what someone says about their relationship to science (indeed, it also arises through participation in one’s various figured worlds and therefore inherently involves interaction with the structures of those figured worlds and the recognition of the other people in those figured worlds, as detailed in Carlone and Johnson (2007)), in this study I am focusing only on what students said about their own science identities and therefore am only analyzing the emic portions of their science identity negotiation.

All data analysis, including those processes detailed below, was conducted in an open, iterative, recursive, and abductive way. This iterative and abductive approach was conducted systematically and robustly, and inherently shaped the data analysis process in nonlinear and cyclical ways. The presentation of the data analysis process here has thus been adjusted to read as linear, only for the purposes of readability; this linearity does not reflect the actual sequence of analysis that took place.

The Coding Process

**Highlighting**

All coding and analysis was informed by my status as a participant-observer (Spradley, 1980) in the classroom community, and informed by my previously articulated theory of identity. After all ten interviews were transcribed, all identity expressions in the transcripts were highlighted (Goodwin, 2015). In this initial round of highlighting, all identity expressions were highlighted; this included expressions of science identity and other aspects of students’ identities. Identity expressions were defined as the student describing something (for example, an experience or idea, a way of thinking, or a belief) that seemed to inform the way they carried themself in the world; i.e., informed who they are. For example, Andi explained that “emotional reactions with animals, too, is something else I'm kind of interested in.” She
elaborated that “...if I sort of get to know the animal, and I'm careful with it, it will be more comfortable with me doing things like picking it up or petting it.” These excerpts were coded as identity expressions because they detail one of Andi’s interests and give the reader a glimpse into who Andi is by providing some detail about what she finds intriguing.

Students’ descriptions or explanations that did not include any elements of their own personal beliefs, values, philosophies, etc. were not labeled as identity expressions and were not highlighted. For example, when explaining a past experience with a river, Annette explained:

...the stream was kind of, I don't know, it was like, because of the river kind of like leaked in and it made these little like, kind of water, path, things that kind of like, I don't know, it was something like that.

This excerpt was not coded as an identity expression because although it is a description of one of Annette’s past experiences, it does not tell the reader anything about Annette’s interests, ways of thinking, values, hobbies, etc. It does not include any elements that help the reader “know” Annette, and so it was not coded as an expression of identity.

This process of highlighting was repeated until saturation was achieved. For the rest of the analysis, each of the identity expressions that was originally highlighted in the transcripts was set in the context of all that was known about each student from the total time spent working with them in the classroom. In other words, the transcripts were interpreted from my status as an active member of the classroom community.

**Creation of an Attribute Map**

All highlighted identity expressions were then copied from the transcripts and collated in an Excel spreadsheet. Each identity expression was entered in its own cell into the first column of the spreadsheet. Attributes of each identity expression were then identified, and listed as column headings across the top of the spreadsheet. Each identity expression was coded for as many attributes as applied to it, by marking a “1” in the appropriate column across each identity expression’s row. This process, which I am referring to as creation of an attribute map, was informed by Kelly and Chen’s (1999) concept of an event map. The full group of identity expressions was coded three times, which was the number of repeats
required to reach saturation (where no new attributes could be identified, and every identity expression was coded for all relevant attributes).

These attributes were then grouped according to categories that emerged when looking across the whole set of attributes. This grouping was done first at the finest level of detail; i.e., attributes were first grouped according to specific identifiable similarities. This grouping process was then repeated with increasing “coarseness,” meaning that the groups identified in the first round of grouping were then grouped according to their similarities, and so on. This grouping process continued iteratively, and allowed categories to emerge from the attributes themselves. These groups ranged in their level of detail; as the grouping process continued, groups were identified on a spectrum between both “fine” and “coarse” levels.

From this initial process of grouping, two groups emerged at the coarsest level of detail. These were: identity expressions containing students’ ideas about science, and expressions of science identity that did not contain students’ ideas about science. This is where the highly intertwined nature of students’ science identities and their conceptualizations of science started to emerge.

**Analysis of Identity Expressions Containing Students’ Conceptualizations of Science**

First, the group of identity expressions containing students’ conceptualizations of science were analyzed in greater depth. Students’ conceptualizations of science were considered to be a significant and important component of students’ identity expressions because the processes of science identity authoring and recognition are inherently influenced by (and influence) one’s understanding of what science is. The choice to analyze students’ conceptualizations of science came not only from the fact that they were present in a significant portion of students’ identity expressions, but also from my own theory of science identity, which rests on the understanding that you can’t see yourself in relation to science without at the same time defining or conceiving of science in some personal way. This personal process of conceptualizing science is inherently shaped by the figured worlds in which one encounters science and engages with/in it, and this process also shapes one’s way of thinking, acting, and being in those figured
Therefore, I hold that students’ conceptualizations of science are contextual and situated, made and remade, and negotiated alongside their science identities.

Using the iterative, abductive, and recursive process of identifying connections between attributes of the identity expressions that contained students’ conceptualizations of science, I worked from grouping according to similarities between attributes at finer levels of detail and nuance towards grouping those subgroups into umbrella groups (at broader levels of similarity). During this grouping process, three umbrella groups emerged at the broadest level of similarity. These three umbrella groups were identified as three influences on students’ conceptualizations of science. Two of these were figured worlds (or more specifically, collections of nested figured worlds): the figured world of “school,” and the figured world of “outside school,” and the other was not a figured world but the paradigm of WMS itself. These were identified as shaping how students signaled and communicated their personal conceptualizations of what science is. Table 1 provides examples of identity expressions that include each of these influences on students’ conceptualizations of science.

The figured worlds of school and outside-school became exceedingly more apparent as this iterative and abductive process of grouping continued. For example, one of the three umbrella groups was titled “student conceptualization of science draws from school science,” as all the attributes under this umbrella group were found to describe some reference to the figured world of school (and therefore all of the identity expressions coded for these attributes included student sensemaking about science shaped in some way by the figured world of school). Another of these three groups was titled “student conceptualization of science draws from world outside school.” All the attributes under this umbrella group were found to describe some reference to the outside-school figured world (really, to the unique group of numerous and overlapping outside school figured worlds that each student belongs to). Therefore, all identity expressions coded for these attributes included student sensemaking about science that drew from the outside-school figured world in some way. This outside-school figured world became apparent through students’ descriptions of their experiences with family, friends, and interactions with other elements of their cultural and community contexts, interactions with/experiences in outdoor spaces,
(both near and far from home) time spent engaging in personal interests, and in student sensemaking about the similarities and points of contrast between their outside-school actions and ways of being with science (see Table 1).

The last of these three groups emerged in contrast to the two groups described above. Attributes in this group didn’t directly describe or show influences from either the figured worlds of school or outside school, but instead showed influences of students’ ideas about what they referred to as “real science.” This umbrella group was titled “student conceptualization of science shaped by WMS.” The influence of the ideals of WMS became apparent in students’ descriptions of/ideas about where science happens, who does it, why science is important, useful, or valuable, and in students’ sensemaking about their ways of thinking and doing in relation to science.

Table 1 Excerpts illustrating each of the three influences that were identified as shaping students’ conceptualizations of science: their school figured worlds, their outside-school figured worlds, and the paradigm of Western Modern Science (WMS).

<table>
<thead>
<tr>
<th>Influence on Student’s Conceptualization of Science</th>
<th>Example Excerpt</th>
</tr>
</thead>
<tbody>
<tr>
<td>School Figured World</td>
<td><em>Alli:</em> Well when I was in fourth grade we had to do a science, uh third, sorry- science experiments. Uh, I did an apple one. It uh, took two days to do. It, uh, I did uh, you had to put water in uh, water and lemon juice in one, water and vinegar, and water and, just plain water. Those were my three slices of apples. My experiment, I was assuming lemon would do it because uh lemon usually keeps everything moist and good.</td>
</tr>
<tr>
<td>Outside-school Figured World</td>
<td><em>Ravi:</em> You don’t have to be, considered a scientist to be a scientist. Like <em>Interviewer:</em> What do you mean? <em>Ravi:</em> You don’t have to have a job in science to be one. <em>Interviewer:</em> Okay, you don’t have to. <em>Ravi:</em> Yeah. <em>Interviewer:</em> So like, what would be an example of somebody… <em>Ravi:</em> Uh, my friend’s dad is a scientist, he just, he doesn't actually have any, like sort of degree. He just learns about how electricity works, and how it connects to the water, and, so, like…</td>
</tr>
<tr>
<td>Paradigm of WMS</td>
<td><em>Yasmine:</em> Um, I think that, like, I think that a lot of times, what I do is like, kind of loose and free, and like, I think that scientists may be a little more like, know what they’re doing thing. But like, I just kind of sometimes I'll like, jump into something but I don't really know what's gonna happen.</td>
</tr>
</tbody>
</table>
Through analysis of all the excerpts coded as identity expressions that contained students’ conceptualizations of science, two types of science conceptualizations emerged. Students articulated a broad and inclusive conceptualization of science, as well as a narrow and exclusive conceptualization. Each of these conceptualizations was found to include subgroups of identity expressions that expressed specific inclusive or exclusive ideas. Excerpts illustrating the broad and inclusive conceptualization emerged as subgroups of the larger school and outside-school figured world groups, while excerpts illustrating the narrow and exclusive conceptualization emerged as subgroups of the larger school figured world and WMS groups. See Chapter 4 for a discussion of these two conceptualizations and their associated ideas, illustrated via representative excerpts.

**Analysis of Identity Expressions Not Containing Students’ Conceptualizations of Science**

When looking at those attributes of the identity expressions that did not contain students’ ideas about science, I used the same abductive, recursive, and iterative grouping process to work up from similarities between attributes at the “fine” scale towards the “coarse” scale. This process of iterative and abductive grouping and regrouping ultimately illuminated two subgroups within this larger group of attributes. These largest subgroups were: identity expressions where students were authoring science selves, and identity expressions where students were recognizing (or not recognizing) those science selves.

**Identity Authoring.** As discussed in Chapter 2, I theorize the process of identity negotiation as composed of the processes of both identity authoring and identity recognition. Students’ authoring of science selves to me during their interviews constituted one of the components of students’ science identities that was analyzed. The other component of students’ science identities that was analyzed was the ways in which students recognized the science selves that they authored. (Analysis of science identity recognition will be discussed in the following section.)

Identity authoring is the process of asserting one’s identity through continual bids for recognition (Gee, 2000). Acknowledging the importance of identity authoring requires a theory of identity as fluid, and an approach to studying it that conceptualizes identity as a process; that process is the process of
authoring a self in context (Johnson et al., 2011). An acknowledgement of the process of identity authoring is an acknowledgement of the fact that identity is constantly made and remade through one’s own ways of thinking, acting, and being. These acts of identity authoring are performances of identity that are shaped by the figured worlds in which they are made, and by one’s own personal history (Johnson et al., 2011).

An identity expression which contained some aspect of science identity authoring was defined as any identity expression in which the student described their own ways of thinking, acting, and/or being which I labeled as scientific (according to my personal conceptualization of science as detailed in Chapter 2). These moments of science identity authoring did not necessarily have to be categorized as scientific by the student (by, for example, the student’s discussion of a similarity between their own way of doing something and what they considered to be a scientific way of doing something). Instead, these moments of science identity authoring were categorized as scientific by me, the researcher, as I was coding each interview (again, according to the conceptualization of science detailed in Chapter 2). In fact, many of the identity authoring moves identified in the data did not include any discussion by the student of science, but instead were purely students’ descriptions of their own ways of being (or acting, or thinking) that I identified as scientific. In these identity-authoring expressions, students authored science selves. Students’ science selves were defined as their own descriptions of a self that engages in scientific ways of thinking, acting, and/or being in either the school or outside-school figured world. See Table 2 for selected examples of identity expressions in which students authored science selves.

Table 2 Selected examples of identity expressions in which students authored each of the three most common types of science selves which were identified in the data.

<table>
<thead>
<tr>
<th>Identity Expression: Moment of Science Identity Authoring</th>
<th>Science Self the Student Authored</th>
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<tbody>
<tr>
<td>Noah: …Well you also have to study- kind of study the body of water. Like if there’s something that they eat there, or a habitat that they- that they like.</td>
<td>Science Self 1: Observer/Investigator</td>
</tr>
</tbody>
</table>
Table 2 Continued

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<tr>
<th>Interviewer: So you researched that [the method of getting worms to come up out of the dirt]. And then you went and tried it and it actually worked? Ravi: Yeah. Well, we actually tried two different things that didn't work but yeah, then it worked. Interviewer: Before that, one that did work? Ravi: Yeah. You're gonna have a lot of trials.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science Self 2: Experimenter/Tester of ideas</td>
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</table>

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<tr>
<th>Yasmine: … The most like exciting slash nerve-wracking thing [about school science] is probably the actual, like experiments we get to do. Like, we um, like we get to do a bunch of different hands-on activities. And like, I think those are really fun because, like we can actually be part of it. And we get to, like, connect ourselves to it, so.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science Self 3: Enjoier of hands-on science</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Bryce: … When we did the erosion thing we basically, what it's doing is it's demonstrating a mini version of like a river.</th>
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<tbody>
<tr>
<td>Sub-type of Science Self 3: Modeler</td>
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</tbody>
</table>

Grouping and regrouping attributes of these identity-authoring expressions illuminated a total of nine subgroups; these comprised the full collection of types of science selves that students authored during their interviews. From those nine subgroups, three emerged as the most frequently occurring; these were the three most common types of science selves that students authored. These three main types of science selves included: Science Self 1 (Observer/Investigator), Science Self 2 (Experimenter/Tester), and Science Self 3 (Enjoier of hands-on science). One significant subgroup of those expressions in which students authored Science Self 3 was identified, so these were grouped to illustrate a sub-type of Science Self 3: Modeler. See Figure 2 for a summary of the different types of science selves that emerged through the grouping process. Students authored science selves (for example, the self of “observer” or “investigator”) by describing their engagement with science in their own figured worlds. This often included students making comparisons between their own ways of thinking, acting, and being and their own broad conceptualization of science, but also included students describing their ways of thinking, acting, and being without explicitly connecting those ways to their ideas about science. (For example, a student might describe a time they made careful observations of something either with or without stating that observing is a scientific thing to do.)
Figure 2 Diverse collection of science selves that emerged during the grouping process of students’ identity expressions that contained aspects of science identity authoring. The three most common types of science selves that emerged are highlighted in blue.

Identity Recognition. The second component of students’ science identities that was analyzed was students’ recognition (or lack of recognition) of the science selves that they authored during their interviews. The ways in which people author their identities (i.e., the ways in which they make bids for recognition) and the ways in which those authoring moves (bids) are recognized combine to inform one’s identity through time. Calabrese-Barton et al. (2013, p. 43) articulate the relationship between identity authoring and recognition when they explain that "within figured worlds, identity is made evident through what individuals say and do, [and] how a student and their work is recognized and by whom..." Here, the “what individuals say and do” is what I am referring to as “identity authoring,” and I am focusing on how students recognized (or didn’t recognize) their own science selves made salient by their identity authoring moves.

An identity expression which contained some aspect of identity recognition was defined as any expression in which the student put themselves in relation to their understanding of “a scientist” or put
their own ways of thinking, acting, and/or being in relation to their understanding of the ways of thinking, acting, and/or being of scientists. Grouping and regrouping attributes of these identity expressions illuminated the nuances of how students did/did not recognize themselves as scientists. However, the most significant pattern that emerged during this grouping process was that the majority of students did not recognize themselves as scientists. See Figure 3 for selected examples of identity expressions which were categorized as moments of self-recognition.

**Figure 3** Selected examples of identity expressions in which students failed to recognize themselves as scientists.

As discussed in Chapter 2, much research has been done on the importance of recognition by others to the process of identity negotiation. From my review of the literature, I found that less research has explicitly focused on the importance of self-recognition to identity. However, I hold that while recognition by others is a key component of identity, self-recognition is equally as important. Carlone and Johnson (2007) focus heavily on the role of recognition in science identity, decomposing recognition into both recognition by self and by others. They define self-recognition as recognition of oneself as a “science person,” and found for their participants that self-recognition was heavily shaped by recognition received from external others.
In this study I instead focus on the interaction between self-recognition and students’ conceptualizations of science, as my analysis was bounded to the emic component of students’ science identities. (Only those elements of their science identities which they made salient in the discourse of their interviews was analyzed.) Therefore, I focused my analysis on the ways in which students (primarily) did not recognize the science selves that they authored, and on how that self-recognition was shaped by their ideas about science derived from their experiences in both figured worlds and their learned ideas about science as influenced by the paradigm of WMS. This focus on self-recognition is not shared by many other science identity studies. Therefore, this work contributes to the growing understanding of how and why middle school students do/do not recognize themselves “as scientists.”

**Analysis of Disconnects Across Major Attribute Groups**

Once saturation was reached in the grouping process of each major category of identity expressions (in other words, once regrouping yielded a consistent pattern of groups and subgroups), tallies (Hufnagel, 2019) were done to bring out overarching patterns within and across groups at differing levels of “coarseness,” and to illuminate rich points of contrast to those patterns (Agar, 1991) as well as disconnects within and between groups.

Making tallies of the frequency with which various attribute subgroups appeared within the larger umbrella groups of identity expressions (which were: (1) those including students’ conceptualizations of science, (2) those including moments of identity authoring, and (3) those including moments of identity self-recognition) made salient major patterns within each of these umbrella groups. Identification of these major patterns through the process of tallying led to the description of students’ broad and narrow conceptualizations of science (and articulation of the specific inclusive and exclusive ideas about science which comprised each of those conceptualizations), the description of the diverse ways in which students authored science selves, and the ways in which students ultimately failed to recognize those science selves. For example, tallies were done to determine which figured worlds students’ specific ideas about science seemed to be centered in, which helped make salient which figured worlds students’ broad and
narrow conceptualizations of science seemed to originate from. See Chapters 4 and 5 for detailed descriptions of these patterns.

Making tallies across subgroups of each of these umbrella groups illuminated the frequency with which particular attributes co-occurred within individual identity expressions, and ultimately made salient interesting disconnects between subgroups of each of the three umbrella groups. This analysis made salient the main (or: most visible) disconnect between the ways in which students authored science selves and the ways in which they ultimately did not recognize those science selves, and illuminated the role that students’ conceptualizations of science played in shaping this disconnect. For example, tallies were done to illuminate which figured worlds students drew from when recognizing their own science selves, and these tallies were compared to which figured worlds students drew from when authoring those science selves. These tallies across these two umbrella groups of identity expressions helped illuminate a potential reason for the observed disconnect between authoring and recognition by making salient the fact that during moments of self-recognition, students drew more frequently from their ideas about science acquired in school and influenced by WMS than from their own experiences engaging in science in their own outside-school figured worlds. See Chapter 5 for an introduction to this disconnect, and see Chapter 6 for a detailed analysis of the relationship between students’ conceptualizations of science and the ways in which they failed to recognize the science selves that they authored during their interviews.

Throughout this process of tallying and disconnect analysis, I made tables detailing emerging disconnects and relationships across/within each of the umbrella groups of identity expressions. These tables allowed me to collate all emerging disconnects and relationships, and helped me choose which disconnects to focus on by making it clear which were most visible in the data (the most visible disconnect that emerged from this process was the disconnect between students’ identity authoring and recognition, informed by students’ conceptualizations of science). As the details of this authoring/recognition disconnect emerged through further tallying and articulation, I distilled these tables of findings into concept maps, which allowed for easier visualization of the connections between various aspects of students’ conceptualizations of science and the ways in which they authored science selves but
failed to recognize them. Figure 4 shows the final iteration of the concept map which emerged from this iterative process of: (1) disconnect/relationship recognition through tallying, (2) articulation of the disconnect/relationship in a findings table, and (3) distillation of the disconnect/relationship into a concept map.

Figure 4 Concept map showing the relationship between identity authoring, conceptualizations of science, and identity recognition. This concept map emerged from disconnect analysis using iterative sequences of tallying, creation of findings tables, and concept mapping.

Limitations

As previously mentioned, my analysis of this interview data was purposefully bounded in many ways. In this section I will briefly touch on some other aspects of the interview data that emerged during analysis but which were not investigated in detail due to the ways in which my analyses of students’
science identities were limited (to control the scope of this study). Some of the possible ways in which analysis of these aspects of the interview data might have enriched the study are discussed.

One of the most salient aspects of the data that emerged but which was not analyzed was students’ articulation of their ideas about possibilities for future science selves. While I do conceptualize identity as cumulative, and therefore acknowledge that the identity work of these students during their interviews has implications across time and space (the foundation of the concept of an identity trajectory, as defined by Calabrese-Barton et al., 2013), analysis of only one set of interviews did not feel sufficient to make any claims about these students’ possible identity trajectories. This study therefore does not address Lucy Avraamidou (2020) and Allison Gonsalves’s (2020) calls to operationalize intersectionality by attending to moments of identity work as movement along a path shaped by power across time and space. Put simply, this study provides a snapshot of what Gonsalves would call the larger picture, which is the continual making and remaking of science identities “on the move” (p. 355). However, students did discuss what kind of future they might see for themselves in (or not in) science, and analysis of these descriptions could have illuminated other facets of students’ science identities in-the-moment (Calabrese-Barton et al., 2013). Perhaps analysis of the ways in which students articulated possible futures in science could have added depth to the explanation for the observed disconnect between science identity authoring and recognition, as well.

Students also expressed many of their beliefs and ideas about why science is important, both to them on a personal level and to the world in a larger/less individualized sense. Analysis of these expressions of value could perhaps make salient some interesting connections between the ways in which students engage in science and what they find important or valuable about it, and could have enriched my discussion of their science identity authoring. Additionally, analysis of students’ ideas about what is important about science could have enriched my descriptions of their conceptualizations of science, adding depth to perhaps both their broad and inclusive ideas about science by incorporating an aspect of what these students value about the processes and content of science.
Expressions of ownership and agency were also seen in the interview data, but not analyzed purposefully. Ownership over the process and content of science, as well as expressions of agency to use those processes and content, are both important aspects of science identity. Studies of the intersection of ownership and agency with science identity (for example, see O’Neill, 2010) form their own dimension of the science identity research literature. Therefore, analysis of these aspects of the identity expressions in the interviews most certainly would have enriched my descriptions of the ways in which students authored science selves, and perhaps would have provided more insight into why (despite authoring a diverse range of science selves) the majority of students ultimately did not recognize themselves as scientists.

Two other interesting aspects which emerged in students’ identity expressions were emotional expressions and expressions of connection (to local outdoor places in the students’ communities). Both of these are also inherently connected to students’ science identities. Analysis of these certainly could have enriched my descriptions of students’ science identity authoring and recognition, and illuminated different aspects of their conceptualizations of science (and the possible origins of those conceptualizations).

This chapter has detailed the methodological framework and analytical processes used in my analysis of the interview data. The following chapters (Chapter 4 and Chapter 5) will present findings from these analyses. Chapter 4 discusses findings about the ways in which students conceptualized science during their interviews, and Chapter 5 discusses the ways in which students articulated their science identities.
CHAPTER 4
FINDINGS: STUDENTS CONCEPTUALIZED SCIENCE IN TWO DISTINCT WAYS

Introduction

Research Questions:

1. What experiences and ideas do students draw from when communicating how they conceptualize science?

What immediately became clear from analysis of the data was that students’ science identities were so highly entangled with their conceptualizations of science that it would be impossible to describe one without the other. Indeed, nearly every time students expressed their science identities, their identity expressions were informed by their understanding of science. Only 24 out of the 149 total identity expressions identified in the interviews were not in some way informed by the student’s thinking about science. Intuitively, this makes sense: of course students’ science identities are highly entangled with their ideas about science. In order to place themselves in relationship with science—in other words, in order to express their science identities—students needed to communicate their ideas about what science actually is.

Students drew their conceptualizations of science from their lived experiences engaging with science in their school and outside-school figured worlds, as well as their ideas about “what scientists do.” Drawing from these varied sources of ideas about “what science is,” students communicated conceptualizations of science that were unique products of students’ own lived experiences and learned ideas about WMS. However, students’ generally conceptualized science broadly when speaking from their own lived experiences, and narrowly when speaking from their learned ideas about science (coming from school and/or WMS). These relationships are summarized in Figure 5.
Students drew their conceptualizations of science from their own lived experiences in their school and outside-school figured worlds, as well as from their learned ideas about science. These informed students’ conceptualizations of science in different ways; students generally drew a broad and inclusive conceptualization of science from their lived experiences engaging with it, and drew a narrow and exclusive conceptualization of science from their learned ideas.

In descriptions of their experiences engaging with science in their own figured worlds, students articulated a definition of science that is broad and inclusive. The undercurrent of all these ideas can be summed up in a short list: these students think that science happens in many different places and can be done by many different people, that science is done in unique ways by unique individuals, and that science includes many different disciplines. Students drew from their lived experiences engaging with science to characterize it as a diverse and varied thing that impacts their lives in many different ways. Interestingly, this broad and inclusive conceptualization of science did not seem to open up any space for students to recognize themselves as scientists, as discussed in Chapter 5.

In addition to this broad and inclusive conceptualization of science, students also articulated another conceptualization of science: the science that scientists do, that doesn’t happen in their figured worlds but happens elsewhere. Ideas about this kind of science seemed to come from students’ experiences in school science and their ideas about WMS, or “real science.” These ideas about science led
students to a narrower definition: they described specific places where this kind of science happens, specific people who do it, and specific ways it is done. This narrow definition of science was the one that the majority of students drew from when recognizing their science selves as discussed in Chapter 5.

It is important to note that while these two conceptualizations of science are quite different, and in some ways even incompatible, every student expressed ideas about science that contributed to both of these conceptualizations. In other words, every student seemed to hold both of these conceptualizations of science simultaneously.

**Science as Broad and Inclusive**

Through descriptions of their own ways of thinking, acting, and being in both school and outside-school figured worlds, students communicated a broad and inclusive conceptualization of science (Figure 6). This conceptualization centered on four main ideas, which individual students illustrated differently through their descriptions. These ideas were: 1) science can happen in many different places (essentially anywhere), 2) anyone can do science, 3) science encompasses many different disciplines, and 4) different people do science differently.

![Figure 6](image)

**Figure 6** Summary of students’ broad conceptualization of science, drawn from lived experiences in their school and outside-school figured worlds.
Inclusive Idea #1: Science Can Happen Anywhere

Students communicated that although science does happen in labs and science classrooms, it can happen in many other places too. Taken together, the diversity of locations/spaces that students described science occurring in shows that in general, these students believed science can happen just about anywhere. Some students expressed this idea directly, and some students communicated this idea through descriptions of their experiences in either of the two figured worlds. The main idea that emerged from students’ discussions of their experiences in their outside-school figured worlds was that science happens around students’ homes. The main idea that students expressed from their school figured worlds was that science doesn’t happen only in the science classroom, but can happen in other classes as well. In this section, direct expressions of the idea that science happens everywhere will be discussed first, followed by the idea that science happens around students’ homes, and then the idea that science happens in non-science classrooms.

Science Happens Everywhere

In total, five out of 10 total students expressed the idea that science is everywhere, or as Yasmine put it: “it’s like, it’s really part of everything. Because you always find science in something.” These expressions seemed to be informed by students’ lived experiences in both figured worlds. Bryce articulated his ideas about where science happens by explaining that “it probably happens like, everywhere.” Yonni explained that “everything is basically science. Like, like, if it wasn't for science, we wouldn't be standing.” Giving an example, she reasoned that if it weren’t for friction, instead of standing on the Earth we would be “holding on to our dear life.” She extended this thinking to her body’s daily functioning, as well: “I walk. I sit. I, I, I use my fingers,” she said. “You're moving your muscles. So muscles are kind of a part of science, I guess.” Ravi emphasized a similar understanding when he explained that “we wouldn’t be here every day if science weren’t a thing.” Alli’s explanation of the time she first learned about science illustrates a similar idea: that science is all around us. She explained:

I just caught on to like what people keep saying and like, the velocity cause like, we went up when I was down with my, at my dad’s cause we- I was spending the spring break with uh, my family down, down in [town]. We were defying physics because we could watch uh, not a
boomerang, a frisbee up and it would come immediately back so we were defying something. And I say our velocity had to be pretty fast and it came down straight to us.

Here Alli used words like “physics” and “velocity,” to communicate her understanding that science can be used to understand the forces operating behind the scenes of everyday activities such as playing frisbee with her family. Annette focused on how a science process showed up everywhere for her. “…when you’re doing anything, really,” she explained, “it’s more of like a… a test and go. Like you test it and if it doesn’t work you, redo it in a different way.” In different ways, these students all expressed the idea that science is all around them (whether it is happening around them or they are the ones actively doing it). Students seemed to draw from their lived experiences in both figured worlds when expressing these ideas. However, when students drew from just their outside-school figured worlds, they generally expressed the idea that science happens in and around their homes.

Science Happens In/Around Students’ Homes

Seven students described science occurring in and around their homes. These students’ descriptions add to the types of places that students understand science to be happening in, expanding their conceptualization of science beyond labs and science classrooms to include their own home places. Alli explained that her stepdad “does a lot with hard work and wood. He's a carpenter. And he fixes cars. So he has some- a lot of things to do with science.” This qualification of her stepdad as a sort of scientist role model in her outside-school figured world makes salient her orientation to science as something that happens at her home place. These ideas about science came through again later in her interview, when Alli was asked where she learned the most about science: “I’d say outside of school,” she said. “Cause the more I learned on cars, cause I was with my stepdad and he was telling me about the engine, I just learned more of that.” Holden also explained that “technically I do science in my garage. … When I’m working on stuff.” Ravi’s descriptions of using his “magic slash scientist kit” in the stream behind his home provide another example of how students explained science happening in their home places. He said, “I got this[part of the kit] last year … And put it in our, we have like a little stream going down, like, actually pretty big – but put it down our river, put it in there, and it just kept getting bigger and bigger.”
Whether students described themselves as the ones engaged in science at home (as Ravi and Holden did), or whether students described others as the ones doing science (as Alli did), seven of the ten students communicated that science happens in or around their homes. When students drew ideas about where science happens from their school figured worlds, they generally emphasized the idea that science doesn’t happen only in the science classroom.

**Science Happens in Social Studies and Math Classrooms**

When discussing their experiences in school science, eight students contributed to their broad definition of where science can happen by emphasizing that it doesn’t happen only in their science classrooms. These students’ descriptions also served to expand their conceptualization of science as happening beyond labs and science classrooms, characterizing science not as what happens in science classrooms but instead as something that can be used or done in different disciplines.

Three students explained that science can happen in social studies class. When discussing his understanding that science involves making models and using those models to collect information, Ned explained that his social studies class “made like models of [stone tools]” during a unit on early humans, emphasizing that this is something scientists do: they “make like, prototypes.” Ned emphasized that his social studies class used science to learn about early humans, which involved “the science in finding out what they[early humans] looked like by their bones and stuff.” Ravi explained his use of a scientific process–testing different sites– in his social studies class. “Here[social studies] we have to take notes, we had to test a few different sites,” he explained. “…we were doing the five themes of geography. … And we did that, and then we could figure out, well, we had to test different sites...” He emphasized that in science, “you don’t just like take the first site you get and just, call it good,” drawing a connection between processes in his science and social studies classes.

Five students discussed science happening in their math classes. Annette explained how she might reference something from science in her math class; if a math question is “worded a specific way, …[her] mind will go back to something we learned in science maybe like a few months ago.” Yasmine explained that her “…biggest class best relates to science would probably be like math.” She focused on
the overlap of “terms” used in those two classes, explaining that “it[science and math]’s a lot of the same like, skill base.”

In short, students explained that science is all around them, that it happens in and around their homes, and that it happens in different classrooms at school. This diversity of spaces in which students discussed science happening (whether they were the ones doing it or others were) indicates that in general, students think that science can happen anywhere and everywhere. These ideas about all of the different places in which science takes place exhibit this first component of students’ broad and inclusive conceptualization of science.

**Inclusive Idea #2: Anyone Can Do Science**

In their discussions of their own ways of thinking, acting, and being in their figured worlds, students expressed the understanding that science, as a process or an action or a thing, can be done by anyone who knows how to do it. This idea was not mutually exclusive with the idea that there are “scientists” who specialize in doing science, but students did communicate a conceptualization of “people who do science” as broader than just that group of scientist specialists. (Indeed, in authoring science selves, students made it clear that they consider themselves to be within that category of “people who do science.” This is discussed further in Chapter 5.) Every student authored a science self and therefore communicated that they are part of that “people who do science” group, and additionally, four students communicated their ideas about who else can do science. These four students seemed to categorize who can do science based on the knowledge and skills that a person has; in other words, science can be anyone’s job or be done by anyone, if they have scientific knowledge and skills.

One of these four students, Ravi, drew on various experiences from his outside-school figured world to explain that anyone can do science. As Ravi he put it: “you don’t have to be, considered a scientist to be a scientist. … You don’t have to have a job in science to be one.” One of the most formative experiences in creating this understanding seemed to be a project Ravi did with his friend’s dad, where he learned “how to build like a- like a box that could create electricity.” Ravi explained that “my friend's dad is a scientist, he just, he doesn't actually have any, like sort of degree. He just learns
about how electricity works, and how it connects to the water… he investigates electricity, but he’s not like a research scientist.” In these excerpts we see another example of a kind of broadening of the definition of science (specifically, to include people who don’t “have any, like, sort of degree”), yet interestingly this broadening does not seem to open up space for Ravi to recognize himself as a scientist, consistent with the pattern exhibited by other students (see Chapters 5 and 6). Ravi focuses here on the fact that what his friend’s dad does—the skills and knowledge he has (e.g., learning about and investigating electricity)—is the thing that makes him a scientist, not his identity or background (degree, etc.). Interestingly, Ravi still does acknowledge the fact that there is such a thing as “a scientist” who has a “job in science,” but that these are not the only people who do science.

Alli also referenced someone from her outside-school figured world as a doer of science. Her stepdad, she explained, “does a lot with hard work and wood. He's a carpenter. And he fixes cars. So he has some- a lot of things to do with science.” Here Alli communicates that anyone who knows how to do carpentry or knows how to work on cars is actually a doer of science. Her emphasis is on her stepdad’s knowledge and skills; those are the things that make him a doer of science. Ned explained simply that “anyone can [do science]. … As long as they, like work for it. They have to, like, put work into it and learn … about how to do science.” Here, Ned emphasized the knowledge and skills of the person instead of their identity; the person doing the science could be anyone, as long as they put effort into learning how to actually do the science. Bryce emphasized a similar idea: that science can be done by different types of people. He explained that in his science class “sometimes, like the teacher will do [science], … but then there’s other times where we’ll do it…” Bryce also noted that anyone who has the knowledge to notice changes in their environment is actually a doer of science: “…if you live like, on a river or something, and it’s like starting to erode pretty bad, and like you notice this, that’s like science…”

Through these examples, the students seemed to communicate that science, as a process or an action or a thing, can be done by anyone who knows how to do it. These ideas about who can do science illustrate the second component of these students’ broad and inclusive conceptualization of science.
Inclusive Idea #3: Science Includes Many Different Disciplines

Yasmine summed up students’ ideas about what disciplines are included in science and what types of subjects are studied in science when she said that science is “anything with multiple answers, in a variant of fields.” Annette elaborated on a similar idea when she explained:

...in science, there’s a lot of different fields, and things that you can go into and look into, like, there’s Earth science, and there’s, um, people science– oh I don’t know... oh, life science. And then there’s also like, archaeologists, and like, that, I think, all falls under the science category.

Students generally communicated, via discussion of their lived experiences in both figured worlds, a wide range of topics and professions that, as Yonni said, “count” as science. Every student drew from their experiences in school, and four students also drew from their lived experiences in their outside-school figured worlds, to communicate a wide range of disciplines that are included within science. Taken together, the diversity of subjects and areas of study that students included under the umbrella of science formed the inclusive idea that many things are science, another core component of students’ broad science conceptualization.

Four students’ ways of thinking, acting, and/or being outside of school clearly seemed to influence their understanding of what disciplines or subject areas are included in science. Andi explained that one of her main interests is emotions, and studying “animal patterns, the way people like humans react to what I do, or what I say, or how certain people will react to things I do.” The influence of these interests came through in her description of science as “studying people in general, or studying the way someone reacts to another person doing something” and “studying a classroom.” None of the other students recognized studying interactions between people as science. It seems that here, Andi’s interest in emotions and reactions in her outside-school figured world may influence how she conceptualized what science is.

For Alli and Holden, science includes working on cars, an understanding that seemed to come from their experiences interacting with this type of work in their outside-school figured world. Holden explained that his work with engines involves science because “there's a lot of wiring, um, some confusing stuff, and there's carburetors, um, and you have the parts, um, and if you don't have- it's not
what you need, it will either damage it more, or not run,” citing the fact that working on engines requires knowledge of many complicated parts as what makes it science. He mentioned being “mechanically inclined,” “engineering,” and “inventing stuff” as aspects of science that align with working on cars. Alli also noted that carpentry (another discipline she engages with in her outside-school figured world via her stepdad) involves “a lot of hard work and wood,” which makes it a part of science.

Similar to Alli and Holden, Ravi’s experience learning about electricity with his friend’s dad (a scientist, as discussed above) seemed to shape his conceptualization of science as involving the study and use of electricity. When talking about electricity as science, Ravi brought up a similar idea to Alli and Holden: that the disciplines and subject areas of science are challenging to do and figure out— they require hard work. He said “electricity, someone had to find that out. And they had to try, I’m betting that they had to tr- uh, that they tried to figure out tons of different ways to get it, and to use it for what…” Here, these students not only characterized science as carpentry, mechanics, and working with electricity, but also communicated that science, regardless of “type,” is challenging for those who do it.

Every student drew ideas about the different disciplines of science from their experiences learning and doing science in school. Five of the ten students mentioned that studying the Earth is a branch of science, an idea no doubt shaped by the fact that the sixth grade science course is focused on Earth and space science. Annette’s comment that in science class “you could be doing, you know, … like deltas and currents, one, at one point. And then the next point, you could be learning about volcanoes, like it's just kind of all over the place” provides one example of how these students defined studying the Earth as science. Yonni provided a different example when she said “…the science that we're learning right now is like Earth and space. So like … I think science is mostly like mixing chemicals and, I... and Earth stuff. Like dirt and trees and stuff.” Five students emphasized that science involves math, as Ned explained when he said “in math class we’re learning the mean, median, and mode and we use that a lot in science.” Yasmine echoed this idea when she explained that her “biggest class best relates to science would probably be like math. Because a lot of like, even terms we use, um, right now, we're using a term that we use in science, mean median and mode. And um I think that, like, it's a lot of the same like, skill base.”
Students also identified archaeology as a type of science. Ned, who was very interested in the “early humans” social studies unit, explained that archaeology involves:

…the science of like, like, um early humans. … like all the stuff, that they had like, settlements in some- settlements in like, places that, um... and, like, I'm not sure but the themes had a little bit of science like, in it. Like science in studying early humans, studying like what they did. The science in finding out what they looked like by their bones and stuff.

Yonni made a similar connection when she said “some scientists, um, I think it counts if you dig,” describing how she learned about archaeology in social studies through a project. Similarly to how students communicated a wide range of places in which science can happen, they also communicated that science involves the study of many different things. These excerpts illustrate the students’ broad conceptualization of the different disciplines under the science umbrella, and together form the third component of that inclusive conceptualization.

**Inclusive Idea #4: Science is Done Differently by Different People**

The last of the four major ideas that comprised students’ broad conceptualization of science was the idea that different people have different ways of doing science, suggesting that students understand science to be, to some degree, personal or individual. In total, seven of the ten students expressed this idea. Two subthemes that emerged within these students’ ideas were: 1) that people’s unique ways of doing science are dynamic and can change as a result of learning about others’ approaches, and 2) that they are influenced and shaped by each person’s lived experiences. These students drew from their lived experiences in their own figured worlds when communicating these ideas.

While all seven students expressed the idea that science is an individual practice, two students explained that those individual ways of doing science can be modified through learning about others’ ways. Ned signaled his belief in this idea by using the possessive words “their” and “your” to explain why it’s important to learn about how other people do science: “...it can help you use, like, parts of their science in your science,” he said, adding that learning about others’ ways of doing science “…can add on to your way, of doing science. … Or change your way” and “can help you learn science.” Here Ned acknowledged that each person has their own approach to doing science, and indeed has their own science
itself. Ned seemed to view these individual approaches as dynamic, though, indicating that they can change as a result of interaction with others. Yasmine seemed to share this belief. She likened science to a skill that each person uses differently: “I think that it’s important, like with any skill,” she explained, “...to learn how other people do it, because it's like, you may find a way you may find that you don't like … But you also might, may find things that you like and it may improve your thoughts on science.” Here again, Yasmine communicated that every person does science differently and those unique approaches are influenced by interactions with others.

Two different students emphasized the idea that people’s individual approaches to science are a result of their unique lived experiences. Ravi explained that some of his peers might have different ideas about how to do science because “everyone’s different.” Interestingly, Ravi added that “probably a few [peers] would have close enough [approaches to science], not like the same stories for fishing and sports, but something similar.” Ravi seemed to be explaining here that his lived experiences (fishing and sports) have influenced his ideas about how to do science. Annette recognized that groups can also have their own way of doing science when she used the phrase “our classroom science, like [science teacher]’s class science,” to describe the science she does at school. “...I know that teachers have a lot of different teaching styles,” she added, “so they might be teaching [science] in a different way.” Here, Annette seemed to recognize that the ways that individuals do science can be influenced by their own lived experiences learning it.

These excerpts provide examples of how students expressed the big idea that science is done differently by different individuals, while also expressing their ideas about the dynamic nature of those individual approaches to science and the fact that those individual approaches are a result of different people’s unique lived experiences engaging in science in their own figured worlds. These ideas illustrate the fourth component of the broad and inclusive conceptualization of science that students communicated via discussion of their own lived experiences. The next section will focus on the second conceptualization of science that students communicated: one that was not broad and inclusive, but narrow and exclusive.
Science as Narrow and Exclusive

In addition to the broad conceptualization of science detailed in the four inclusive ideas above, students also communicated an opposing *narrow and exclusive* understanding of science (Figure 7), which they seemed to hold congruently with the broad conceptualization. Students communicated this narrow conceptualization via their ideas about “what scientists do,” ideas which seemed to be informed by their experiences in school and by the tenets of Western Modern Science (WMS). This conceptualization centered on four main ideas, which individual students illustrated differently through their descriptions. These ideas are: 1) that science happens only in special places (like labs), 2) that science is planned, purposeful, and methodical, 3) that science is only done by specific people, and 4) that science doesn’t leave room for wrong answers.

![Diagram](image)

**Figure 7** Summary of students’ narrow conceptualization of science, drawn from lived experiences in their school figured worlds and learned ideas about science influenced by WMS.

Interestingly, when sensemaking about science some students seemed to draw from this narrow conceptualization first and then expand upon it. In this way, the narrow conceptualization of science that students communicated seemed to be almost the surface-level or less-nuanced understanding of science.
that students would pull from, which, given more time to think, students would add to and expand upon and thus communicate aspects of the broad conceptualization. This narrow conceptualization is also the understanding of science that many students drew exclusively from when recognizing their own science selves; illustrating that this conceptualization of science seemed to live in the front of students’ minds while the broader conceptualization of science seemed to live behind it. Annette’s explanation of why Albert Einstein is the first person that comes to her mind when she thinks of science perfectly illustrates the tendency students had to draw first from the narrow conceptualization of science. She explained that:

…when I think of science, I think of, like I said, before, I don't think of like all the different groups of scientists working in science, I think more of, you know, people in a white lab coat, or someone holding, [holds up hand making a pipetting motion] like, a thing, or Albert Einstein, or just like, you know, that very stereotypical science... definition. … Like initially, that's what I think of. And then as I go on … then my mind will kind of drift in that situation, or think more in depth of what science really is. But at first initially I just think of that.

Here Annette acknowledges her own broader understanding of science as “all the different groups of scientists” and as “what science really is” but explains that the first thing that comes to mind when she thinks of science is instead “that very stereotypical science,” involving lab coats and represented by Einstein. When sharing their ideas about this “stereotypical” sort of science, students made their narrow and exclusive conceptualization of science salient.

Often, students shared these ideas while making comparisons between science and their own ways of thinking, acting, and being. One of the major findings from this study is that seven of the ten students’ conceptualizations of “what scientists do” seemed to prevent them from recognizing themselves as scientists. When asked whether they would consider themselves to be scientists, these students focused on the differences between this narrow conceptualization of science and their own ways of thinking, acting, and being instead of making a recognition decision based on the many similarities that they had articulated between their own ways of thinking, acting, being, and scientific ways of thinking, acting, and being. This focus on differences between this exclusive type of science and students’ own ways of thinking, acting, and being prevented seven students from recognizing themselves as scientists even
though they had authored science selves throughout their interviews. This section will provide examples of the main “exclusive” ideas about science that students communicated in their interviews.

Exclusive Idea #1: Science Happens Only in Special Places (Like Labs)

Although students did express the understanding that science happens in a wide variety of places (as discussed in Inclusive Idea #1), their descriptions of where science happens were often prefaced by some mention of a lab. Seven students mentioned that science happens in labs, and of those seven the majority of students mentioned that science happens in labs before expanding on that idea to discuss other places that science can happen. In this way, the influence of WMS on students’ ideas about science was made salient.

As discussed above, Holden mentioned that he does science in his garage. However, Holden prefaced this idea with the statement that science happens “in the lab,” and only when asked to expand did Holden add “yeah sure, lot’s of places. Technically I do science in my garage.” Similarly, Noah explained that “the first thing that I think of would be like, when I'm studying something in a lab like, yeah, like somebody studying something in a lab room.” Interestingly here, Noah positions himself as the doer of science in the lab. When asked to expand, Noah added “I feel like [science] can, still- yeah. I feel like it can still happen outside.” With both of these students, “the lab” is the place that they first identify as a place where science happens. Only after expressing this narrow understanding did they elaborate and make their broader conceptualization of “where science happens” salient. Yasmine provided rich point to this pattern when she explained that:

…when I was younger, would probably say that science happens, like, in the lab, or like, not really, in like a structured place where like they want to do science. But I would see that like, science happens, kind of everywhere.

Here Yasmine illustrated that her initial understanding of science was that it only happened in “structured places” such as labs, but her current understanding of science is that it actually happens everywhere. In this way, Yasmine provided a rich point as one of the few students who recognized that her conceptualization of science has actually broadened over time, acknowledging that she used to have a narrow conceptualization of science, but that she doesn’t anymore. This provides a rich point of contrast
to the majority of students, who expressed both broad and narrow conceptualizations of science simultaneously in their interviews.

Taken together, these ideas about science happening in labs or other “structured places” form the first component of students’ narrow conceptualization of science. The next major component of this conceptualization that emerged from students’ descriptions was that science is methodical; this exclusive idea will be discussed next.

**Exclusive Idea #2: Science is Methodical, Planned, and Purposeful**

The second exclusive idea that students communicated about science was that it is done by scientists in a planned, methodical, and purposeful way. By comparing their own ways of thinking, acting, being to what scientists do, five students made this exclusive idea salient. This exclusive idea seemed to be informed by the ideals of WMS.

Yasmine explained that one of the biggest differences between her own way of acting and science is the fact that what she does “is like, kind of loose and free,” compared to scientists, who “may be a little more like, know what they're doing thing.” She explained that “…I just kind of sometimes I'll like, jump into something but I don't really know what's gonna happen.” Alli identified a similar contrast between her way of baking, where she operates by the principle of “when you don't have the right ingredients so you use something different” and the way that scientists operate. “I know a lot of scientists have all of their stuff ready,” she explained. “I usually don't I just go with it. So I just wing it…” She explained that science is “pretty different cause from what I've been doing lately. Um, I say scientists more have more estimations than I do. Because I usually just roll with it.” It seems here that Alli is using the word “estimations” to mean having a plan or procedure laid out before beginning, in contrast to her own way of “winging it” as she bakes. In comparing their own ways of thinking, acting, and being to those of scientists, both Alli and Yasmine here illustrated that they understand science to be the opposite of “loose and free.” Instead, scientists have “all of their stuff ready.” Ravi echoed this same idea by saying: “I just go for it. I don’t really… I don’t really think” as an explanation for why he isn’t a scientist. Again, his
response emphasizes the idea that science involves thinking before you act: having a plan, procedure, or method ready to follow.

While the three students mentioned in the above paragraph focused on the planned and put-together nature of science, Andi focused on the fact that science and the behaviors involved in science have a purpose. She explained a difference between science and her hobby of drawing her pets, identifying that while she draws to “know what it looks like” (here “it” meaning, her pets at home), science involves investigating or observing something not only to know what it looks like but because you are “searching up new information about it” in order to “observe or learn.” Andi identified that because her drawing isn’t dictated by this purpose of learning, because she doesn’t plan to learn but rather just draws for leisure, it is different than science. Therefore, Andi communicated here that science is in part defined by the intent to acquire new knowledge.

Bryce illustrated another facet of this idea: that the methods of science involve planned repetition and specialized equipment. These ideas came through in his discussion of making seasonal observations of his backyard pond. This year, “I took a big stick,” he said, “and I just like put it down there[into the pond] to see how deep it was and it was like, really, cause I've done it before and it's not been that deep. It was like really really deep.” Noting a key difference between his own methods and those of a scientist, he explained that a scientist might measure the water level, “probably like not with just a stick. Probably with like a, measuring device or something to like, see if the levels or something like drop or increase. … and if they go back next year and it's deeper, or it's not as deep, it can like, do somethin.” Here Bryce communicated his idea that science involves using a particular method (yearly testing) and specialized tools.

The ideas expressed by these five students centered around a characterization of science as organized by particular methods, a clear purpose, and a well thought out plan. These kinds of ideas formed the second component of students’ narrow and exclusive conceptualization of science. In the next section, the third component of this conceptualization will be discussed.
Exclusive Idea #3: Science is Only Done by Specific People

The third exclusive idea that students communicated about science was that it is done only by specific people: scientists and science teachers. Four students communicated this idea, drawing from their ideas about WMS and their experiences in school.

Even those students who somehow expressed the idea that they do science, or that science is done by people in their families or people that they know outside of school, focused their explanations of who does science on science teachers and the WMS-type scientist. For example, when asked about who does science Alli explained that “I… scientists, like, don’t know who else. I don’t know the names of like, the scientists. But all I know is like, Albert Einstein and someone else.” Here Alli draws from the WMS-informed idea that scientists like Albert Einstein are the ones who do science, choosing to identify that type of scientist instead of her stepdad, who elsewhere in her interview she categorized as someone who also does science. Adding to this explanation, Alli mentioned “Just like teachers teach us science.”

Similarly, Holden explained that the first person who came to his mind when he thought about science was his science teacher, adding, “well, I’m sure there’s a lot of scientists…” Annette characterized doers of science in a similar way. The first person she explained that she thinks of when she thinks of science is Albert Einstein, too. However, Annette acknowledged the complexity of how she thinks about science, illustrating the same pattern of students drawing first from their exclusive conceptualization of science and then expanding upon it. Annette began her explanation of who does science with the statement that those who do it are “just people in white lab coats with glasses on, and stuff.” However, she then goes on to expand this WMS-informed idea of a scientist, saying:

But it's also way more than that. There's like people like [her science teacher], let's use him again. He, he doesn't, like, look like what I picture when I think of science. And so there's a lot of different people who look different when they're in science.

Annette draws first from her “stereotypical” definition of a scientist before expanding that label of “scientist” to also include her science teacher. Interestingly, she does not expand her definition of a scientist any further, although her sensemaking does illustrate another example of the ways in which students drew first from their WMS-informed understandings of science and then expanded upon those
via their own lived experiences. (In this case, the experience that seemed to expand her conceptualization was learning science from her science teacher.)

Bryce communicated an even more specific definition of who does science through his explanation of why doing science in school doesn’t make him a scientist. “…we do it[science] in school,” he said, “and it’s not like, we don’t choose it as a profession, like a job, we don’t do it for a job…” Here Bryce communicated the idea that scientists are those who get paid to do science, simultaneously explaining that learning science is not enough to actually make you a scientist.

In these slightly different ways, these four students expressed the idea that science is done by scientists—a specific set of people who students often used the example of Albert Einstein to illustrate—and science teachers. Students often drew exclusively, or at least drew first from, this exclusive idea when explaining who does science, even though they may have also expressed that they themselves do science or that someone in their figured worlds does science. This idea formed the third component of students’ narrow and exclusive conceptualization of science; the next section will discuss the final component of this narrow conceptualization.

**Exclusive Idea #4: Science Doesn’t Leave Room for Wrong Answers**

The fourth exclusive idea that students communicated about science was that it has right answers that must be adhered to. Two students communicated this idea; one drew from WMS-informed ideas about science and one drew from her experiences with science in school.

Andi communicated the idea that there is a “right” way to understand science when she explained that it is important to learn about how other people think about science because:

… if someone has an understanding of science that might be perceived as wrong, or in a bad way, like, a lot of anti-vaxxers I hear are really against a lot of scientific facts and things like that. I think that at a younger age, it’s important to get into people’s brains what science is mainly about, not saying that everyone’s opinions are wrong, but saying that some opinions can end people in a bad place.

Here Andi used an example from the COVID-19 pandemic to explain that it’s important to communicate the truths of science in order to correct potentially false or misguided opinions. In this explanation, Andi
implies that science communicates truths and can be used as a tool to snuff out opinions based on things other than those truths.

Yonni communicated a similar idea about science in a very different way, when talking about her own experience of difficulty with school science. Yonni explained that she finds science challenging because “…there's certain names for everything. And then, you gotta like, make sure everything is correct.” Here she expressed the idea that in science there is an expectation of “correctness.” Yonni emphasized that this emphasis on being right makes it challenging because for her, although she has taken Earth science for three years as she has moved around from school to school, she is “still not getting everything right.” Although in a much different way, and by drawing from her own experiences with science in school rather than her WMS-informed ideas about science (as Andi did), Yonni communicated here that science is composed of truths, and demands of its users that they know and use those truths in the right ways. These two students’ ideas illustrate the fourth component of the narrow conceptualization of science that students communicated via discussion of their own lived experiences in their school figured worlds, and their WMS-informed ideas about science.

Conclusion

Students conceptualized science in two distinct ways throughout their interviews (Figure 5). Students articulated a broad conceptualization of science based in their own experiences engaging with science in their figured worlds (both school and outside-school), and at the same time articulated a narrow conceptualization of science based in both their experiences with science in school and their learned ideas about science influenced by WMS. This narrow conceptualization of science was the one that students often drew from first; many times students shared the broad and more inclusive ways that they conceptualized science when expanding on their initial narrow and exclusive ideas. Interestingly, this narrow and exclusive conceptualization of science was also the one that students drew from most often when recognizing themselves as scientists (or not). It is this relationship between students’ conceptualizations of science and the ways in which they recognized themselves that is the focus of the discussion (Chapter 6). In order to discuss this relationship, however, findings need to be shared about the
nature of students’ science identities. Therefore, the next chapter (Chapter 5) will discuss two ways in which students made their science identities salient in their interviews: through authoring science selves and recognizing (or not recognizing) those science selves.
CHAPTER 5
SCIENCE IDENTITY: COMPLEXITY OF SCIENCE SELVES AND RECOGNITION OF THOSE SELVES

Introduction

Research Questions:

2. What kinds of science selves do students author? How do they author them?
3. How do students recognize (or not recognize) themselves as scientists?

Students’ science identities are composed of an elaborate web of ever-evolving components; however, two components came to the forefront during analysis of students’ science identity expressions and are therefore presented in detail here. These were: 1) the ways in which students authored science selves, and 2) the ways in which students recognized themselves (as scientists, or as non-scientists).

Together, students’ authoring and recognition of science selves are presented to partially illuminate the nature of students’ science identities. In this chapter, findings will be shared about the diverse collection of science selves that students authored during their interviews, and the ways in which the majority of students ultimately did not recognize the science selves that they authored.

Students authored science selves through their descriptions of their own ways of thinking, acting, and/or being in both their school and outside-school figured worlds. Every student authored at least two different types of science selves throughout their interviews. Interestingly, although every student authored science selves through their descriptions of engagement with science, 7 of the 10 students did not recognize themselves as scientists. When explaining whether or not they considered themselves to be scientists, the majority of students did not draw from their broad definition of science formed from their experiences engaging with it. By and large, students instead drew from their narrower, WMS-informed ideas about science. The result of this was that although every student authored science selves, describing that they engage in science and scientific ways of thinking, acting, and/or being, seven of the 10 students did not ultimately describe themselves as scientists. This disconnect is the focus of Chapter 6.
In this chapter, the diverse collection of science selves that students authored will be illustrated first. The second half of the chapter will present findings on how students failed to recognize themselves as scientists despite authoring a diverse collection of science selves.

Diverse Ways in Which Students Authored Science Selves

Research questions:

2. What kinds of science selves do students author? How do they author them?

Students authored a diverse collection of science selves through descriptions of their own scientific ways of thinking, acting, and being in both their school and outside-school figured worlds. In total, the group of ten students authored nine different types of science selves (Figure 8), with each student authoring at least two different types of science selves. See Table 3 for a summary of the different types of science selves authored by each student. This authoring of science selves occurred as students described their engagement with science or scientific ways of thinking, acting, and being in both school and outside-school figured worlds (Figure 8). The focus of this section is the diversity of ways in which students authored science selves. Interestingly, even though students authored many different types of science selves during their interviews, this wide range of science-identity authoring did not seem to open up space for students to recognize those science selves. (This disconnect is the focus of Chapter 6.) In this section, a summary will be presented of the diverse collection of science selves that students authored, and findings from three of the different types of science selves that students authored will be discussed in detail.
Through descriptions of their own scientific ways of thinking, acting, and/or being in both school and outside-school figured worlds, students authored a diverse collection of nine different types of science selves.

The three types of science selves that are discussed in detail in this chapter are: 1) observers/investigators, 2) experimenters/testers, and 3) doers and enjoyers of hands-on science. These three types of science selves were chosen for more detailed presentation in the findings because all ten students authored one (or more) of these types of science selves, and because students’ authoring of these three types of science selves provides a stark contrast to the ways in which students failed to recognize those science selves.
Table 3 Science selves authored by each student. Every student authored more than one of the nine different types of science selves. Three of the most commonly authored types of science selves are highlighted in blue (with “modeler” being a subset of “enjoyer of hands-on science”); these science selves are presented in further detail in the text.

<table>
<thead>
<tr>
<th>Student</th>
<th>Estimator</th>
<th>Observer /Investigator</th>
<th>Question-asker</th>
<th>Experimenter /Tester</th>
<th>Problem solver</th>
<th>Predictor /Hypothesizer</th>
<th>Enjoyer of hands-on science (Modeler)</th>
<th>Understannder of complexity</th>
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Science Self 1: Students as Observers and/or Investigators

One of the most common types of science selves that students authored during their interviews was the “observer/investigator” science self. Eight out of the ten students authored these science selves through descriptions of their own ways of thinking, acting, and/or being in their figured worlds.

One of these students, Andi, explained that by “observing” her group of fish at home, she noticed that “there's a couple of them that once, like after I finished cleaning their tank, they're a little like spooked. … And they stay in a group and then they separate when they're no longer scared.” Describing that she noticed this behavior pattern through repeated and careful noticing, Andi authored herself as a careful observer of these pets at home.

Noah, another one of these eight students, authored himself as a careful observer of what makes a good fishing spot, explaining that the species he likes to fish for live where there are “a lot of, like, little
bait fish,” because those fish “like eating those[bait fish] a lot, and a lot of grass, usually. They like to hide in the grass.” Later in his interview Noah explained that choosing a good fishing spot involves a process of investigation based on careful observations: “Well you also have to study- kind of study the body of water,” he explained. “Like if there’s something that they[fish] eat there, or a habitat that they-they like. … Or pretty fast moving water. They like to [inaudible] in fast moving water.” Here, he drew a connection between his own observations of the river and the process of “studying:” investigating something based on those observations.

Noah also authored himself as an observer and investigator when discussing hunting. Explaining how hunting requires making lots of observations, Noah said: “you hafta really study like, watch where it[the animal] goes. And you hafta study the ground and find blood or something, and find tracks in the mud or something…” Noah again used the word “study” here to explain that hunting involves both making careful observations and using those to investigate something (here, where the animal went).

Bryce provided another example of one of the ways students authored themselves as observers through descriptions of his favorite fishing spot. He explained that at one particular spot in the river he always catches something. “...It's super clear water, it's not like up around here where it's not very clear- it's super clear water it's not too too deep...you can see the fish really… usually, you always catch a fish.” Here Bryce described specific observations about the water quality in this fishing spot, and compared the water quality to other places he’s fished in the river. Like Noah, Bryce authored himself here as an observer of the river’s different environment and details.

Ned authored himself as both an observer and investigator, by explaining that one of his favorite activities involves observing his local stream and searching for “old stuff.” He explained that he usually goes down to the stream in the summer “to look for like old stuff. Right near the beaver dam I found that um, dog tag.” Authoring himself as an investigator of the objects he finds; he explained that “I find a lot of old bottles, that I search up to see what they used to be.” Ned’s descriptions showed that these trips have also led him to make observations of seasonal changes in the stream environment: “During the spring we usually would [go down to the stream],” he said, “but it’s really high right now… cause a
beaver dam just broke down.” Expressing his interest in seeing what new changes this event might have brought, Ned said “I'm excited to be able to go down where the dam used to be to see what’s there, behind where it was.” Ned’s descriptions of time spent observing this streambed provide another example of one of the varied ways in which students authored themselves as observers and investigators of environments within their figured worlds. These excerpts provide a view of how students authored the “observer/investigator” science self by describing both observations and investigations they conducted and/or the ways in which they did that observing/investigating.

Science Self 2: Students as Experimenters and/or Testers of Ideas

Another one of the most common types of science selves that students authored during their interviews was the “experimenter/tester” science self. Four out of the ten students authored these science selves through descriptions of their own ways of thinking, acting, and/or being in their figured worlds.

Annette authored herself as a user of “test and go,” emphasizing that “…when you're doing anything, really, it's more of like a... a test and go. Like you test it and if it doesn't work you, redo it in a different way.” She used the example of learning a soccer trick to explain:

So, in... for soccer for example, if you try a trick and it doesn't work, then you might want to either ask for help or, so they can teach you a different way, or try a different way on your own, so that you know a different way to do it, or you would do it right. And you kind of have to like, it’s all, kind of a test. And then if it doesn't work, retry, and if it does work then great, you did it.

Here Annette authored a science self who uses the process of trial and error, or “test and go” to learn a new skill, reach a goal, or solve some sort of problem.

Ravi authored an experimenter/tester science self in a very similar way, through his descriptions of using trial and error, or as he explains it, “take one take two,” to figure out how to dig worms to use as fishing bait. Ravi explained that only through trial and error did he finally figure out an effective method to get worms to come up out of the dirt:

Interviewer: So you researched that [the method of getting worms to come up out of the dirt]. And then you went and tried it and it actually worked?
Ravi: Yeah. Well, we actually tried two different things that didn't work but yeah, then it worked.
Interviewer: Before that, one that did work?
Ravi: Yeah. You're gonna have a lot of trials.
Here Ravi authored a science self who tests out different ways of solving the worm problem, much like Annette authored a science self who uses “test and go” to learn a soccer trick. Ravi likened his experience using this sort of trial and error to a method he has used in school science class, by explaining that worm-digging is “like when we take one take two. We messed up on our first thing today, [in science class] so we ended up doing take two... " Through these descriptions, Ravi authored the “experimenter/tester” science self in much the same way as Annette.

Other students authored themselves as experimenters, although rather than using experimentation to achieve a particular goal (like Annette with her soccer trick), they explained experimenting “just to see what happens,” as Yasmine put it. Yasmine explained that she likes to “experiment with things… so like, sometimes, like, if I like have the opportunity to change something that I'm doing, I might go ahead and change it just to see what happens.” Here Yasmine authored herself as an experimenter for experimentation’s sake. Alli also described this exploratory kind of testing; she explained that although her at-home experiments with baking soda and dish soap don’t usually “come out with anything,” she still enjoys “experiment[ing] like with baking soda, cause we have a bunch of it.” Yasmine and Alli both authored themselves as experimenters who use the experimentation process for fun.

Together, these excerpts provide a view of how students authored the “experimenter/tester” science self by describing the ways in which they engage in processes of “test and go” “take one take two” and experimentation in their figured worlds, whether to reach a goal, solve a problem, or just experiment with things for fun.

Science Self 3: Students as Enjoyers of Hands-On Science

Another one of the most common types of science selves that students authored during their interviews was the “doer/enjoyer of hands-on science” self. Seven out of the ten students authored this science self through descriptions of their own ways of thinking, acting, and/or being in their school figured worlds. Within the larger group of students who authored themselves as enjoyers of hands-on school science, a smaller group authored themselves specifically as modelers. Excerpts to illustrate how students authored themselves as modelers will be discussed at the end of this section. Together, the
excerpts in this section show how students authored science selves who enjoy school science when it involves not only their minds, but also their bodies.

Yonni, one of these seven students, explained that she doesn’t “really like typing research and like, and like, doing worksheets. … Because I think it’s kind of like boring.” Instead, she expressed enjoyment for the “STEM day type of science.” According to Yonni, STEM day involves design challenges and other hands-on activities; “like making stuff.” One example of a STEM day project she gave was a challenge to create a parachute to safely transport an egg to the ground from the top of a ladder. Yonni explained that she liked STEM day “Because it's not, it's like learning but like, you're like, it's motivational to do it. Like it's not like, 'you gotta do this' … you feel like you made the choice to do it. … Because it’s fun.” Through these descriptions Yonni authored herself as someone who enjoys engaging in hands-on school science.

Yasmine expressed an enjoyment for hands-on school science as well. She explained that “…the most like exciting slash nerve-wracking thing [about school science] is probably the actual, like experiments we get to do.” Yasmine explained that those “hands-on activities,” as she called them, “are really fun because, like we can actually be part of it. And we get to, like, connect ourselves to it, so.” Here Yasmine authored herself as someone who enjoys hands-on science, because of the feeling of connection to the process she gets from it. Noah authored himself as an enjoyer of hands-on school science as well, saying that although he doesn’t usually “find science, that, exciting,” he does when “we’re doing, like, outside[indoors] research, studying something outside.” These students authored science selves who enjoy engaging in school science when it has a hands-on aspect.

Together, these excerpts illustrate some of the ways in which students expressed enjoyment for tactile school science experiences, ones that they described being involved in with both their minds and bodies. Through descriptions like these, seven of the ten students authored themselves as enjoyers of hands-on school science. The next section will discuss those students who authored themselves specifically as modelers, when discussing how they enjoy the hands-on process of modeling in school science.
Students as Modelers

One specific aspect of hands-on school science that students expressed enjoyment of was modeling. Of the seven total students who authored themselves as enjoyers of hands-on school science, three students also authored themselves as modelers.

Bryce expressed his enjoyment of hands-on school science when he explained that the most exciting part about school science for him has “always been probably like when we do the projects.” Giving an example, he explained a current project in his science class which involved using river models to learn about erosion:

...when we did the erosion thing we basically, what it's doing is it's demonstrating a mini version of like a river. It was really cool to see how that all worked. And like, that's actually like what happened with our river. And like, because we also then did sum’n where, we like stopped the erosion or decreased the erosion so it's pretty cool to see that, like, people actually do that.

Here Bryce authored himself as the user of a model, or the “mini version of like a river,” to solve a problem (i.e., stop and/or decrease erosion). At the same time, Bryce authored himself as someone who enjoys this hands-on science process, saying that “it was really cool to see how” the model worked.

Ned authored himself as a modeler in a slightly different way, when expressing his enjoyment of the hands-on process of making “prototypes.” He described being “really interested in what we learned in social studies with early humans. … Um like, their, their tools and stuff that we got to make a, like a prototype of.” Here Ned authored himself as a builder of these “prototypes.” When discussing his experiences in science class, Ned also authored himself (like Bryce) as a user of models. He explained that in science class he used “a river model” to “show erosion;”

[The river model] has some kind of thing that can cause erosion, like one of them is a, has a, cliff that’s on the thing with it, and you can just lean it over. And then you have a wavemaker that you just move over and over you hit on the sand cliff that can show, erosion.

Here Ned authored himself as a user of a river model to investigate the process of erosion, via manipulation of the “wavemaker.” Similar to Bryce, Ned both authored himself as a modeler and an enjoyer of the hands-on science that modeling entails. Yasmine referenced this same science project, authoring herself as a user of a river model as well as a problem-solver (see Table 3).
Together, these excerpts illustrate some of the ways in which students expressed enjoyment for tactile school science experiences while at the same time authoring themselves as makers and users of models. Through descriptions like these, three of the ten students authored themselves as modelers.

This section detailed three of the most salient ways in which students authored science selves: as observers/investigators, as experimenters/testers, and as enjoyers of hands-on school science (and within that, as modelers). While the full group of ten students authored a more diverse collection of science selves than just these three (as seen in Table 3), every student authored a science self of at least one of these three types. The following section will present the ways in which students failed to recognize themselves as scientists, despite the diverse and numerous ways in which they authored science selves. The discussion (Chapter 6) will then unpack the apparent disconnect between students’ prolific authoring of science selves and lack of self-recognition.

The Majority of Students Did Not Recognize the Science Selves They Authored

Research questions:

3. How do students recognize (or not recognize) themselves as scientists?

In this section, findings will be presented to show how the majority of students did not recognize themselves as scientists, despite authoring one or more science selves. Seven of the 10 total students did not recognize themselves as scientists, despite authoring science selves through their descriptions of their own ways of thinking, acting, and being in both figured worlds. Students’ lack of self-recognition presented in three ways: 1) four of these seven students made their recognition contingent on their beliefs about “what scientists do,” 2) one student made their recognition contingent on their performance in school science, and 3) two students made their recognition contingent on ideas about what “counts” as science (Figure 9). This section will detail what it looked like when these seven students failed to recognize their science selves in these three ways.
Seven of the 10 students did not recognize themselves as scientists, despite authoring one or more science selves. Each of these seven students hinged their self-recognition on one of three main factors: their performance in school science, their ideas about “what scientists do,” or their ideas about what “counts” as science. These ideas came from students’ lived experiences in their school figured worlds and from learned ideas about science (shaped by WMS).

**Self-Recognition Contingent on Ideas About “What Makes a Scientist a Scientist”**

*I’m Not a Scientist Because I Don’t Plan Things Out*

One of the ways in which students did not recognize themselves as scientists was by articulating contrasts between their own ways of thinking, acting, and being, and the ways of thinking, acting and being that make scientists *scientists*. Three of the seven students (Ravi, Alli, and Yasmine) hinged their self-recognition on the fact that their own freeform styles of being did not match their understanding of the more regimented, purposeful, and methodical ways of scientists. They described their own tendencies...
to “wing it,” “roll with it,” not think before they act, or deviate from the plan, and contrasted this with very specific ideas about science.

Ravi authored the hypothesizer science self, the observer/investigator science self, the problem solver science self, and the experimenter/tester science self. However, when explaining why he would not be described as a scientist, he said “I, I, I don’t think, I just do. … I just go for it. I don't really… I don't really think.” Here, Ravi failed to recognize the science selves that he authored throughout his interview by focusing on a particular aspect of his own way of thinking and acting, and comparing that to an idea he has about how scientists act.

Like Ravi, Alli authored a multitude of science selves. These included: estimator, observer/investigator, question-asker, experimenter/tester, problem solver, predictor/ hypothesizer, and enjoyer of hands-on science. Also like Ravi, however, Alli recognized herself as a non-scientist when she made a comparison between her own way of thinking and acting and scientific ways of thinking and acting. She talked about how her baking style is different from what a scientist might do when explaining why she didn’t really feel like a scientist: “Like, when you don't have the right ingredients so you use something different” she said, “I know a lot of scientists have all of their stuff ready. I usually don't I just go with it. So I just wing it.” Here Alli seemed to suggest that her own “wing it” style is the thing that prevents her from recognizing her science selves.

Yasmine also authored science selves: experimenter/tester, problem solver, enjoyer of hands-on science, modeler, and understander of complexity. And yet when detailing how she is not like a scientist, she reasoned in a similar way to Alli and Ravi:

…a lot of times, what I do is like, kind of loose and free, and like, I think that scientists may be a little more like, know what they're doing thing. But like, I just kind of sometimes I'll like, jump into something but I don't really know what's gonna happen.

Like Ravi and Alli, Yasmine failed to recognize those science selves that she authored throughout the course of her interview, by focusing on a very specific aspect of her own way of thinking and acting and contrasting that with a very specific idea about scientific ways of thinking and acting.
I’m Not a Scientist Because I Don’t Get Paid to do Science

Another way in which students’ recognition of differences between themselves and scientists came through in the data was during comparisons between very specific aspects of their way of engaging with science and scientists’ ways of engaging with it. One student, Bryce, made these kinds of comparisons. While Bryce authored numerous science selves (observer, problem solver, enjoyer of hands-on science, and modeler) by describing his engagement in the same kinds of activities that scientists do, he ultimately recognized himself as a science student, but not a scientist. This lack of recognition became clear when Bryce explained that learning science isn’t the same thing as being a scientist; “I wouldn't say I'm a scientist,” he explained, “I would say I learn about science but I wouldn't say I'm a scientist.” Bryce’s self-recognition seemed to be determined by the fact that “...we[students] do it in school, and it's not like, we don't choose it as a profession, like a job, we don't do it for a job.” This idea of scientists as those who do science “for a job” shapes his recognition of himself as a student of science, rather than a scientist. For Bryce, it seems that learning about and/or doing science in school doesn’t make you a scientist— to be a scientist, you have to get paid to do science.

Self-Recognition Contingent on Ideas About What “Counts” as Science

I’m Not a Scientist Because the Things I Do Aren’t a Part of Science

Another of the ways in which students did not recognize themselves as scientists was by excluding the content they engage with from the realm of science. Two of the seven students (Yonni and Ned) who did not recognize themselves as scientists made comparisons between the kinds of activities that “count” as science and the kinds of activities they engage in.

Yonni explained that “I'm not really, I don't really think I'm a scientist. I'm more of- maybe like I can help with tech stuff. I don't know if that counts for science, like helping with tech.” Here Yonni does not recognize herself as a scientist because of an uncertainty about what kinds of activities and disciplines are included in science. Interestingly, Yonni did not recognize the other science selves she authored throughout her interview (which included observer/investigator, question-asker, and enjoyer of hands-on
science) and instead focused her self-recognition on her technology skills (her “understander of complexity” science self).

Ned also authored a variety of science selves throughout his interview; these included the observer/investigator, the estimator, the predictor, the enjoyer of hands-on science, and the modeler science self. However, when asked if he thought of himself as a scientist Ned explained that he did not, because “I don't like do a whole lot of things that like, use science... that I know of. ... what I’ll usually do is not usually, um, and, what I know of, that it doesn’t have to do much with science.” In contrast to Ned’s descriptions of his engagement in scientific processes, Ned’s lack of self-recognition here seems to illustrate that he doesn’t include those kinds of experiences as “using science.” This characterization of his own ways of thinking, acting, and being as not having “much to do” with science seemed to be the impetus for Ned’s lack of self-recognition.

_I’m Not a Scientist Because the Things I Do Don’t Count as Real Science_

A similar yet subtly different way in which students did not recognize themselves as scientists was by excluding the content they engaged with from the realm of what they seemed to think counted as “real” science. One of the seven students (Bryce) who did not recognize themselves as scientists drew this distinction.

When explaining a recent project in science class, Bryce authored an inside-school science self limited to engaging in “the tinier version of what scientists actually really do,” a student who can’t be a part of “the whole big operations” that scientists engage in out in the “real world” but is instead limited to modeling science that real scientists would actually do in the field. Bryce’s descriptions of the river modeling project illustrated these ideas; he explained that “…we[his class] didn't manually learn, like we didn't go to a river and physically watch it. We like, put it all on physically, and then pour the water in like a river, or like rain.” Here Bryce seemed to categorize modeling (or as he explained it, “put[ting] it all on physically”) as an approximation of science, by referring to it as “tinier” than what scientists really do, which is work with real rivers. While scientists are “out like, where it really happens,” he said, “…we[his science class] just kind of like build it ourselves.” Bryce’s characterization of building and using models
as an *approximation* of science, rather than as real science itself, seemed to limit his ability to recognize himself as someone who might be considered a scientist.

**Self-Recognition Contingent on Performance in School Science**

*I’m Not a Scientist Because I Don’t Do Well in School Science*

The last of the of the ways in which students did not recognize themselves as scientists was by connecting their science identity to their performance in school science. One of the seven students who did not recognize themselves as scientists hinged his self-recognition on the fact that he didn’t always do well in school science. Noah explained that “I don’t, feel like I am a scientist. I feel like I’m far off [inaudible]. I don’t know, like, depends how I do in school…” Like the rest of these seven students, Noah authored multiple science selves: the observer/investigator science self and the enjoyer of hands-on science self. However, when recognizing himself Noah focused on his performance in school science class instead of on those experiences engaging in scientific ways of being in other spaces. Therefore, Noah’s self-recognition seemed to be linked to his experiences with school science, not those with science in his outside-school figured world.

**Conclusion**

This chapter has detailed the two major components of students’ science identities that emerged from the data: students’ authoring of science selves and students’ recognition (really, lack of recognition) of those science selves. All ten students authored more than one type of science self. In total, the full group of students authored a collection of nine different types of science selves. Students authored these science selves through their descriptions of their own ways of thinking, acting, and/or being in both their school and outside-school figured worlds.

A major disconnect emerged, however, between the ways in which students authored science selves and the ways in which they recognized themselves as scientists (Figure 10). Indeed, while every student authored at least two different types of science selves, seven of the 10 students *did not* recognize themselves as scientists. While students drew from their own lived experiences in both figured worlds
when authoring science selves, they tended to draw from their WMS-informed ideas about science and their experiences in school science when making self-recognition decisions. Students made their self-recognition contingent on three factors, informed by their narrow conceptualizations of science: ideas about “what scientists do,” ideas about what “counts” as science, and their own performance in school science. The following chapter will discuss the role that students’ conceptualizations of science might play in creating this striking disconnect between the ways in which these students authored science selves and the ways in which they failed to recognize them.

**Figure 10** Disconnect between the ways in which students authored a diverse collection of science selves via their descriptions of their own ways of thinking, acting, and/or being in their figured worlds, and the ways in which they did not recognize themselves as scientists despite that identity authoring.
CHAPTER 6
DISCUSSION: HOW DID STUDENTS’ CONCEPTUALIZATIONS OF SCIENCE SHAPE THEIR SELF-RECOGNITION?

Summary of Major Findings

One of the most significant findings of this thesis project is that students’ science identities are shaped by their ideas about science, and that students’ ideas about science come from both their lived experiences and from learned ideas about “real” science. Among this group of sixth grade students, conceptualizations of science were shaped by their lived experiences engaging with/in science in their school and outside-school figured worlds, and by the paradigm of WMS. These lived experiences engaging with science and learned ideas about science certainly shaped students’ science identities directly, but they also informed students’ conceptualizations of science, which also shaped their science identities in significant ways as seen in Figure 11.

![Diagram](image.png)

Figure 11 Relationships between students’ engagement with/in science, their conceptualizations of science, and their articulation of science identities. Note: the bi-directional arrow between students’ conceptualizations of science and articulation of science identities indicates that the ways students articulate their science identities does also shape their ideas about science. However, only the relationships indicated by the blue arrows were considered in this thesis research.

Another set of significant findings from this study is that students’ conceptualizations of science influenced their articulation of science identities in a very particular way. The students articulated their science identities in two ways: by authoring science selves and by recognizing (or not recognizing) those science selves. Students’ lived experiences engaging in science in their school and outside-school figured worlds contributed to a broad and inclusive understanding of science. Through their descriptions of
engagement in this broad form of science, students authored a diverse collection of different types of
science selves. However, students’ experiences engaging in school science and their learned ideas about
“real” science (ideas stemming from the paradigm of WMS) contributed to a narrow and exclusive
understanding of science among these students, which shaped their articulation of science identities in a
much different way. Despite authoring a diverse collection of science selves, when recognizing
themselves as scientists the majority of students did not draw from their own (scientific) ways of thinking,
acting, and/or being in their school or outside-school figured worlds, which may have led them to
recognize themselves as scientists. Instead, during moments of self-recognition, seven of the ten total
students focused on the ways in which their own ways of thinking, acting, and/or being didn’t fit their
narrower, WMS-informed conceptualization of science or scientists.

This chapter will further explore the disconnect between students’ identity authoring and identity
recognition and the role that students’ conceptualizations of science appeared to play in preventing
students from recognizing themselves as scientists, despite authoring science selves.

**Tension Between Students’ Broad and Narrow Conceptualizations of Science**

*Research Questions:*

1. *What experiences and ideas do students draw from when communicating how they conceptualize
science?*

The middle school students in this study conceptualized science in multifaceted ways. Interestingly,
they constructed their conceptualizations of science on the fly, by drawing from specific memories of
experiences engaging with science in their school and outside-school figured worlds and from certain
engrained ideas about science and scientists. As detailed in Chapter 4, students expressed both narrow and
broad conceptualizations of science. In fact, drawing from these two knowledge bases produced such
contrasting ideas about science for most students, that perhaps students’ conceptualizations of science
should be characterized as split, or dual conceptualizations composed of both broad and narrow
components. As students expressed their ideas about science during their interviews, a tension emerged
between these broad and narrow conceptualizations of science that manifested in two notable ways.
In general, the findings from this study agree with other research (see Palmer, 1997) that attempts to uncover more nuance in students’ conceptualizations of science. In short, stereotypical ideas about science and scientists do exist in the minds of students, but those stereotypical ideas do not comprise the entirety of their understanding of what science is, who does it, where it happens, and so on. However, more research of this kind (which attempts to analyze students’ ideas about science in depth, going beyond what I have referred to as the stereotypical ideas that live nearest the surface of students’ more complex entanglement of ideas about science) is needed. Many studies continue to rely heavily on reductive and simplistic instruments such as the DAST, which preclude any sort of discussion of multifaceted conceptualizations of science like those made salient by the kind of analysis performed here. The following sections will explore the tension in students’ multifaceted conceptualizations of science in more detail and in relation to the literature.

**Students Constructed Multilayered Conceptualizations of Science**

One interesting way in which tension between broad/narrow emerged in students’ sensemaking about science was that students would often first share their narrow understanding of science, then expand on it to illuminate their broad one. Often, they would first share what other researchers have referred to as “stereotypical” ideas about science, and then (sometimes with more prompting, sometimes not) expand on those initial ideas by drawing from their own personal experiences to build a more nuanced conceptualization of science. Students’ discussions of the “Albert Einstein” image as the first thing that comes to mind when they think about science (discussed in detail in Chapter 4) illustrates this tendency. Archer et al. (2010) describe this characterization of scientists as the “scientist as boffin,” and note that among their participants, Einstein was most commonly evoked to represent this construction of scientists as brainy and somewhat aloof. This characterization matches that of the stereotypical scientist that has been well-documented as an image existing in the minds of many students in the US.

As Avraamidou and Schwartz (2021) note, decades of research on students’ views of scientists and on students’ ideas about the kinds of qualities that make someone a scientist has made it clear that the perception of the scientist as an eccentric white male in a lab coat is a common one. They assert that
public images and the media (in addition to, of course, science education) have played a role in establishing this perception. Of course, with the pervasive portrayal (in the media, in schools, etc.) of science as a regimented, objective process (lacking creativity) that takes place in very specific sorts of places/contexts and produces only factual knowledge, we would expect students to have these kinds of ideas about science.

What was interesting, though, was that among the students in this study these stereotypical ideas formed, as explained in Chapter 4, only the surface layer of the full web of ideas each student held about science. These students’ characterizations of science as both broad and narrow (each of which is associated with particular inclusive or exclusive ideas as detailed in Chapter 4), shows that they do understand what Meyer and Crawford (2011) call the real “tenets” of science. Particularly through their expression of the idea that science is done differently by different people (Inclusive Idea #4), these students illustrated that, on some level, they understand science to be a product of humans: creative, subjective, and tentative. Clearly, their ideas about science aren’t entirely restricted to the “stereotypical” ones which students primarily shared first, and which have been so well documented in the literature.

**Students Referred to Two Different Types of Science**

Another interesting way in which tension between broad/narrow emerged in students’ sensemaking about science was that students often referred to two different types of science. The two different kinds of science that emerged in students’ descriptions were: the kind that happens in their figured worlds and the “real” kind, or the kind that is done by scientists elsewhere. These two types of science emerged as students drew some of their ideas about science from their own lived experiences in both school and outside-school figured worlds, while at the same time they drew other ideas about science from what they had learned about “real” science.

Sometimes this tension was borne out in students’ uncertainty, as Yonni, put it, about what “counts” as science: its processes, content, purposes, etc. Discussing her uncertainty about technology (one of her interests outside of school) “counting” as science, Yonni signaled that her experiences in school science were shaping her conceptualization of science as something that might not involve
technology (see Chapter 4). This sort of separation of school science from other science has been documented in other studies as well. For example, Archer et al. (2010) noticed that their student participants drew a distinction between school science and, as they called it, “real, or adult science,” although the distinction drawn by the students in their study was one of safe/dangerous. Here the distinction students drew was more subtle, but appears to be between “science I learn in school” and the (somewhat unknown) “science of the real world.”

Interestingly, although much research has emphasized that the relevance of school science to students’ lives outside school should be increased (due to a documented feeling among students that school science has little to do with “real” science (Archer et al., 2010)), the students did often describe connections between their lives outside school or between other aspects of the “real world” and the science experiences they had in school. These connections, however, did not seem to encourage students to equate school science to “real world science.”

Of those studies that have used means other than instruments like the DAST (namely, interviews) to dig deeper into students’ ideas about science, a picture of complexity has emerged that mirrors the findings of this study. For example, Wheaton and Ash (2008) conducted various interviews with participants in a Spanish/English bilingual marine biology aquarium camp and found that two sisters (who had grown up in the same Latinx home and therefore shared similar linguistic, cultural, and economic backgrounds) arrived to the summer camp with drastically different ideas about science. One sister held ideas falling within the narrow conceptualization of science as defined in this study, and the other held ideas falling within the broad conceptualization. Taking an identity-informed approach to the analysis of these students’ understandings of science, Wheaton and Ash (2008) concluded that learning about science is a process influenced by all of a person’s lived experiences and is therefore a fundamentally social process. Zimmerman (2012) conceptualized recognition work (including both self-recognition and performances of identity recognized by others) and the social construction of science (grounded in the “when is science?” literature) as mutually constituting processes. These researchers’ findings support the idea, made salient in this study, that students construct their conceptualizations of
science as they do their science identities: from the many experiences they have with science in the different figured worlds they inhabit. Therefore, it only makes sense that students’ conceptualizations of science would be multifaceted and characterized by the kinds of tensions presented here.

**Students’ Self-Recognition Was More Heavily Shaped by Their Narrow Conceptualizations of Science**

_Research Questions:_

3. How do students recognize (or not recognize) themselves as scientists?

4. How do students’ conceptualizations of science shape the ways they recognize their science selves?

When asked whether or not they would consider themselves to be scientists, seven of the ten total students who were interviewed said they would not. Initially, given the broad and inclusive ideas students had shared about science, this was surprising. Throughout their interviews, every student authored at least two types of science selves, many of them acknowledging that they had “done” science on numerous occasions, many of them detailing similarities between their own ways of thinking, acting, and/or being and their own understandings of scientific ways of thinking, acting, and/or being. Why, then, did the majority of these students not extend this broad and inclusive thinking to their own relationships with science?

Seven of the ten students focused on the _differences_ between themselves and their understanding of “what scientists do” (i.e., ways of thinking, acting, and being dictated by WMS) rather than the similarities that they had authored, to qualify themselves as non-scientists. It seems, therefore, that students’ narrow and exclusive understanding of science acquired through learning about “real” science more heavily shaped their self-recognition than their broad and inclusive ideas about science did.

The majority of students’ self-recognition appeared to be influenced by a larger category of exclusive ideas about “what makes a scientist a scientist,” and by an associated set of ideas about what “counts” as science. (Specifically, six of the seven total students who did not recognize themselves as scientists did so on account of these ideas.) The emergence of both of these ideas in the discourse of students’ interviews is discussed in Chapter 5. The following sections will explore the ways students’
narrow ideas about science shaped their self-recognition and put these findings in conversation with the literature.

**Self-Recognition Shaped by Ideas About “What Makes a Scientist a Scientist”**

When making comparisons between their own ways of thinking, acting, and being and the ways of thinking, acting, and/or being that “make” a scientist, three of the ten students arrived at differences that prevented them from recognizing themselves as scientists. In particular, the exclusive idea that scientists are (and therefore science is) methodical, purposeful, and planned, (Exclusive Idea #2) prevented students’ self-recognition.

School science, while imbued with many of the characteristics of WMS, often fails to capture the true complexity of what Aikenhead and Ogawa (2007) call the “Eurocentric Sciences;” indeed those authors argue that school science (in general) has distilled WMS down in such a way as to simplify and idealize some of its tenets, a distillation which has served to transfer overly one-dimensional ideas about science to students. In general, research scientists are the vision of a scientist which school science aims to profess, and their community of practice is the one which school science encourages students to negotiate identities within (Brickhouse et al., 2000). Such idealized notions of science and scientists are undoubtedly influencing these students’ ideas about the kind of science that scientists do. For example, the continued influence of positivistic ideals on Western Science is visible in these students’ characterizations of scientists as methodical, and following established procedures. Positivism has imbued Western Science with notions of objectivity, and emphasizes the field’s basis in deductive logic and strict methodologies towards creation of “objective” knowledge.

Three students pointed out contrasts between the regimented and methodical ways of scientists and their own self-identified “loose” and “free” ways of thinking, acting, and being. These three students, Alli, Ravi, and Yasmine, pointed out fundamental differences between their ways of approaching questions, tasks, and problems and the ways of scientists. Alli and Yasmine’s comparisons were strikingly similar; they both emphasized contrasts between the purposeful planning of scientists and their own lack of such planning. This focus on scientists as adhering to procedure, and students’ concurrent emphasis of
their own individualized, “loose” and “free” ways of thinking, acting, and being as non-scientific, stand in
direct contrast to one of the ideas that comprised students’ broad conceptualization of science: that
different people do science differently (Inclusive Idea #4). This provides one example of many different
points of tension between students’ broad and narrow visions of science.

These students’ understandings of science as rigid and regimented align with the WMS-based
concept of science as involving communication of replicable procedures (Aikenhead and Ogawa, 2007;
Stephens, 2000). While none of the students mentioned the scientific method in their descriptions or
comparisons, it could be possible that their previous learning about such a method shaped some of these
ideas about science as procedural and planned. Indeed, since the publication of John Dewey’s book How
We Think in 1910, ideas about the scientific method continue to permeate schools (Aikenhead and
Ogawa, 2007), and the notion of the scientific method continues to be perpetuated by the media in diverse
ways.

Alli and Yasmine’s comparisons are presented here as two examples of a larger pattern: in the
midst of the tension created by the incompatibility between students’ ideas about science grown from
their own lived experiences in their figured worlds and their narrow, WMS-informed vision of science,
students chose to elevate their narrow conceptualization of science over their broad one. The fact that
Alli, Ravi, and Yasmine chose to hinge their self-recognition on an idea about science that rests in
positivism (an inherently WMS-based concept) suggests that their narrow conceptualization of science is
the true vision of science- the one they need to match if they are to call themselves a scientist. This was a
pattern seen across the seven students who did not recognize themselves as scientists.

Self-Recognition Shaped by Ideas About “What Counts as Science”

Students’ ideas about what makes a scientist a scientist were also inherently entangled with their
ideas about what makes science, science. When making sense of what kinds of things “count” as real
science, another three of the ten students (Bryce, Ned, and Yonni) arrived at differences between their
own areas of engagement and those of “real science” that prevented them from recognizing themselves as
scientists. These students’ ideas about what science actually is prevented them from being able to see themselves as scientists.

One of the ways this tension presented itself was in a distinction between doing/learning science and actually being a scientist. As discussed in Chapter 5, Bryce explained this distinction perfectly himself, making it clear that he believes that learning science is not the same thing as doing real science; in fact, learning science is not real science at all but is instead “the tinier version of what scientists actually really do.” He therefore doesn’t recognize doing science in school as a type of engagement with science that actually makes him a scientist. Bryce’s own distinction—between learning science and doing real science—therefore prevented him from recognizing his own engagement with science as the sort that would make him a scientist.

Perhaps this distinction between doing science and actually being a scientist provides one possible explanation for the incongruence between how students authored science selves and how they (did not) recognize them. It may be that students’ assessments of similarities and differences between their ways of being in the world and what they conceptualize as scientists’ ways of being, or what they think of as “real” science, are somewhat independent of their science-self authoring. The doing/being distinction makes it possible for students to think of their own engagement in science, and their own scientific ways of thinking, acting, and/or being in their own figured worlds as “doing” science, while the possibility of “being” a scientist remains invisible due to the weight of their narrow conceptualizations of what actually makes a scientist a scientist, and what actually “counts” as science. Indeed, Archer et al., (2010) found that 10-11 year-old students from four UK schools also made what they referred to as both a conceptual and discursive distinction between doing science and being a scientist. Those authors argued that such a distinction helped explain their participants’ abilities to report enjoying science while at the same time expressing that they did not want to become a scientist, emphasizing that the drawing of this distinction spoke to the fact that the students were not able to construct and inhabit science identities congruent with other aspects of their identities.
This study investigated students’ in-the-moment expressions of science identity, not students’ identity trajectories. However, the same dynamic Archer et al. (2010) identified may be at play. As has been demonstrated here, a student’s conceptualization of science is indeed an important component of their science identity, and therefore will shape the ways they articulate it. If a student’s conceptualization of science is not congruent with their own understanding of their ways of thinking, acting, and/or being in their own figured worlds (i.e., if a student draws from their narrow conceptualization of science instead of their broad one when making recognition decisions) how are they to recognize their ways of thinking, acting, and being as scientific, and therefore recognize themself as a scientist? Interestingly, these students did not redefine science in ways that allowed them to see themselves in science, as Carlone and Johnson (2007) observed among some of the women in their longitudinal study. These students, when faced with a vision of science incongruent with their understanding of parts of themselves, were simply unable to recognize themselves as scientists. Perhaps this distinction between “doing” and “being” is what made it possible for these seven students to believe that using scientific processes and ways of thinking doesn’t actually make them scientists.

Another of the ways in which this tension between the kinds of things students engage in and the kinds of things that count as “real” science presented was in direct questions about what science is. Students’ perceptions of what counts as “real science” can heavily shape their ability to recognize themselves as scientists. Yonni’s uncertainty about whether or not technology counts as science (discussed above) provides an example of this uncertainty. Her questions about the types of things that qualify as science (“I don’t know if that counts for science, like helping with tech”) translated into an uncertainty as to whether she could call herself a scientist (“I’m not really, I don’t really think I’m a scientist. I’m more of- maybe like I can help with tech stuff.”)

The idea that school science is founded on and primarily perpetuates Western conceptions of science (and the associated universalist and positivist approaches to understanding the world) is not new; calls to expand the conceptual foundations of school science have been made at least since the 1990s (for an example, see Stanley and Brickhouse, 1994). Indeed, the exclusive ideas that comprised students’
narrow conceptualizations of science in this study came from both learned ideas about WMS and from their experiences with science in school, two sources which are inherently entangled here in the US. In Yonni’s remarks, however, another dimension of the ways in which school science shapes students’ ideas about what science really is is made salient. Here we see that students’ experiences with science in school may be functioning to narrow students’ understandings about the particular content areas that actually qualify as science. How might a student be able to recognize themself as a scientist if their conceptualization of science has been narrowed to only those content areas they learn about in school?

Not only do these school experiences expose students to the ideals of WMS, but they also expose students only to particular content areas, such as “dirt and trees and stuff,” as Yonni described her Earth science class. Analysis of students’ interviews showed that both of these (experiences in school and broadly influential ideals of WMS) narrow students’ conceptualizations of science in powerful ways. The fact that students drew only from their narrow conceptualizations of science (instead of from their broad conceptualizations of science, or some combination of the two) when making self-recognition decisions allowed these narrowing influences to prevent students from recognizing the science selves that they authored.
CHAPTER 7
CONCLUSION

This chapter concludes the thesis with a discussion of the implications of these findings for both science identity research and science teaching, a reflection on the generative value of the inclusion of Indigenous ways of knowing in this thesis research, and recommendations for further research.

Implications for Science Identity Research and Science Teaching

The major findings from this study have intertwined implications for science education research and science teaching. This study has shown that students’ science identities are shaped in significant ways by their conceptualizations of science. Digging deeper into what ideas these ten students have about science, and where those ideas come from, showed that these students hold conflicting conceptualizations of science: a broad understanding of science informed by inclusive ideas about where science happens, who does it, and what kinds of things count as science, and a narrow understanding of science informed by exclusive ideas about these same things. This study has also shown that although every one of these ten students authored at least two different types of science selves (i.e., explained that they engage in scientific ways of thinking, acting, and/or being in both their school and outside-school figured worlds), they were prevented from recognizing themselves as scientists by their own narrow conceptualizations of science. The questions now are: 1) how can science identity research continue to investigate the ways in which students’ ideas about science intersect with their negotiations of science identity? and 2) what role can science education play in helping students recognize the scientific ways of thinking, acting, and being that they already have? The following sections will discuss approaches to answering these questions, putting the findings from this study in context of what has been done by other science education researchers and suggesting avenues for further exploration.

Research and Teaching Should Acknowledge (and Mitigate) Recognition as Reproduction of the Status Quo

One particular way in which both school science and science education research can respond to this question begins with a consideration of the ways in which recognition (by both self and others) can
function to reproduce the status quo in science. Indeed, science identity research needs to further explore the intersection of science identity and the complicated process of recognition (Avraamidou, 2019). This thesis project addresses an even more underexplored intersection within this one: the ways in which self-recognition hinders the development of science identity within middle school youth. While the role of recognition by others has been shown to exclude students with diverse identities from science, the results of this study show that self-recognition can have a similar exclusionary effect, for students with both historically marginalized and non-marginalized identities.

Carlone and Johnson (2007) found that the composition of actors in the field of science (mostly white males) along with “the institutional and historical meanings of being a scientist” (p. 1207) made it difficult for the participants in their 2007 study to receive recognition as women of color who did not fit the images and meanings most firmly seated in the discipline of science. For the seven students in this study who did not recognize themselves as scientists, a similar effect was observed, except their own self-recognition was complicated by an incongruence between the science selves that they authored and the images and meanings of science that they compared those selves to. Indeed, if a student’s view of themself includes certain characteristics (for example, creativity), which they perceive to be incongruent with their narrow view of science (for example, science as objective), they may not be able to resolve that conflict to enable their own recognition of a science identity (Avraamidou and Schwartz, 2021).

Essentially, the effect of recognition, which Carlone and Johnson (2007) argue is to reproduce the “historical and prototypical notions of scientist” (p. 1207), was borne out within students in this study, as opposed to between students and meaningful others. Regardless, the structural influences of WMS functioned to keep the students in this study—who were hunters with detailed knowledge of the plants and animals in their home places, girls with an interest in technology, and students with a love of investigating the natural world, to roughly characterize just a few—from being able to see those selves as compatible with the field of science. The nature of these students’ self-recognition decisions highlights the need for science education to acknowledge these students’ lived experiences as ones that are valuable and relevant to the field of science. As Brickhouse et al. (2000) argue, communities of practice should be relevant and
accessible to students to encourage formation of science identities. Science education should therefore leverage these students’ ways of thinking, acting, and being as the embodiments of the scientific identities that they are. Archer et al. (2010) make a similar argument: that science education researchers should investigate ways to “bridge the gap” between the identities that are valued in students’ various figured worlds and the identities held as “scientific” by “real” science.

However, it has been well established that school science often does not value (and sometimes does not even acknowledge) students’ lived experiences and ways of being outside school (Hughes et al., 2020). If efforts are made to expand what counts as relevant and productive disciplinary performances of self (Bell et al., 2017), for example, by valuing students’ personal and community histories and lived experiences in the classroom, students can leverage the identities and the ideas about science they hold from participation in all of their diverse figured worlds.

**Teaching Should Expose Students to a Broad and Inclusive Vision of Science**

So, science education should expose students to a vision of science that expands their conceptualizations of what it is, who does it, and where it happens, not one that narrows. And to do this, it should make visible and valued (i.e., mirror) the broad and inclusive ideas that students already have about science. This requires that views of science espoused in classrooms of all kinds recognize that knowledge is both personal and cultural (Avraamidou, 2019), and that knowledge (here: knowledge about science) comes from students’ lived experiences in all of their overlapping figured worlds. Meyer and Crawford (2011) advocate for instruction about science, emphasizing science as “a social process of knowledge production rather than a body of factual information” (p. 537). They argue for the presentation of science as “its own cultural way of knowing with its own language, processes, and customs” (p. 539). However, I argue that this approach could allow for the further entrenchment of the tenets of WMS, and instead advocate for explicit instruction in NOS that expands science by emphasizing it as an inherently cultural field, diverse as the unique individuals who construct it.

Avraamidou and Schwartz (2021) echo this call by arguing that representations of science and scientists that are holistic, inclusive, and equitable can disrupt what they refer to as the “incompatible”
view of science. These representations of science can only be achieved through acknowledgement of the
diversity and subjectivity of science, as a field shaped by a collection of diverse, subjective, and cultural
individuals. Similarly, Wade-Jaimes and Schwartz (2019) argue that authentic portrayals of science
should present science as empirically-based, and at the same time socially negotiatted, cultural, and
creative. This work, the integration of, as Wade-Jaimes and Schwartz (2019) would label it, “the human
as well as the empirical elements of science” (p. 703) can begin with the reimagining of classrooms as
figured worlds where multiple ways of being in science are recognized, and where students can therefore
perform their authentic intersectional identities (Avraamidou, 2019) and see those as compatible with the
identity of “scientist.”

Teaching science in a way that recognizes the broad and inclusive understandings that students
have of it from their own lived experiences in both school and outside-school figured worlds constitutes a
purposeful movement away from what Aikenhead (1996) argues has been a goal of many science
educators: cultural assimilation of all students into science. Allowing the inclusive ideas about science
students already have to carry value in the science classroom, and building instruction around such ideas
(leveraging students’ own ways of thinking, acting, and being as scientific) would undoubtedly make the
process of border crossing, which Aikenhead (1996) argues every student needs to do to get access to
school science, easier for students with all types of diverse and intersecting identities. Avraamidou (2019,
p. 337) calls for a “reconceptualization of science identity in conjunction, and not in isolation, with other
identities” to make space for the idea that there are infinite ways of becoming a science person.

Teaching science in a way that honors students’ ways of thinking, acting, and being as scientific
(perhaps, for example, by explicitly acknowledging them as such, by making space for students to share
and build from their ways of being in their outside-school figured worlds in the science classroom, by
integrating science with other subjects, and by weaving together strengths of different ways of knowing
the world, such as Indigenous Science and WMS) makes space for students to recognize themselves as
scientists. Numerous science identity researchers are investigating teaching practices and curriculum
design strategies towards this goal; see Pinkard et al. (2017), Van Horne and Bell (2017) and Stromholt and Bell (2018) for examples of such work.

**Reflection on the Generative Value of Including Indigenous Ways of Knowing**

Here, I return to the two questions which initially drew me to study student science identity: “what do I believe is the real purpose of science education?” and “how can I teach to that purpose?” This thesis project has expanded my thinking in many ways, and I now have a new perspective from which to work towards answering these questions for myself. After having designed a research project that 1) attempted to expand the definition and vision of science in the discourse of a classroom by intentionally incorporating Indigenous Science, and 2) described students’ articulations of science identity in the context of that attempted expansion, I now think it is important to reflect on the crucial value of working towards this kind of expansion. In other words, I end this thesis with a reflection on the value of the Indigenous frame.

I now offer, as a partial answer to the two questions above, that the real purpose of science education is to facilitate the development, for every student, of a science identity that is congruent with and complementary to their many other intersecting identities. The findings of this thesis and of many other science identity research projects indicate that teaching to that purpose requires that the discourse of science in schools be expanded. I argue that this expansion requires intentional weaving of WMS with Indigenous Science, as an equally relevant and valuable way of knowing the world. As Marie Battiste articulates, “Indigenous knowledge fills the ethical and knowledge gaps in Eurocentric education, research, and scholarship” (2002, p. 7). For me, then, the weaving together of Indigenous Science and WMS is the only way in which to begin to work towards a vision of school science that is, as Avraamidou and Schwartz (2021) write, inclusive and equitable.

Indeed, by engaging in the process of this thesis research I have felt both my own conceptualization of science and my own understanding of scientific research expand. Working to integrate school science with Indigenous science, in a nontraditional science learning setting (i.e., a social studies classroom) made those points of contrast salient: where Western ways of knowing left off, and
Indigenous ways of knowing picked up. My attempts to weave these two ways of knowing together ultimately contributed to my learning, and to the depth of the project, along four dimensions: the personal, conceptual, methodological, and analytical. While I’ve articulated the personal value of this weaving throughout the thesis, here I discuss the relevant learnings that emerged from each of the other three dimensions, to conclude the thesis with a clear articulation of the generative nature and value of working to include Indigenous ways of knowing in this research.

**Conceptual Value**

In this research, the inclusion of the Indigenous frame allowed for an expansion of the concept of scientific knowledge and ways of knowing. Putting Indigenous science side by side with WMS made the form of WMS—its limitations, strengths, and values—salient. Battiste articulated this idea when she explained that “as a concept, Indigenous knowledge benchmarks the limitations of Eurocentric theory—its methodology, evidence, and conclusions” (2002, p. 7). In this thesis project, the conceptual value of the Indigenous frame was to make salient the, as Battiste writes, “ethical and knowledge gaps” that exist in WMS (gaps which can be filled by Indigenous Science), and therefore the need for an expansion of the vision of school science. For example, drawing from Indigenous Science made clear the lack of attention given to human-nature relationships in Western Science (which instead aims to remove all traces of the observer), and also made clear the focus that Western Science generally places on objectivity (in contrast to the Indigenous conceptualization of knowledge as a personal and cultural process). These gaps in WMS were only made salient because, in this work, WMS was held up side-by-side with Indigenous Science, and both were considered as distinct and whole knowledge systems. It was these identified gaps which informed my thinking about how and why school science should be expanded.

**Methodological Value**

Indigenous epistemologies center not the noun of “knowledge,” but the process of “coming to know” (Cajete, 1999; Aikenhead and Ogawa, 2007). Weaving in Indigenous knowledge, then, encouraged a focus on process in this research, particularly the process of intentional expansion, and the
associated research design and analysis moves. Such a focus on process is often lacking in projects working from Western epistemologies, which center product over process. The Indigenous frame, then, encouraged me to value the (difficult) process of weaving together Indigenous and Western theories of science, and allows for a presentation of that process as part of the contribution of this research.

Putting WMS alongside Indigenous Science as a distinct and whole other way of knowing (Bartlett et al., 2012) also encouraged me as the researcher to push beyond what has traditionally been done in science identity research (which is to identify factors shaping science identity negotiation, and articulate those shaping processes). Here, the incorporation of Indigenous Science necessitated that I attempt to go beyond identifying the ways in which the dominant narratives of WMS in classroom discourse shape students’ articulations of their science identities, to actually expand the presentation of science in the classroom discourse so as to try to mitigate some of the influence of WMS’s narratives. While this study by no means fully succeeded in this kind of full expansion, the incorporation of the Indigenous frame necessitated that the research go beyond identifying and describing identity-shaping factors to the next step: mitigating the effects of the discourse of WMS.

In designing the integrated science and social studies unit, Indigenous Science provided the framework from which to approach teaching about human-environment interaction; indeed, what better way to do so than informed by a way of knowing the world that has arisen from Indigenous peoples’ participation in nature’s relationships over millennia (Cajete, 1999). As Kimmerer (2002) has argued, Western Science often cannot adequately explain the dynamic and multidimensional interactions between humans and nature. Indeed, she argues that the Indigenous Sciences “extend the scope of science into human interactions with the natural world” (2002, p. 436). The Indigenous frame, then, was integral to the creation of a unit that allowed students to investigate the richness of human-environment relationships through time, while also working to add richness to the process of science itself by imbuing it with humanity.
Analytical Value

Designing the integrated science and social studies unit using Indigenous Science provided a valuable avenue for describing and understanding the disconnects that emerged in students’ science identity negotiations. The unit itself was a research tool; its intentional incorporation of Indigenous perspectives and its implementation in a social studies classroom (instead of a science classroom) opened up space in the science learning discourse, and created a unique and expanded science learning context. However, even in this purposefully-created context, the influence of the discourse of WMS on students’ negotiations of science identity was still apparent. In other words, students still drew from their narrow conceptualizations of science when making their self-recognition decisions, even in the context of the expanded science learning setting created by the unit.

It seems that the tenets of WMS are so ingrained in the minds of these students (as their vision of “real” science) that they continue to draw from them even when engaged in such a unique science learning experience. The purposeful distance created between traditional WMS-based school science and the integrated science and social studies unit didn’t seem to open up space for students to prioritize their broad conceptualization of science over their narrow (WMS-informed) one. Therefore, the inclusion of Indigenous ways of knowing in this thesis project allowed for the creation of a context in which the crystallization of the tenets of WMS in the minds of students was inadvertently tested, and the disconnects that emerged in students’ science identity negotiations made it abundantly clear that the discourse of WMS is indeed firmly entrenched in these students’ ways of thinking about science.

Along with deepening my personal learning and continuing to expand my own conceptualization of science, scientific research, and the purpose of science education, the integration of Indigenous Science in this thesis project contributed to the depth of the project along the three dimensions discussed here: conceptual, methodological, and analytical. It is my hope that this reflection on the generative nature of my attempt to weave together Indigenous Science and WMS will make the value of such a pursuit clear to science identity researchers, and therefore encourage further research in this spirit.
Recommendations

This study just begins to scratch the surface of the interesting intersection between students’ ideas about science and their negotiations and expressions of science identity. I echo the calls made by Archer et al. (2010), Wade-Jaimes and Schwartz (2019) and Avraamidou and Schwartz (2021) for more research into the ways in which students’ ideas about science shape their articulation and negotiation of science identities. The results of this study have also shown that students’ conceptualizations of science are multifaceted and at times contradictory. It is important, therefore, that future research into students’ understandings of science be done in a way that honors and digs deeper into this complexity, continuing to ask such questions as “where do students’ ideas about science come from?” and continuing to make use of methodologies that honor complexity, not attempt to reduce it.

The intersection between students’ ideas about science and the ways in which they recognize their own behaviors (and ideas, and aspirations) as scientific is also a space deserving of more research. As discussed previously, much more work has been done surrounding the ways in which recognition by others can shape students’ science identities and identity trajectories, but more work is needed to understand how and why students recognize themselves in the ways that they do. Further research should attempt to uncover more nuances in the ways that students’ ideas about science shape how they recognize themselves. This will require investigation of the ways in which influences on students’ understandings of science act at various and overlapping political, social, and cultural scales, and will require researchers to consider how those influences are borne out in students’ negotiations of science identity throughout the figured worlds they inhabit.

Finally, and most importantly, the result of this and future research on the interactions between students’ ideas about science and the ways they author and recognize their own science identities should be operationalized through the development of curricula and teaching strategies that honor students’ multifaceted understandings of science, and work to leverage those in support of successful negotiations of science identities for all students.
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APPENDIX

LIST OF INTERVIEW QUESTIONS

1. What are you curious about outside of school?
2. What do you like to do in your free time?
   a. How are the things you like to do similar to what you think scientists do?
   b. How are those things different from what you think scientists do?
   c. How do you think you are like a scientist?
   d. Do you think others would describe you as a scientist? What might they say?
3. What do you think of when you think of science?
   a. Who does science?
   b. Where does science happen?
   c. Where did you learn these things about science?
4. Is science important to you? Why/why not?
   a. What is most exciting to you about science? Tell me more.
   b. Do you ever notice connections between what you learn in science class and what you
      learn in other classes? Tell me more.
   c. Do you think science matters in your daily life? How?
   d. Do you want to continue to learn science in high school?
5. Do you think your definition of science is different from other peoples’ definitions? How?
   a. Is it important to learn about other people’s ways of doing science? Why?
6. I noticed in class or in one of your reflections that you wrote about/spoke about ______. Can you
tell me more?
BIOGRAPHY OF THE AUTHOR

Hazel Cashman was born in Bellingham, Washington on April 23, 1996. She was raised there and graduated from Sehome High School in 2014. After high school she moved East to attend Bates College in Lewiston, Maine, graduating with a Bachelor’s of Science in Geology and Anthropology in 2018. After graduating from Bates College she worked in various experiential science education roles across the country. She returned to Maine and entered the Master of Science in Teaching program through the Maine Center for Research in STEM Education, at the University of Maine, in the Fall of 2020. Hazel is a candidate for the Master of Science degree in Teaching from the University of Maine in August 2022.