What *Is* and *Who* Can Do Science?
Supporting Youth of Colors' Identities as Learners, Doers, and Change Agents in Science

by

Tammie Ann Visintainer

A dissertation submitted in partial satisfaction of the

requirements for the degree of

Doctor of Philosophy

in

Education

in the

Graduate Division

of the

University of California, Berkeley

Committee in charge:

Professor Na'ilah Suad Nasir (Co-chair)
Professor Marcia F. Linn (Co-chair)
Professor Carolyn Finney

Spring 2015

What *Is* and *Who* Can Do Science?
Supporting Youth of Colors' Identities as Learners, Doers, and Change Agents in Science

by

Tammie Ann Visintainer

Abstract

What Is and *Who* Can Do Science?
Supporting Youth of Colors' Identities as Learners, Doers, and Change Agents in Science

by

Tammie Ann Visintainer

Doctor of Philosophy in Education

University of California, Berkeley

Professor Na'ilah Suad Nasir, Co-chair
Professor Marcia F. Linn, Co-chair

This research explores trajectories of developing the practices of and identification with science for high school students of color as they participate in summer science research programs. This study examines students' incoming ideas of *what* science is (i.e. science practices) and *who* does/can do science and how these ideas shift following program participation. In addition, this study explores the aspects of students' identities that are most salient in the science programs and how these aspects are supported or reimagined based on the program resources made available. This research utilizes four main data sources: 1) pre and post program student surveys, 2) pre and post program focal student interviews, 3) scientist instructor interviews, and 4) program observations.

Findings show that students' ideas about *what* science is (i.e. science practices) and *who* can do science shifted together through participation in the practices of science. Findings illustrate the emergence of an identity generative process: that engaging in science practices (e.g. collecting data) and the accompanying program resources generated new possibilities for students (e.g. capable science learner). Findings show that the program resources made available for science practices determined *how* the practices "functioned" for students. Furthermore, findings document links between an instructor's vision, the design of program resources that engage students in science practices, and students' learning and identity construction. For example, a mentor that employed a politically relevant and racially conscious lens made unique resources available that allowed students to identify as capable science learners and agents of change in their community. This research shows that youth of color can imagine and take up new possibilities for *who* they can be in science when their science *and* racial identities are supported in science programs. Findings highlight the need to re-center race in research involving science identity construction for youth of color.

Findings from this research inform the design of learning environments that create multiple pathways for learning and identity construction in science. Findings can be applied to the creation of opportunities in science programs, classrooms and teacher education that foster successful and meaningful engagement with science practices and empower youth of color as capable learners, doers, and changes agents in science.

Table of Contents

Acknowledgements

It has been an honor and a privilege to be immersed in such a welcoming and inspiring community of scholars. Over the years, I have encountered many open doors, incredible mentors and inspiring graduate student colleagues. This work is a reflection of this amazing community.

My doctoral committees have always been comprised entirely of courageous and inspiring women. While this was unintentional, there is something incredibly special about being guided by the strength, brilliance and perspectives of women who are pioneers in their fields. As people of color, women in computer science; you have pushed boundaries, broken down barriers and shaped your disciplines in profound and lasting ways. Thank you for showing me what it means to be brave and all that is possible when you take risks, follow dreams, stand tall, and stay true.

A special thank you to Marcia Linn for recognizing my potential and opening the doors of opportunity. I still remember our conversation before I was accepted and the excitement I felt about this being a possibility. Thank you for making this adventure a reality. Trustworthy and solid are the first words that come to mind when I think of your mentorship. Your profound knowledge of the world of science education is an inspiration.

I am profoundly grateful for the mentorship of Na'ilah Nasir. Your generosity, careful guidance, sincerity and big heart have transformed me as a scholar and a person. It was your class during my first year that ignited this amazing trajectory and you have continued to open doors of opportunity ever since. Quite simply, I wouldn't be doing the work that I'm doing, and that I believe so strongly in, without your guidance and inspiration. Your warmth and brilliance are unmatched. Thank you for helping me find my scholarly wings and teaching me how to fly!

Thank you to Carolyn Finney for stepping in and sharing your positive energy, and to Kim Tallbear who offered guidance during my earlier years. Your mentorship as women of color in science and your courage to push boundaries has transformed my work in profound ways.

To Cal Teach & MACSME, and especially Elisa Stone and Dor Abrahamson for the amazing opportunities to teach, create, learn, grow and dream in the world of pre-service teaching.

Thank you to the GSE community including: Judith Warren Little, Lisa Garcia Bedolla, Janelle Scott, and so many others. Standing on the shoulders of giants now has new meaning. To my fellow graduate students and the Linn research group. And to CPLD for your inspiration and striving with me to be the change that you want to see in this world.

I extend sincere gratitude to the students, instructors and science programs that made this research possible. Thank you for welcoming me into your spaces and generously sharing your stories. May you continue to inspire others and may your voices always be heard.

Thank you to UC/ACCORD for generous funding and the opportunity to be part of such a brilliant and amazing community of scholars. And to LHS where I got my start doing this work.

Thank you to my parents who taught me to always follow my heart and who support me with all of theirs. To my sister Carrie, for showing me how to take risks and live your dreams. And to the family fan club led by Chris, Jake and Elise. To my incredible communities of friends. And to the ocean for keeping me centered and bringing moments of complete presence and pure joy.

Finally, to my wife Ellery, for your nurturing support, calming presence and tireless dedication. I am honored to have you walking beside me on this journey!

Chapter 1. Introduction & Overview

This research centers on intersections of race, culture, learning, and identity in science education. I explore high school students' ideas about *what* science is (i.e. science practices) and *who* does/can do science and how these ideas shift following participation in summer science research programs designed for racially/ethnically underrepresented youth. In addition, this research explores how identities are constructed through participation in the practices of science. I pay particular attention to the characteristics of science learning environments and how the program resources made available can transform the science experiences of youth of color. Likewise, I examine how local educational contexts are embedded in broader systems of power and privilege with implications for learning and identity construction. The goal of this research is to take a holistic approach to understanding processes of learning and identity construction for youth of color in summer science programs and the *mechanisms* that support the generation of new possibilities for *who* they can become in science.

Introductory Case & Research Motivation

I begin with an example of a student whose experience illustrates the importance of looking at issues of equity in science education in new ways and from the perspective of students' science experiences. Melanie had just completed her freshman year of high school. She identifies racially as Filipina. She described science and math as her favorite subjects in school but expressed frustration at a lack of access to high quality science instruction and coursework. I met her because she was a participant in one of the summer science research programs that was part of my dissertation study. I interviewed Melanie at the beginning of the program to better understand her ideas about science practices and how she conceptualized scientists. I asked her what she envisioned when she thought of a scientist and she responded:

> I think of them in white gowns with clipboards and really high tech equipment and computers, and like people with glasses on and goggles and stuff.

Here, she describes many aspects of a stereotypical scientists, both in what they look like (e.g. glasses, lab coats) and what they do (e.g. use high tech equipment). We also discussed her ideas about how science knowledge is constructed and the content of science textbooks. She said she felt that scientists decided what to write in science textbooks because they had "the power" to make these decisions. When I asked her what gave scientists "power" she responded:

> That they're like labeled *scientist* and it makes them smarter then everyone because they're scientists.

Here, Melanie describes the power and status she associates with the position of scientist. In addition, she describes scientists as powerful because they are "smart" and in this way links power to knowledge. Finally, I asked Melanie how she sees herself, as Filipina, in relation to science:

> I've never heard of a professional Filipino scientist. Maybe it's just a lot of the other races don't feel comfortable. Here, it's a lot of low-income or working class people and they probably don't feel like they're good enough to become a scientist, cause it's like *high*.

Melanie's statement illuminates intersections of race, class, and positioning. She expresses the "high" status at which she holds scientists and suggests that people of certain races (e.g. Filipino) and classes in her community might not "feel good enough to become scientists" because of the high status of this position. It is important to note that Melanie feels anyone *can* be good at science, but her statement suggests that societal positioning complicates this.

Discussions with students such as Melanie have been central to my research process exploring racial/ethnic underrepresentation in science. Her experience underscores the importance of examining the messages students received about *what* science is and *who* can do science based on the resources made available in science learning environments.

Statement of Issue

The underrepresentation of African American, Latino, Pacific Islander and other high school students of color in advanced science courses and the need to increase diversity in science fields is widely agreed upon (Oakes, Ormseth, Bell & Camp 1990; Darling-Hammond, 2010). In addition, developing the next generation of innovators in science, technology, engineering, and math (STEM) is deemed essential because it is linked to the nation's economic prosperity (National Research Council, 2011). This highlights two issues: a need to increase diversity and the necessity to create innovators in STEM.

This also brings to the fore the idea of dominant representations in science and how this intersects with culture and race in our society. Throughout this dissertation, I argue that the challenge of increasing racial/ethnic diversity in science is complicated by two dominant representations: 1) *what* science is (i.e. what gets counted as science practices), and 2) *who* can do science (i.e. who gets to be a science person). These representations too often provide narrow images of science (e.g. prescribed labs) and scientists (e.g. white, male) that are problematic for youth of color who don't see themselves within the bounds of these narrowly defined categories. From this perspective, classrooms and schools are embedded in systems of power and privilege that shape these representations as well as students' ideas about science. Therefore, I view equity in science education as access to authentic science experiences (i.e. *what*) and opportunities to see oneself as a capable science learner (i.e. *who*). It's important to acknowledge that there are numerous issues of equity in science education (e.g. gender). This research focuses on racial/ethnic underrepresentation in science and how intersections of race and science shape students' science experiences.

A typical solution to increasing diversity in science is to focus on reframing *what* science is through curricular and policy reforms that promote authentic and inquiry-based approaches to instruction (e.g. NRC 2012). Yet African American and Latino students continue to lag behind their white and Asian peers and race-based achievements gaps are persistent (National Science Board, 2012). In addition, while instructional reforms and expanding students' ideas about what counts as science are an important part of the solution, conversations with students such as Melanie above suggest that a focus on *what* science is alone is insufficient for dismantling persistent issues of equity in science education. Together, this highlights the complexity of the issue of underrepresentation in science and indicates the need for research that explores this issue in more holistic ways that look beyond access and exposure to science programs for solutions.

Throughout this dissertation I argue that in order to make progress towards increasing diversity in the sciences, we need to extend beyond a focus on *what* science is and pay equal attention to the messages youth of color receive about *who* can they can become in science based on the resources made available in science learning environments.

Objective

This research explores trajectories of developing the practices of and identification with science for high school students of color as they participate in summer science research programs designed for racially/ethnically underrepresented youth. Students conducted investigations alongside scientist instructors as part of the programs. The goal of this research is to take a holistic approach to understanding structures and mechanisms; I examine broad and local *structures* that operate at the intersections of race and science to shape youth of colors' science experiences. In addition, I explore the *mechanisms* associated with the generation of new possibilities for *who* youth of color can become in science. I explore students' incoming ideas about science practices and *who* does/can do science and how these ideas shift following program participation. Likewise, I examine the types of program resources made available through engagement in science practices that support these shifts.

This research builds on and extends the argument that in order to increase diversity and broaden learning opportunities in science, we must understand how the resources made available in science learning environments mediate relationships between race, learning and identification processes in science. I define ***identity*** as how youth of color perceive science and scientists, how they see themselves in relation to science/scientists, and how the interactions they have and believe they can have with science shape *who* they become in science. This involves both their ideas about *who* does science (e.g. characteristics, race) and ideas about *what* scientist do (i.e. science practices). I define ***science practices*** as the types of activities utilized to conduct scientific research and/or produce scientific knowledge through the research process. This definition is intentionally broad to holistically capture students' ideas about and experiences with "doing" science.

I examine how students' science and racial identities develop *together* through participation in the practices of science. I am particularly interested in how the types of program resources made available in science learning environments support youth of colors' practice-linked identities in science (i.e. viewing participation in a practice as central to who one is) (Nasir & Cooks, 2009; Nasir 2012) (see Figure 1). I define ***program resources*** as the types of instruction, pedagogy and designed experiences that instructors make available and the types of resources exchanged between participants during the summer programs. The development of practice-linked identities is supported by three groups of identity constructing resources (material, relational, and ideational) (Nasir & Cooks, 2009; Nasir, 2012) (see Figure 1). For the purpose of this research these identity constructing resources are defined as follows: 1) ideational: instructors' perspectives of race and science and ideas about their instruction; 2) material: instruction for science practices, science equipment, physical objects, artifacts; 3) relational: interpersonal connections and positioning within the science programs. I pay particular attention the types of program resources that support students' science *and* racial identities in science programs. I define this as ***holistic support***. I examine how engaging in science practices and the accompanying program resources generates new possibilities for *who* students can become in science.

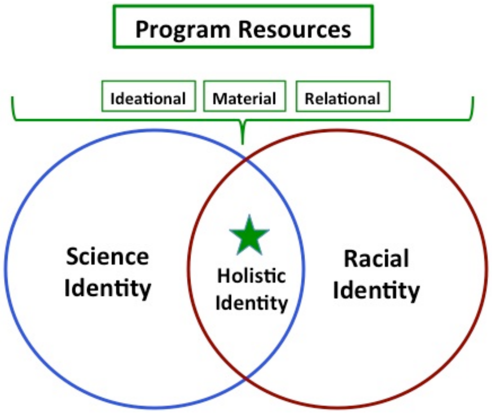

Figure 1. Relationship between identity constructing program resources (material, relational, ideational) and the co-development of students' science and racial identities.

Throughout this dissertation I explore processes of learning and identity construction as student engage in science practices during summer science programs. To understand the mechanisms involved, I explore relationships between how youth of color conceptualize scientists and see themselves in relation to their conceptions. Likewise, I explore students' ideas about science practices and how they view themselves in relation to these practices (e.g. ability to engage with practices). Furthermore, I examine the aspects of students' identities that are most salient in the science programs and how these aspects are supported or reimagined based on the program resources made available. Together, the relational aspects then are how students conceptualize scientists (*who*) and science practices (*what*) and see themselves in relation to those conceptions as well as how program resources support shifts in these conceptions (see Figure 1).

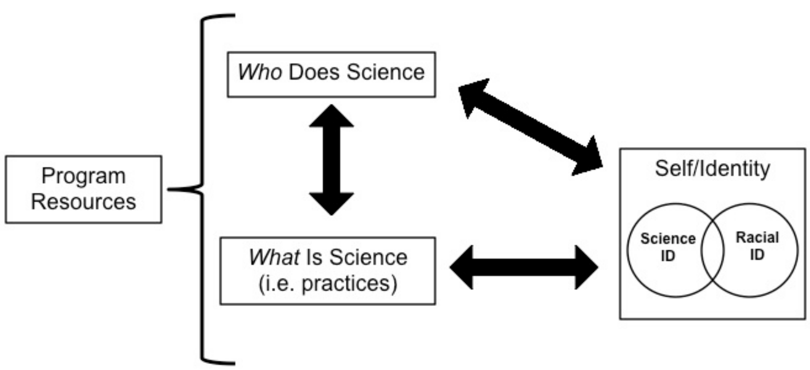

Figure 1.Relationships between students' conceptions of *what* science is, *who* can do science, and how they see themselves in relation to science and the program resources that support identity construction.

How do students' conceptions of *who* can do science and *what* science is develop (and transform) together in science spaces? How does conducting investigations with scientist instructors broaden students' ideas about what counts as science practices and shift their ideas about *who* can be a capable science learner? How do the resources made available in science learning environments support or transform how students see themselves in relation to science? These questions serve as the foundation of my research.

Overarching Research Questions

Throughout this dissertation, I ask the following main research questions:

- What are students' incoming ideas about *what* science is (i.e. science practices) and *who* does and can do science (e.g. characteristics, race)? How do their ideas shift following program participation?

- What mechanisms support the generation of new possibilities and identities for youth of color in the science programs?

- How does an instructor's "pedagogical vision" (i.e. of science, students, race) and the types of instruction, pedagogy and designed experiences made available in the science programs support the co-development of students' science *and* racial identities?

Situating Chapters in the Overall Dissertation

As described above, this research explores students' incoming ideas about *what* science is, *who* can do science, and how they see themselves in relation to science (see Figure 1). In addition, I examine how these relationships shift following program participation and the program resources that support these shifts. I pay particular attention to the types of resources that support holistic identity construction and generate new possibilities for *who* youth of color can become in science (see Figure 1). I explore different aspects of these relationships over the following three empirical chapters:

Chapter 4. *Who* Does & Can Do Science? This chapter explores youth of colors' incoming ideas about *who* does and can do science, how they see themselves in relation to science and how their ideas shift following program participation. In addition, I explore the role of racial narratives in these relationships (see Figure 3, blue portion). This chapter utilizes two main data sources: 1) pre and post program focal student interviews and 2) pre and post program student surveys.

Findings show that students' incoming conceptions of *who* does science serve a relational function, in that students view their conceptions of "science people" (i.e. characteristics, race) in relation to themselves (science, racial identity). For the focal students in this study, perceived ability in science (i.e. seeing oneself as "good" or "bad" at science) was a salient aspect of their identities in the science programs. Findings suggest that a relationship exists between how students characterize scientists, their sense making about racial/ethnic underrepresentation in science, and how they see themselves as science learners. For example, low perceived ability students more commonly associated characteristics such as "smart" with scientists, in ways that contrasted with their own perceived abilities in science. In addition, low perceived ability students more commonly internalized deficit-oriented reasoning about racial/ethnic underrepresentation in science compared to high perceived ability students.

Findings suggest that experiencing a lack of racial representation in science can operate collectively with the characteristics students' associate with scientists to impact high and low perceived ability students differently. This further enhanced some students feeling of belonging or not belonging in science. However, findings show that students *across* the range of perceived ability need resources that support their science and racial identities in order to navigate productive pathways in science. Findings show that the racial narratives that emerged during students' sense making about racial/ethnic underrepresentation in science impacted *all* focal students and served two overlapping functions: a) indirectly linked characteristics associated with scientists to race, and b) confirmed students' ideas about racialized societal perceptions (e.g. *who* is smart). Findings illustrate the disproportionate distribution of identity work that that *all* focal students must do regardless of incoming perceived ability in science in order to pursue pathways in science; constantly redefining and presenting alternative positions from the one's that are placed upon them. Post program findings show that shifts occurred in students' ideas about *who* does and can do science. Interestingly, students from Westport, who entered the program with the lowest average perceived ability in science made the greatest post program shifts and identified themselves and their peers as scientists more commonly than students from other programs. In addition, some Westport students specifically identified youth of color as scientists, a finding unique to this program. Findings show that students identified themselves and their peers as scientists because of what they were able to *do* as scientists. In addition, findings suggest that resources that support students' science *and* racial identities can help create new possibilities for *who* youth of color can become in science. In Chapter 5, I explore how engaging in science practices may have supported these shifts. In Chapter 6, I explore the program resources that generated new possibilities for Westport students.

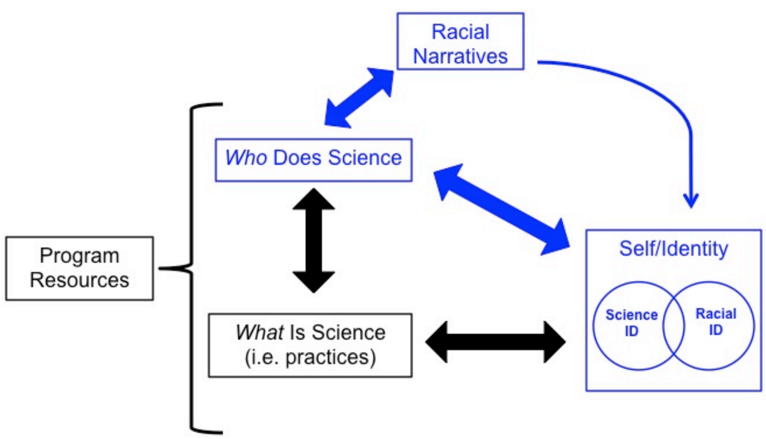

Figure 3. Relationships between students' conceptions of science people, how they see themselves in relation to science and how racial narratives operate in conjunction with these conceptions.

Chapter 5: *What* Is Science? This chapter explores students' incoming ideas about *what* science is (i.e. science practices), how they see themselves in relation to these practices, and how their ideas shift following participation in summer science research programs. I build on the relational aspects explored in Chapter 4 to examine how students view themselves in relation to science practices (see Figure 4, green portion). This chapter utilizes three data sources: 1) pre and post program student surveys, 2) focal student interviews, and 3) scientist instructor interviews.

Findings show that students' ideas about science practices serve a relational function in that some students compared what *they* do in science class with what scientists do, and/or questioned their ability to engage in the types of science practices they viewed as central to the work of scientists. In addition, findings suggest that a relationship exists between the meaning students associate with science practices (e.g. restrictive, expansive) and how students see themselves as science learners. Low perceived ability students described more restrictive views of science practices during pre program interviews. In contrast, high perceived ability students described more expansive views of science practices. This has important identity implications and impacts students' ideas about their abilities to engage with science. Post program findings show that students' ideas about science practices and *who* can do science shift together while engaging in scientific research. Across all three programs, participation in authentic scientific research: 1) allowed students to add new types of science practices to their repertories, and 2) broadened the meanings students' associated with science practices from restrictive (e.g. prescribed, right/wrong) to expansive (e.g. science as iterative process). Findings show that developing expansive meanings promoted learning, allowed students to make connection between practices, helped make science more accessible and allowed students to identify as capable science learners. However, findings suggest a need to attend to both the science practices that are promoted and the messages youth of color receive about *who* can do science while engaging in the practices. Findings show that instructional and pedagogical resources that support students' science *and* racial identities are needed in order to create new possibilities for *who* focal students of color can become in science.

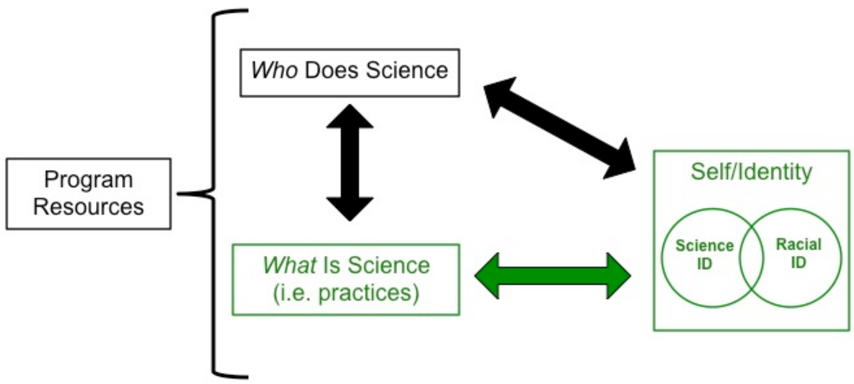

Figure 4. Relationship between how students view the practices of science (*what*) in relation to themselves (see green portion of overall diagram).

Chapter 6. "I Never Thought We'd Go Big!" This chapter builds on Chapters 4 and 5 to examine how Westport students' incoming characterizations of "science people" and the practices they associate with "doing" science are supported or reimagined based on the resources made available in science programs (see Figure 5, red portion). This chapter utilizes four main data sources: 1) pre and post program surveys, 2) pre and post program student interviews, 3) scientist instructor interviews, and 4) program observations.

Findings illustrate the emergence of an *identity generative process*: that engaging in science practices (e.g. presenting research) and the accompanying program resources generated new possibilities for Westport students as *capable science learners*, *scientists*, and *change agents*. Findings show that the instructional and pedagogical resources made available for science practices determined *how* the practices "functioned" for students. In this way, the generation of new possibilities for focal students was program resource dependent. Furthermore, findings show that the Westport instructor's vision of science (e.g. purpose, utility) and his students (e.g. racial background, social positioning) guided the design of the program resources he made available. Because he viewed his students as lacking power and having low self-efficacy due to their race/class positioning in society and he viewed science as a tool to create change, he made unique resources available for particular science practices (e.g. collecting data) that empowered students as change agents in their community. Different aspects of the data collection process created new ways to engage with science, made science accessible and cultivated the identity of a capable science doer and learner. In addition, engaging in multiple aspects of the research process generated new meanings for science practices and uses for scientific research that elevated the power and agency associated with the identities generated. Findings show that youth of color can imagine and take up new possibilities for *who* they can be in science if their science *and* racial identities are supported in science programs. Findings underscore the need to re-center race in research involving science identity construction for youth of color. In addition, findings offer suggestions and regarding the implementation of the Next Generation Science Standards.

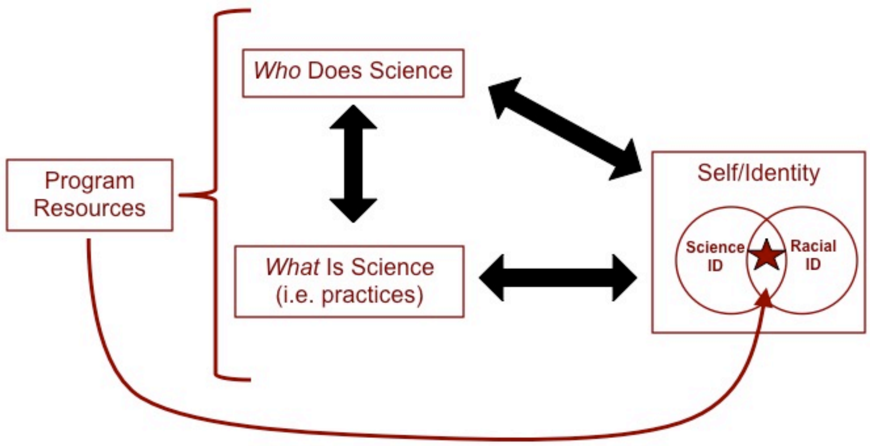

Figure 5. Relationships between students' ideas about *what* science is, *who* can do science and program resources that support holistic identity construction.

Main Findings of Dissertation Research

The main findings from this dissertation are grouped into four main themes:

- Focal students' incoming ideas about *who* does science and science practices are relational (i.e. they see themselves in relation to their conceptions). These relationships shaped the possibilities that students viewed as available to them in science.

- Focal students' science and racial identities developed together in the science programs. Findings illuminate the disproportionate distribution of identity work that youth of color need to do in order to purse productive pathways in science.

- Students' ideas about *what* science is (i.e. science practices) and *who* can do science shifted together through participation in the practices of science.

- Engaging in science practices and the accompanying program resources generates new possibilities for *who* youth of color can become in science when their science *and* racial identities are supported.

Summary & Scholarly Significance

Findings from this dissertation build on and extend our understanding of *how* new possibilities are generated for youth of color through engaging in science practices. This research illustrates the mechanisms that support the generation of new possibilities in science: how engaging in science practices and the accompanying programs resources leads to the generation of new possibilities for *who* students can become in science. Exploring this identity generative process as a unit of analysis highlights that it's not just expansive science instruction or engaging students in science practices, but the combination of the two that generates new possibilities. In addition, this research extends our understanding of the significance of an instructor's "pedagogical vision" in guiding this process. Findings document links between an instructor's vision, the design of program resources that engage students in science practices and student *outcomes* in the form learning and identity construction. Findings support the need for a holistic approach and an examination of how the parts of the identity generative process operate *together* in order to further our understanding of how to create greater opportunities for participation in science.

This research illustrates the need to re-center race in research involving science identity construction for youth of color. Findings illuminate the complexity of identity construction, how youth of color see *who* does science and science practices in relation to themselves, and the disproportionate distribution of identity work that they need to do in order to purse productive pathways in science. This research shows that youth of color can imagine and take up new possibilities for *who* they can be in science if their science *and* racial identities are supported in science programs. This highlights the importance of re-centering race in teacher education opportunities that prepare teachers for both engaging students in science practices and developing racially conscious and politically relevant ways of "seeing" their students. Therefore, this re-centering of race also requires a reframing: not bolstering the science identities of youth of color, but supporting the *co-development* of students' science and racial identities in science learning environments.

This research shows how together program resources and engagement in science practices allowed students' agency and power to come to life. Findings from this research inform the design of learning environments that create multiple pathways for learning and identification in science. In addition, findings can be leveraged across contexts to construct pedagogical and instructional resources that support meaningful learning opportunities in schools. The Next Generation Science Standards (NGSS, 2013) promote an integration of science practices and content through curricular and instructional reforms. As California and other states adopt these standards, a unique opportunity exists to develop educational resources that engage students in science practices and support identity construction for youth of color in holistic ways. Findings can be applied to the creation of opportunities in science programs, classrooms and teacher education that foster successful and meaningful engagement with science practices and empower youth of color as capable learners, doers and changes agents in science. In this way, we can truly create space for youth of color in science learning environments and broaden opportunities for participation in science.

Chapter 2. Review of Relevant Literature

This research centers on intersections of race, culture, learning, and identity in science education and is informed by sociocultural views of learning and identity as well as feminist and multicultural perspectives of science. This research examines how youth of color see themselves in relation to science. In addition, this research explores how identities are constructed through participation in the practices of science. I pay particular attention to how the pedagogical and instructional resources made available in science programs can transform the science experiences of youth of color and create new possibilities for *who* they can become in science. Likewise, I examine how local educational contexts are embedded in broader systems of power and privilege with implications for learning and identity construction.

To support this inquiry, I draw on the following bodies of literature: sociocultural theories of learning and identity; feminist and multicultural perspectives of science; science identity construction for racially/ethnically underrepresented youth; theories of race, stereotypes and racial narratives; equity and inquiry-based approaches to science instruction, and teacher education research.

Sociocultural Theories of Learning

This research draws on socio-cultural theories of learning and views meaning, practice, community, and identity as deeply interconnected and mutually defining relationships (Wenger, 1998). This study explores the complex relationships between knowing and "becoming" when learning occurs through participation in authentic science practices as part of summer science programs. I examine how processes of participation, non-participation, and reification within communities of practice shape students' identity construction in science (Wenger, 1998). It is important to acknowledge that summer science programs and activities are embedded in larger systems of power and privilege, especially when considering the science experiences of students that are racially/ethnically underrepresented in the sciences. This research utilizes the construct of "figured worlds" to build on and extend the idea of communities of practice and to acknowledge that the power and privilege associated with a given context impacts the positioning of individuals within that context (Holland, Skinner, Lachicotte & Cain, 1998). The figured worlds of the summer science programs are viewed as places where activities are historically embedded, socially organized and reproduced, and consist of social encounters in which participants are positioned and distributed (Holland et.al, 1998). In addition, this research utilizes an ecological approach (Bronfenbrenner, 1977) to understanding processes of learning and identity construction in science programs and extends this framework to account for interactions between structures of power and privilege embedded into all layers of the ecological system. This research explores how students' ideas of what science *is* and *who* can do science are informed by macro-level ecological layers (e.g. board narratives and representations of science) and micro-level structures (e.g. positioning) present within these figured worlds.

Feminist & Multicultural Perspectives of Science

As historically and socially embedded figured worlds, the summer science programs in this study, and the practices in which students participate (e.g. scientific research) are shaped by dominant representations of science. Constructions of science as universal, objective and culture-free are ubiquitous. It is the artificial severing of science from political, cultural, and social influences that then gives it permission to be universal, "all knowing", and leads to conceptions of the science domain as "culture free" (Harding, 1995, 2008). This perspective of science claims that the culture, gender, race, ethnicity, sexuality, and interests of the knower are irrelevant to the scientific knowledge that is produced because it's the natural world that judges the validity of our account of it – not vice versa (Stanley & Brickhouse, 1994). In addition, this perspective ignores the role of the scientific community in mediating knowledge claims and denies the influence of a scientist's backgrounds and experiences in decisions made throughout the scientific process (Stanley & Brickhouse, 1994). In this way, science is constructed as a "culture free" enterprise and scientists claim to operate objectively within this system. Harding (1995, 2008) explicitly links science and culture in her critiques of objectivity and neutrality. Science can only be objective if we shed our culture and view of the world at the door because science is a socially embedded activity that progresses by hunch and intuition (Harding 1995). Communities of scientists share values and interests. Their cultural assumptions shape the research they do, how it is designed, and the methods by which it is conducted (Harding, 1995). As a result, science is anything but a "culture-free" enterprise.

The universal, objective and culture-free perspective of Western science presents science as an "all knowing truth". In addition, it is positioned as superior to (and devaluing of) other non-Western knowledge systems (Stanley & Brickhouse, 1994). These representations make clear what counts as science (and what does not) and whose knowledge is valued. In addition, it shapes the norms, values and expectations of science environments including science classrooms and programs. Throughout this dissertation, I argue that the issue of racial/ethnic underrepresentation in science is complicated by dominant representations of science constructed from this perspective. These dominant representations are as follows: 1) *what* science is (e.g. what counts as science and science practices), and 2) *who* can do science (i.e. who gets a to be a scientists). These representations too often provide narrow images of science (e.g. prescribed labs) and scientists (e.g. white, male) that are problematic for youth of color who don't see themselves within the bounds of these narrowly defined categories. In addition, these representations are particularly significant for students of color because it fails to acknowledge the racialized ways that science knowledge is constructed and shapes students science experiences.

Conceptualizing Learning & Identity

The representations of what science *is* and *who* can do science discussed above have clear implications for processes of learning and identity construction in science programs; especially for youth of color. This research views students' ideas about *what* science is, *who* can do science and how they see themselves in relation to science as connected by notions of identity. Therefore, processes of learning and identity construction are central to this research.

Learning & identity: Distinct but inter-related. This research explores relationships between learning and identity construction as students participate in summer science programs. In addition, this research explores how identities are constructed through participation in the practices of science. Processes of learning and identity are conceptualized from a sociocultural perspective. I adopt Nasir & Hand's (2006) view of learning as not only taking on new knowledge structures but guiding personal transformations of "becoming". When learning in practice there is a match between knowing and learning, the nature of competence, and the processes by which knowledge is acquired, shared and extended (Wenger, 1998). Identities in practice are viewed as socially constructed, fluid, negotiated and multiple – a product of lived experience and participation (Holland et.al,1998; Wenger, 1998). In addition, identities are viewed as located both in the individual and the social world and constructed from the resources made available in a given context (Nasir & Hand, 2006). Identity construction is viewed as a process of negotiation including one's ability and inability to shape the meaning that defines communities and forms of belonging (Wenger, 1998). The relationship between learning and identity is based on research that shows that learning and identity are distinct yet highly related and iterative process (Holland et.al, 1998; Nasir & Cooks, 2009, Wenger 1998).

Positioning as mediator of learning & identity. When considering relationships between learning and identity, it is important to remember that the practices of summer science programs are embedded in broader constellations of activity that are framed by particular social, cultural, and political norms (Nasir & Hand, 2006). Learning in summer science programs, as historically embedded figured worlds, links learning through participation in practices to issues of power and positional identities (Nasir & Hand, 2006). Positioning theory explores the distribution of rights and duties in daily encounters (Harre, 2008) and provides a lens from which to view the structures of power present within these figured worlds. Positioning depends on rights and duties being given or taken away, and repositioning can occur through restoration of rights and taking up of duties (Harre, 2008). The roles students take on and/or are assigned to while participating in practices present new possible ways of being (Nasir & Hand, 2006). Research shows that positioning acts as a mediator for the iterative processes of learning and identity construction (Nasir & Cooks, 2009). This research explores the characteristics of micro-learning environments and how students are positioned by their peers and instructors and how they position themselves. In addition, this research explores how the pedagogical and instructional resources made available can transform the science experiences of youth of color and create new possibilities for *who* they can become in science.

Practice-linked identities. The construct of "practice-linked identities" specifies how identities and learning are co-constructed through participation in a particular practice (Nasir & Hand, 2006; Nasir & Hand 2008; Nasir & Cooks 2009; Nasir 2012). Practice-linked identity is defined as viewing participation in a practice as central to who one is (Nasir & Cooks, 2009). This results from a sense that there is a connection between oneself and the activity (Nasir & Hand, 2008). "Practice-linked identities are the identities that people come to take on, construct, and embrace that are linked to participation in particular social and cultural practices." (Nasir & Hand, 2008, p. 147). The construct of practice-linked identity is useful for this research because it provides a means of understanding the interpersonal dimensions of learning and to capture how learning settings support or fail to support new possibilities for students (Nasir & Hand, 2008). Practice-linked identities illustrate how participation in practices can foster deep connections between learning in practice, membership and belonging in a community, and ideas about and definitions of who one is and who one is becoming (Nasir & Hand, 2008).

There are important connections between practice, engagement, and identity formation that must be considered when examining participation in science practices during summer programs. Research shows that three aspects of the learning environment that are important for engagement and development of practice-linked identities in a domain: 1) access to the domain, 2) integral roles, and 3) opportunities to make a unique contribution and feel valued. These findings are important for conceptualizing how identities are constructed in practice. In addition, this research helps determine the aspects of learning contexts to focus on when researching learning and identity construction through engagement in science practices during summer science research programs.

Science identity construction for underrepresented youth. How does research on learning and identity relate specifically to science environments? The concept of "science identity" is becoming ubiquitous in the science education literature. Though there is a lot of previous research examining science identity construction for youth that are racially/ethnically underrepresented in the sciences, there is not consistent agreement in the literature about what science identity is, how it is constructed, or how it develops. The science identity work relevant to this research recognizes that science identities develop in science contexts (i.e. figured worlds) that are culturally based and biased by the representations of science discussed above (Calabrese Barton, 1998; Brickhouse, 2001; Aschbacher, 2010; Tan & Calabrese Barton, 2010). Previous research conceptualizes identities-in-practice as the authoring of oneself in a particular context (Johnson, et.al, 2011) and the identities students acquire or choose to adopt in the science classroom (Tan & Calabrese Barton, 2010). This important work points to the narrow range of identities offered in science classrooms and learning environments and the need for the creation of hybrid spaces that makes use of youths' funds of knowledge (Tan & Barton 2007/2010). However, more research is needed that explores the mechanisms of *how* identities develop through participating in science practices. Additionally, though this work acknowledges structures of power that shape representations of science, more research is needed that explores how dominant representations of *what* science is and *who* can do science shapes how youth of color see themselves in relation to science and the options they view as available to them. Finally, the majority of research exploring science identity construction for racially/ethnically underrepresented youth is comprised of studies involving elementary (e.g. Archer, 2010; Brown, Reveles & Kelly 2005; Tucker-Raymond, Varelas, Pappas, 2007) and middle school students (Calabrese Barton 1998; Tan & Calabrese Barton 2007/2010, Rahm, 2007). In addition, there is research involving female undergraduate and graduate students (Malone & Barabino, 2008; Carlone & Johnson 2007) and professional female scientists (Johnson, Brown, Carlone & Cuevas, 2011). More research is needed that explores processes of learning and identity construction for high school-aged youth of color. Research approaches are needed that explore how identities are taken up or resisted in the context of science learning environments, how students are positioned in these spaces, and how this informs *who* students become in science. The goal of this research is to explore the mechanisms of *how* practice-linked identities develop *in context* for high school students that are racially/ethnically underrepresented in science. In addition, this research aims to make connections between broad and local structures of positioning that shape learning and identity construction in the summer science programs.

Intersections of race and science identity. Scholars examining racial/ethnic underrepresentation, learning, and identity construction in science provide important insights into the types of identities offered in science classrooms and across formal and informal contexts (Aschbacher, 2010; Brickhouse, 2001; Calabrese Barton, Tan & Rivet, 2008; Polman & Miller, 2010; Tan & Calabrese Barton 2010). While research shows that racial positioning matters for women of colors' long-term science trajectories (Carlone & Johnson, 2007; Johnson et al, 2011, Malone & Barabino, 2008), treatments of race in relation to science are limited (Parsons, 2014). Research is needed that directly addresses race when exploring identity construction for racially/ethnically underrepresented youth. Encouraging this more holistic approach, researchers posit a theoretical framework that considers relationships between science learning and multiple aspects of identity construction (racial, disciplinary, academic) when examining learning and identity construction in science for youth of color (Varelas, Martin, Kane, 2012). Holistic approaches that account for multiple aspects of racial and science identity construction (Varelas, Martin & Kane, 2012) and are inclusive of socio-emotional, and psychological components of the cultural processes of learning (Lee et al., 2003) show promise for understanding how to make more expansive learning opportunities available in science for youth of color. This research explores how youth of colors' science and racial identities develop *together* through participation in the practices of science during summer science programs.

Race, Stereotypes & Racial Narratives

Building on ideas above, research involving racial narratives and stereotypes further underscores the need to re-center race in research examining science identity construction for youth of color. Foundational research illustrates the ways racial constructions inform relationships between learning and identification processes and the identities made available and taken up by youth of color (Nasir 2012; Nasir & Hand, 2006; Nasir & Shah, 2011). Race is conceptualized as socially constructed, historically embedded categories of power and privilege (Omi & Winant, 1994). This research views the meaning of racial categories as determined by social, political and economic forces that create hierarchies with tangible outcomes for inequity and access (Omi & Winant, 1994). Foundational work on stereotype threat illustrates the pervasiveness of racialized stereotypes in our society and that these stereotypes have negative psychological consequences that impact performance in numerous domains (Steele, 1997; Steele & Aronson, 1995). This research suggests that race and racialized stereotypes must be attended to when examining processes of learning and identity construction for youth of color (Steele, 1997; Steele & Aronson, 1995).

Research provides empirical evidence that gender-based stereotypes and racial narratives effect disciplinary self-concepts and long-term trajectories in mathematics (Cvencek et al., 2011; Nasir & Shah, 2011). Research in developmental psychology illustrates how relationships between different aspects of identity (e.g. gender identity) and math-specific stereotypes operate at a cognitive level to impact self-concept and desire for future participation in math (Cvencek et al., 2011). Of particular significance is that researchers found that for children, boys have a higher math self-concept than girls and these gender differences in math self-concept *preceded* actual differences in math achievement. In other words, stereotypes function in relation to cognitive factors to shape one's trajectory in a discipline well *before* differences in academic performance exist (Cvencek et al., 2011). While this work does not address race-based stereotypes, it is plausible that similar relationships would apply in that context.

Research at the intersections of race and mathematics illuminates how discipline-specific racial narratives can shape the subject positions or possibilities that African American young men view as available to them in math. Researchers utilize the term, "racial narratives" to emphasize the lived and invoked nature of racialization in our society (Nasir & Shah, 2011). Research shows that the internalization of negative racial narratives about math competence may impact African American males' discipline-specific trajectories by limiting the *types* of subject positions available to them (Nasir & Shah, 2011). Of particular significance is that youth are "hailed" into subject positions. In addition, racialized structural inequities limit access to particular options (i.e. capable math learner). Once hailed, students are forced to respond by taking up/confirming, or resisting the positions by modifying, repurposing or deploying counter narratives (Nasir & Shah, 2011). Findings emphasize the power dynamics associated with this type of positioning and identity work. In addition, this research points to disparities in the distribution of *who* is required to do this work based on race. This study builds on this important work to examine how youth of color see themselves in relation to science and how their science and racial identities develop together in science programs. In addition this research explores how students make sense of racial/ethnic underrepresentation in science, the racial narratives that emerge during these discussions and how this shapes students' ideas about the options available to them in science.

Conceptualizing Science Practices

Previous science education literature highlights some of the potential identity constructing resources that support the development of practice-linked identities in science. Research shows that engaging with science practices and the sense making and analytical work involved can help expand students' ideas of what counts as science practices (Warren, Ballinger, Ogonowski, Rosebery & Hudicourt-Barnes, 2001). In addition, research shows that authentic inquiry-based approaches to science allow students to grapple with real-world problems and present multiple ways to express knowing and understanding. An overarching theme is that authentic inquiry tasks are important because they provide opportunities for students to experience knowledge development in actual contexts and identify as capable learners (Lee & Songer, 2003). As argued by Bowen & Roth (2007), if we want to attract more students to science then we need to provide them with images of science that better represent a broad range of sciences and what scientists actually do. Likewise, Sandoval (2005) argues that students need their own authentic experiences in science (i.e. "practical epistemologies") from which to base their ideas about science knowledge production instead of relying on their perceptions of the work of professional scientists. This research builds on this by exploring what students learn about science practices from conducting research alongside scientist instructors.

Science research & investigations. As one type of authentic inquiry, student-designed investigations provide unique opportunities for students to develop deep understanding of science content (Lehrer, 2009) and construct unique epistemological stances (Metz, 2004; Sandoval, 2005; Lehrer, Schauble & Lucas, 2008). Building on this further, research shows that engaging with science practices through investigations has positive impacts on identity construction. Findings from previous studies show that conducting investigations increases interest and engagement in science (Linn & Hsi, 2000) and allows students to perceive themselves as real scientists and identify as capable learners (Barab & Hay, 2001; Bouillion & Gomez, 2001; Bowen & Roth, 2007, Lehrer, 2009). Research shows that while struggling to design and conduct investigations (i.e. struggling with "material means"), students' developed a deeper understanding of scientific content and identified as capable learners (Lehrer, 2009). In addition, research shows that community-based research projects provide a context that bridges the home culture of youth from urban contexts with the culture and practice of doing science in school (Bouillion & Gomez, 2001). Findings from this research show that engaging in community-based research increased students' conceptual understanding of science phenomena, as well as their interest and sense of empowerment (Bouillion & Gomez, 2001).

I build on this research to explore the mechanisms involved with *how* learning and identities are constructed in context through engaging in science practices. I examine the types of practices that scientists instructors promote, how they are taken up and utilized by students, resulting implications for learning and identity construction. In addition, the program contrasts capture how engaging in different types of scientific research (community-based vs. traditional) impacts processes of learning and identity. This research builds on findings above to explore how new possibilities are generated for students through engaging in community-based research.

Conceptualizing "Pedagogical Vision"

When conceptualizing identity construction through engagement in activities, Nasir (2004) emphasizes the importance of examining the nature of the setting including norms, institutional beliefs, distribution of roles, nature of participation and *imagined trajectories* embedded within activities. As one source of power in science classrooms, teachers have the ability to offer alternative possibilities and roles for their students through the organization of institutional structures, cultural practices, social interactions, and relationships (Nasir, 2004). Through participation in summer science programs students interact with scientists who have particular experiences with and perspectives of science that inform how they shape learning experiences for student participants. Likewise, students develop ideas about what is good and valued in the practice of science and their place in the practice. An analysis of artifacts as mediators of human experiences and prolepsis as the mechanism through which cultural artifacts carry meaning across time offers an understanding of how ideational artifacts are created and maintained (Cole, 1996, Nasir, 2004). Cole (1996) uses the idea of prolepsis (artifacts carry meaning across time) to illustrate the mechanisms through which ideal artifacts from cultural pasts and projected into imagined futures mediate human activities at present. Adults create different material forms of interactions based on their own cultural experiences and their resulting conceptions of the world and what the future holds for their children/students etc. This can be extended to scientist instructors who have particular backgrounds and experiences with science, students, and race shape their perspectives.

Applying these ideas to schooling, Nasir (2004) examines how ideas and cultural conceptions as ideational artifacts inform the construction of identities within the cultural activities of classrooms. Nasir (2004) argues that teacher's ideational artifacts and actions often align with one another which has direct implications for the role of teachers in students' identification processes. Teachers can draw on and create – or recreate these ideational artifacts of the schooling environment during their practice (e.g. in response to resistant behavior) by offering alternative identities for students through the ways they organize structures, cultural practices, social interaction, and relationships within their classroom (Nasir, 2004). In addition, research shows how educator's can facilitate the process of "social dreaming" for students that cultivates hope and possibility and the imagining of new possible futures (Gutierrez, 2008).

Nasir & Hand (2006) discuss ideas about race as an ideational artifact that has particular relevance to schooling and the science experiences of students of color. When employed in institutional practices, ideational artifacts involving race can create disparities in access to participation for different groups of people (Nasir & Hand, 2006). Nasir (2012) illustrates the complexity of identification processes as students negotiate the alignment and conflicting identities offered in their everyday lives, different learning environments and schools. Nogurera & Akom (2000) argue schools play a significant role in shaping students' racial identities. Racialized institutional practices (e.g. tracking) send messages to students about where they do and don't belong (Nogurera & Akom, 2000) and who they can become (Nasir, 2012). Furthermore, based on findings from their study of professional African American and Latino female scientists, Johnson et.al (2011) suggest that learning settings are needed in which obstacles facing women of color in science are explicitly recognized and women are supported as they work to overcome them. Through program contrasts, this research aims to shed light on the types of resources that might make this possible.

Role of teachers: Projecting possible futures. When embedded in a view of prolepsis, a teacher's pedagogical vision and future imaginings for their students plays a powerful role. This vision organizes the activities within a learning environment in the present and creates or limits access to resources and opportunities that mediate processes of learning and identity construction. Research shows how educators and coaches can offer and constrain access to resources and opportunities that impacts future trajectories of students and athletes. In addition, research shows how a coach as the identifier offers differential access to particular resources that shape students' trajectories as track athletes (Nasir & Cooks, 2009). In this example, the coach's perception of an athlete's dedication and drive determined the resources he made available to certain athlete in ways that impacted the athlete's identity outcomes (Nasir & Cooks, 2009). These findings illustrate the ways the coach, as the identifier, utilizes ideal artifacts about what constitutes a successful track athlete to project different futures for certain athletes.

Research in teacher education shows that beginning teachers' orientations to science, students, race and diversity on personal, social and political levels informed their perspectives of science and views of science teaching (Bianchini & Solomon, 2003). This impacted teachers' views of equity in science and ideas about equitable approaches to science instruction (Bianchini & Solomon, 2003). In addition, Oakes et al. (1997) shows how teachers' perspectives of their students based on factors including race hold incredible weight. Through their research, Oakes et al. (1997) show that when teachers confronted a racialized institutional practice (i.e. tracking) in their school as a cultural and political struggle they found it difficult to support traditional conceptions of students' abilities or the segregated tracking structure in their schools. As power agents, teachers began to realize that they had control over the creation (and re-creation) or dismantling of institutionalized structural inequity.

Bringing these ideas into the science programs, this study explores how an instructor's pedagogical vision guides the program resources made available, how they are taken up or resisted by students, and the types of identities made available and constructed through program participation. I examine how an instructor's ideas about and experiences with science, their students, and race impact the possible futures they imagine for their students and organizes the structure of activities and opportunities in the science programs at present. In addition, through contrasts of programs that explicitly vs. implicitly address race and diversity, I examine what is possible when program resources that support holistic identity construction are made available.

Chapter 3. Overview of Methods

This research employs qualitative (e.g. interviews) and quantitative (e.g. surveys) data sources with students as my unit of analysis in order to illuminate the mechanisms associated with shifts in students' ideas about *what* science is and *who* can do science based on their experiences in summer science programs (Maxwell, 2004). I utilize a multiple case sampling approach (Miles & Huberman, 1994) with variability on student's incoming identity and perceived ability in science to capture a range of student experiences. I observed associations between engaging in science practice, the accompanying program resources and science identification processes by examining the types of program resources made available and how they were taken up, resisted and/or utilized by students. This research provides rich descriptions that maintain high levels of construct and internal validity in order to contribute to and build on existing theory (Light, Singer & Willet, 1990). External validity of this work is low due to small sample sizes and the absence of comparison cases (Light et.al, 1990). Therefore, this research design does not allow for generalization beyond the target populations in these summer science programs.

Research Design

This study examined three summer science programs that served high school students that are racially/ethnically underrepresented in the sciences. Students conducted scientific research as part of the programs.

Program contrasts. The study was designed to highlight two main program contrasts: program content (race diversity explicit vs. implicit) and scientific research content (traditional vs. community based) (see Figure 1). The goal of this design was to determine how the program contrasts impacted the types and availability of program resources and the resulting impacts on student learning and identity construction. Program contrasts are defined as follows:

- Program content (race diversity implicit vs. explicit):
    - Race/diversity *explicit*: Programs directly addressed issues of equity, diversity, and/or racial/ethnic underrepresentation in science through program content (e.g. workshops, culturally-relevant pedagogy).
    - Race/diversity *implicit*: Programs served youth racially/ethnically underrepresented in the sciences but did not directly address issues of equity, diversity or racial/ethnic underrepresentation in science through program content.

- Scientific research content (community-based vs. traditional):
    - Community-based: Students conducted research that addressed a scientific issue relevant to their community (e.g. air quality research).
    - Traditional: Students conducted field or lab-based research in more typical/traditional science disciplines (e.g. physics).

This research explores how the program contrasts impacted the program resources made available and intersections of race, learning and identity construction for student participants. Redwood and Westport were both race diversity *implicit* programs but differed by research content (see Figure 1). Bayside was a race diversity *explicit* program and students conducted traditional scientific research (see Figure 1). The race/diversity explicit and community-based scientific research box is blank because no summer program was found that fit these descriptions (see Figure 1).

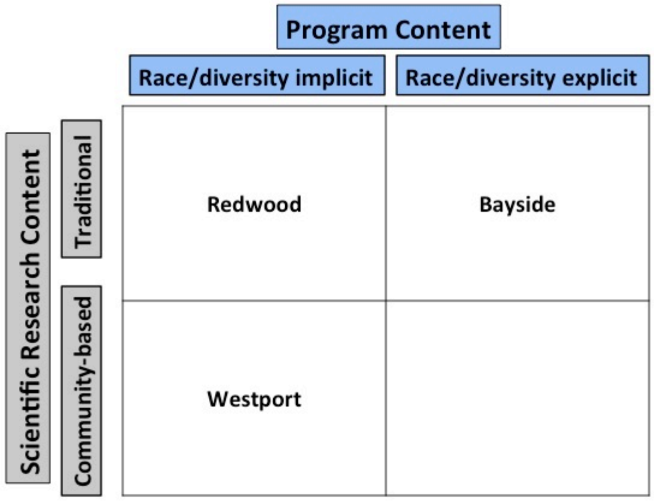

Figure 1. Study design and program contrasts: Program content (race/diversity implicit vs. explicit) and scientific research content (community-based vs. traditional).

Focal student selection: Range of perceived ability & science identity. In addition to the program contrasts, this study was designed to explore how students who ranged on incoming perceived ability in science and science identity experienced the science programs. Based on pre program surveys, six focal students were selected per program to capture the greatest amount of variability on scores for incoming science identity and perceived ability in science. Students' science identity and perceived ability in science scores were averaged and ranked from highest to lowest by program. In general, students' perceived ability in science and science identity scores coincided. Together the rankings were used to select six students from each program: two that ranked "high" on perceived ability/science identity, two that ranked "medium" and two that ranked "low". This range of students was used to determine how different "types" of students experienced the science programs in different ways. When possible, gender was held constant by selecting one boy and one girl for each category (i.e. high, medium, low) per program because the effect of gender on identification processes in science was not the focus of this research. Likewise, when possible, students' year in school was similar for all six focal students per program so that years of experience in school was held constant. Selected focal students were interviewed before and after completion of the program as well as during the following school year to determine pre to post program shifts and the ideas that they carried with them following program participation.

Summer Science Programs

The three summer science programs included in this study took place in or near a Northern California metropolitan area during the Summer of 2012. All programs were free of charge. In addition to the program contrasts described above, the programs differed by length, duration of the research project, and application procedures.

Duration of Program. The summer science programs differed by length and intensity of the program. Students in the Westport program met for four hours/day, five days/week for a total of five weeks. Both the Redwood and Bayside programs were residential programs and students lived in the dorms on university campuses for the duration of the five-week (Bayside) and seven-week long (Redwood) summer program (see Table 1). Students from Bayside and Redwood spent the majority of the day in program-related activities. Bayside activities extended into the evening.

Duration of Research Project. The length of the scientific research projects differed across programs. The research project was the focus and main component of both the Redwood and Westport summer programs. The Bayside summer program contained multiple components (e.g. Biology class, workshops) and the research project was one of these components. Students in the Bayside program attended a science research course two days per week for three hours per session (i.e. 6 hours/week). During this research course students conducted research projects with scientist instructors (see Table 1).

Table 1. Summer Science Programs: Program & Research Content, Duration & Requirements.

Program	**Program Content**	**Research Content**	**Duration (Program, Research)**	**Program Requirements**
Bayside	Race/diversity *explicit*	Traditional (*e.g. physics*)	• **Program**: 5 weeks, residential • **Research**: 6 hours per week	• Strong math skills/grades required • Math assessment required • Accepted as 9th graders, required to attend program for 3 consecutive summers
Redwood	Race/diversity *implicit*	Traditional (*earth science*)	• **Program**: 7 weeks, residential • **Research**: main focus	• Application • Recommended by teacher • No specific grade requirements
Westport	Race/diversity *implicit*	Community-based (*air quality*)	• **Program**: 5 weeks, 4 hours/day • **Research**: main focus	• Application • No specific grade requirements • Most students joined to make up science credits and/or had failed science class

Due to the variability between programs, the goal of this research was not to make program comparisons. The objective was to better understand students' experiences across the different summer programs based on the main contrasts described above, and to better understand the mechanisms associated with intersections of race, learning and identity construction based on the types of program resources made available in different programs.

Application procedures. The application procedures differed by summer science program. Bayside and Redwood students completed a rigorous application process and were selected from a pool of applicants in order to participate. In addition, Redwood students obtained a recommendation from a teacher to attend the program. Bayside students took part in a competitive application process in order to participate. First, students were required to take a math exam and obtain above a certain cutoff score in order to be included in the eligible pool of applicants. Finalists completed an interview process and the incoming cohort of students was selected from this process (see Table 1). In contrast, Westport students completed an application, but the majority of students joined the program because they had failed their science course in school and/or needed to make up science credits. Differences in application procedures resulted in different "types" of students in each of the programs (see Table 1). These differences were taken into consideration during analysis.

Participants

Students. 67 students total participated in the three summer science programs. Of the total number of participants across programs, 52 students participated in this study. Each program served approximately equal numbers of boys and girls. The specific demographics, grades, and number of students per program are shown in Table 2. The majority of students involved in this study were from racial/ethnic backgrounds that are underrepresented in the sciences (see Table 2). The Bayside and Westport programs served only youth racially/ethnically underrepresented in the sciences. Bayside students were required to identify with one of the following racial groups in order to be eligible for program participation: African American, Chicano/Latino/a, Southeast Asian, Pacific Islander, Native American, or mixed race/multiracial. The Westport program targeted students from underserved schools and participants were mostly Latino/a but included South East Asian and African American students as well. The Redwood program was comprised of a racially heterogeneous group of students. Approximately half of the students were from racial/ethnic groups underrepresented in the sciences. All focal students selected from Redwood self-identified racially as Mexican or Latino. All racial group affiliations reported throughout this dissertation reflect focal students' *self-reported* racial categorization based on surveys and/or interviews.

All students involved in the study attended grades 10-12 at various high schools in or near a Northern California metropolitan area. Student participants differed by grade level and high schools attended (see Table 2). All participants from Bayside (n=22) were rising 10th grade students. Bayside participants attended a variety of public high schools. Students from Westport (n=11) attended grades 10-12 at the same public high school with the exception of one student that attended a different school. Redwood students (n=19) attended grades 10-12 at various public and private high schools. All focal students from Redwood attended the same public high school. Since the science program took place during the summer, all grade levels are reported as students grade level during the upcoming academic year (e.g. a student who had just completed their freshman year would be categorized as a rising 10th grader).

Pre and post program interviews were conducted with 18 focal students across programs (Bayside (n=6), Redwood (n=5), Bayside (n=7)). As described above, interviewees were selected to capture a diverse range of students with varying backgrounds, experiences and incoming perceived ability in science and science identity scores.

Scientist instructors. 10 scientist instructors participated in this study across programs. Scientist instructors were graduate students and postdoctoral scholars in various science disciplines or science instructors with strong disciplinary and scientific research backgrounds. The instructors' research expertise spanned a range of science disciplines (e.g. physics, environmental science, engineering). The majority of scientist instructors identified racially as white. There were six female and four male instructors across programs. The types and racial make-up of instructors varied by program (see Table 2).

Table 2. Student and Instructor Demographics & Grade Level by Program.

Program	Student Demographics	Student Grade/School	# of students	Focal students (Grade, Self-reported racial affiliation)	Scientist Instructors
Bayside	African American, Latino/a Southeast Asian, or mixed race/multiracial	• 9th grade • Various high schools	• Program: 27 • Study: 22 • Focal: 6	All focal: 10th grade • Low: Lorenzo, Elana (Mexican) • Medium: Gabriella, Ronald (Chicana, Black) • High: Naomi, Lucas (African American, Latino)	• Graduate students in various science disciplines (n=2) • Majority white • Mix female/male
Redwood	~ 50% Latino/a, Mexican ~50% white	• 10th-12th grade • Various high schools • Focal students: same high school	• Program: 29 • Study: 19 • Focal: 5	All focal: 12th grade, Mexican • Low: Jasmine • Medium: Alejandra, Antonio • High: Carlos, Ricardo	• Graduate students/ post doctoral scholars (earth sciences) (n=5) • Majority white • Mix female/male
Westport	Majority: Latino/ Chicana/ Mexican Also: South East Asian, African American	• 10th-12th grade • Majority same high school	• Program: 11 • Study: 11 • Focal: 7	• Low: Serena, Natasha, Fernando (12th gr, Mexican, Chicana, Latino) • Medium: James (11th gr, African American) • High: Melanie, Vincent (10th gr, Filipina, Latino)	• Science instructor (environmental science); Assistant, Graduate student • White (2), African American (1) • Male (2), female (1)

Data Sources

To answer my research questions, I utilized four main data sources: 1) Pre and post program student surveys, 2) Pre and post program focal student interviews, 3) Scientist instructor interviews, and 4) Program observations.

Pre & post program student surveys. 41 students total completed pre and post program surveys across the three summer science programs. The goal of pre and post program surveys was to establish a baseline (pre) and determine changes (post) in students' attitudes towards, ideas about, and perceptions of ability in science. Pre program surveys were administered on the first day of the program. Post program surveys were administered on the last day of the program. All surveys were administered and completed on paper copies during class time and turned in together. Surveys were designed to capture the following types of data (see Appendix 1: Pre, Appendix 2: Post):

- ***Student background information & previous science experiences*** (*pre program survey only*): Questions about background information included: how students found out about the program, their academic interests and grades. Previous science experience included: prior science courses taken, science grades, and participation in other science-related programs and extra-curricular activities. This information was used to determine differences in student populations between programs.

- ***Attitudes towards science & perceptions of science ability*** (*pre and post program surveys*): Validated scales that measured students' interest, attitudes towards, and perceptions of ability in science were used to create Likert scale items. Validated scales measured: science identity (Girod, 2005), perceived ability: self-concept in science (Kind, Jones & Barmby, 2007), interest in science (Girod, 2005), relevance and utility of science/scientific research in life (Siegel & Ranney, 2003), and work of scientists (Aschbacher, Ellen & Roth, 2010). From these validated scales, 37 Likert scale items were constructed in check box format with choices that ranged from strongly agree to strongly disagree.
- ***Ideas about the scientific research process*** *(pre and post):* various questions were designed to capture students' ideas about the process of conducting scientific research. Items contained a check box portion (i.e. how much do you agree or disagree with the following statement) and an open-ended response section that asked students to explain their choice. Two main items were used for analysis in this study: Item #1: "In order to do good work, scientists need to closely follow the steps of the scientific method"; Item #2: "Scientists rarely stray from their plan when they do experiments". In addition, survey items asked students ideas about uses for and the importance of scientific research.

Pre program surveys in combination with pre program interviews (described below) created a baseline for students: 1) science identity and 2) perceived ability in science. Post program surveys mirrored the pre program version and were designed to capture changes in students' attitudes and ideas about science and the scientific research process following program participation. In addition, questions were added that asked students to describe how their ideas about the scientific research process and uses for scientific research changed following program participation.

Interviews. Semi-structured interviews were designed to capture a holistic picture of students' and instructors' experiences with, perspectives of, and ideas about science. Interviews were designed employing an interpretivist perspective. The lead author aimed to understand the world of someone with a background and experiences different than her own. Interviews were conducted in a way that encompassed Iris Young's idea of "asymmetrical reciprocity", accepting that there are parts of a subject's position that we cannot understand, but being open to asking about, listening to, and trying to understand to the best of our ability (Edwards & Mauthner, 2002). Interview protocols were designed with different types of questions as suggested by Spradley (1979). Descriptive questions elicited students' and instructors' ideas and used interviewee's native language in follow-up questions to better understand their world and to validate their experiences (Spradley, 1979). Structural questions were used to capture the different terms students and instructors used to explain the scientific research process and students' ideas about *who* does science. Contrast questions were used to better understand their conceptions of science in different contexts. All interviews were conducted one-on-one and audio-recorded.

Pre & post program focal student interviews. 18 focal students total across programs completed pre and post program interviews. 7 students total completed follow-up interviews during the school year following program participation. Pre program interviews were conducted on the first day of the program with approximately six focal students per program (Bayside (n=6), Redwood (n=5), Bayside (n=7). Post program interviews took place on the last day of instruction with the same set of focal students. Interviews were conducted during program time but outside of the main program activity area. Follow-up interviews were conducted with as many focal students as possible (n=7) at the student's school site or a public location near their home (e.g. library).

Pre program interviews were designed to capture students' ideas about science practices, *who* does/can do science, how students saw themselves in relation to science and other aspects of their science and racial identities. In addition, interviews were designed to capture students' ideas about science practices (see Appendix 3). ***Identity*** is defined as how youth of color perceive science and scientists, how they see themselves in relation to science/scientists, and how the interactions they have and believe they can have shape *who* they become in science. Post program interviews mirrored the pre program version and were used to determine shifts in students' ideas about *who* does and can do science, aspects of their science and racial identities, and science practices following program participation. In addition, questions were added to determine changes in students' ideas and how they saw themselves in relation to science (see Appendix 4). Interview protocols were designed to capture students' ideas, sense making, and experiences in the following categories:

Conceptions of who does & can do science. In order to gain an understanding of how students' characterizations of scientists, pre program interviews were designed to capture how students envisioned scientists. This included the skills, characteristics, gender and race that students associated with scientists. Post program interviews asked students to describe someone they had met during the summer that they considered a scientist and the skills and characteristics they associated with this person.

*Science & racial identity***.** Pre program interviews were designed to explore aspects of students' science and racial identities and how they saw themselves in relation to their conceptions of scientists. Questions captured students' backgrounds and experiences with science, their conceptions of their abilities in science (e.g. tell me a time that you felt good at science), and their interests in science. To capture intersections of race and science and how students saw themselves in relation to science, questions captured disparities that students noticed in *who* is a scientists by race and gender and their sense making about racial/ethnic underrepresentation in science. During interviews, racial narratives commonly emerged during students' sense making about racial/ethnic underrepresentation in science. ***Racial narratives*** are defined as raced-based narratives that capture how racialized societal perceptions and stereotypes are invoked, kept alive, and used in everyday contexts (Nasir & Shah, 2011). As a result, questions were asked to probe about racial narratives that emerged. Post program interviews captured shifts in students' science and racial identities, how aspects of their identities developed together, and if and how their pursuit of science as youth of color was supported during the program.

Science practices. In order to gain an understanding of students' ideas about science practices and how they see themselves in relation to these practices, pre program interviews were designed to capture students' ideas of what scientists "do" to conduct research. ***Science practices*** are defined as the types of activities utilized to conduct scientific research and/or produce scientific knowledge through the research process. This definition is intentionally broad in order to holistically capture students' ideas about and experiences with "doing" science. Interviews were designed to capture two types of science practices (school and scientist) defined as follows:

a) School science practices: the types of activities students participate in during science class in order to "do" science in school; b) Scientists practices: the types of activities utilized by scientists to conduct scientific research and/or produce scientific knowledge through the research process. Pre program interview questions asked students to describe what it "looked like" to do science in school and their ideas about what they thought scientists did to conduct scientific research. Post program interviews asked students to describe their research projects and what *they* did to conduct scientific research during the summer science programs.

In addition, focal students were asked about observed moments of positioning (e.g. by peers, instructors) informally throughout the program. This allowed for triangulation of interviews with observations made in real-time. Post program interviews also probed for the types and availability of program resources that may have supported these shifts. When possible, follow-up interviews were conducted with focal students during the school year following program participation to determine what ideas about science, and aspects of the summer science program resonated and carried with them after completion of the program.

Scientist instructor interviews. 10 instructors total across programs completed interviews. Interviews were conducted at or near the end of the summer science program at the program site. Interviews were designed to capture instructors' perspectives of science and their students as well as their sense making about racial/ethnic underrepresentation in science. Interview questions captured instructors' ideas about science that included: goals for instruction, utility of scientific research, science practices that they used themselves and found important to promote, ways that they used science in their own lives and how they hoped students would use science in their lives. Interviews also captured instructors' ideas about their students that included: racial backgrounds, societal positioning. Finally, interviews captured instructors' sense making about racial disparities in the professional science community (see Appendix 5). Together, interview responses were used to determine an instructor's "pedagogical vision". ***Pedagogical vision*** is defined as the ways that teachers' own backgrounds and experiences inform their goals and purposes for teaching science, what they envision their students *doing* with science, and the possibilities they create for *who* their students can become in science. This included instructional approaches, the experiences they designed and the spaces they created for learning. Ultimately, the vision constructed the pathways and opportunities they made available for students. Instructor interviews were used in conjunction with program observations to determine how their vision played out in real-time and impacted the types of program resources made available.

Program observations. Program observations were made two to three times per week per program for a total of approximately 116 hours. The goal of program observations was to explore the mechanisms involved with engaging students in science practices and how the accompanying resources supported shifts in students' ideas about *what* science is and *who* can do science. Program observations were designed to capture moments of positioning between participants and instructors and the types of resources made available and exchanged between participants (e.g. students, instructors) during the programs. ***Program resources*** are defined as the types of instruction, pedagogy and designed experiences that instructors make available and the types of resources exchanged between participants during the summer programs.

Program observations across programs included: students conducting scientific research, classroom discussions and interactions, culminating research project presentations and informal interactions between students and instructors. Program observations were focused on the selected focal students in each program but also captured activities holistically. The Bayside program contained multiple program components (e.g. Biology class) that were also observed. The main focus of the Redwood and Westport programs was the research project. In all cases, field notes were recorded using pen and paper.

The "practice-linked identity" framework (i.e. viewing participation in a practice as central to who one is) and supporting identity-constructing resources (Nasir & Cooks, 2009; Nasir 2012) was used to guide the observations and field note analysis. For the purpose of this research these identity constructing resources are defined as follows: 1) ideational: instructors perspectives of race and science, ideas about their instruction; 2) material: instruction for science practices, science equipment, physical objects, artifacts; 3) relational: interpersonal connections, positioning within the science programs. A particular focus of observations was the types of program resources that support students' science *and* racial identities in the science programs. This is defined as *holistic support*. Program observations were used to determine the types of program resources (e.g. material, relational, ideational) made available to focal students through participation in summer science programs as well as other unique resources. The availability of resources was determined through observation of instructor/student and student/student interactions. The following types of mechanism were explored through program observations.

- What identity constructing resources are made available through this practice?
- How are resources made available through this practice?
- How are resources taken up or resisted by students?

Program observations were used in combination with instructor interviews to determine how their pedagogical vision played out and impacted the types and availability of program resources. In addition, program observations were used in conjunction with student interviews to determine moments of positioning, uptake or resistance of program resources, and the resulting impact on students' identity construction.

Data Analysis

Pre & post program surveys. Of the 52 students involved in this study, 41 students completed pre and post program surveys across programs. Students with missing data were excluded from pre to post program comparisons. The number of total students that completed pre and post program surveys differed by program: Redwood: 14/19, Bayside: 18/22, Westport: 9/11.

Attitudinal survey items. Attitudinal questions appeared as Likert scale items on pre and post program surveys. Likert scale items were scored from 1-5 with 5 representing the most positive response and 1 representing the most negative response. All items for a validated scale were considered a subcategory (e.g. science identity). To determine differences between students, data was averaged by subcategory for individual students and compared within and across programs. To determine differences between programs, student data was averaged by program and compared across programs. Plots were created to determine patterns between different groupings of students that included: 1) high vs. low perceived ability, 2) high vs. low science identity, and 3) male vs. female students. Findings were reported as within and between program differences.

All student pre and post program surveys included items that measured perceived ability in science (e.g. I am good at science) (Likert scale). Preliminary analyses revealed that this measure was a salient aspect of students' identities in the science programs and is therefore described in greater detail. It is important to note that perceived ability in science scores were not designed to assess students' *actual* ability in science, but rather served as a measure for how students' viewed themselves as science learners (i.e. view themselves as "good" are "bad" at science). Students' scores were averaged for all perceived ability items, arranged from high to low scores and divided into quartiles across programs. Students in the top quartile were labeled "high perceived ability students" and students in the bottom quartile were labeled "low perceived ability students". To determine relationships between perceived ability in science and students' incoming ideas about science practices and *who* can do science, survey data was analyzed in conjunction with interview data for focal students who fell into the top (i.e. high) or bottom (i.e. low) quartiles.

Science process questions & open-ended responses. Pre and post program surveys contained items that assessed students' ideas about and understanding of the scientific research process. Questions about the scientific research process contained a statement (e.g. scientists closely follow the steps of the scientific method), a check box portion that asked students how much they agreed or disagreed with the statement, and an open response section for students to explain their answer. Check box items were scored from 1= strongly agree to 5 = strongly disagree. A scoring rubric was created to assess students' open-ended responses for two assessment items. The rubric was designed to capture a range of responses that described prescribed to more authentic views of the scientific research process. The scoring rubric was scored on a scale from 1-5 for Item #1 (see Appendix 6) and 1-6 for Item #2 (see Appendix 7) with the highest score indicating the most authentic views of science. Check box and open-ended response scores were analyzed separately. Scores were averaged and analyzed across programs. Similar to the Likert scale items described above, patterns were assessed for different groupings of students (e.g. high vs. low perceived ability) and to determine pre to post program changes.

Interview analysis. All student and mentor interviews were transcribed using InqScribe transcription software. Coding was done inductively and categories for the emergent ways students described their ideas about science practices, *who* can do science, and aspects of their science and racial identities were constructed through an iterative process (Miles and Huberman 1994). The same process was used for instructor interviews that included their perspectives of science and students. For all student and instructor interviews, coding categories *emerged* from the data and were not pre-determined. The same analysis process was followed for all student and instructor interviews: First, transcripts were coded using descriptive codes. Transcripts were read through in their entirety and statements involving concepts of interest for this research (e.g. science practices) were noted. Second, interpretive codes were applied. Phrases involving the concept (e.g. perspectives of science) were coded as ideas. A subject's sense making and the meaning they associated with these ideas was inferred through analysis of their statements before and after the phrase to provide sufficient context. Third, codes were developed and refined in collaboration with colleagues. The lead investigator presented initial coding schemes and definitions of coding categories for instructor and student interviews to a research group of colleagues consisting of faculty, postdoctoral scholars and graduate students. The number of coders involved in different aspects of the process ranged from two to four coders throughout the process. In all cases, coding categories were refined through a process of collaboration with the researchers interpreting and applying codes to sections of interview transcripts (Hammer and Berland, 2013). However, it is important to note that interviews were coded and analyzed through the lead investigator's lens. This provides limitations to truly capturing and understanding all the factors involved with students' and instructors' experiences from their position. Previous research shows the importance of examining intersectional aspects of identity (e.g. race, gender) to capture the experiences and long-term trajectories of women of color in STEM (e.g. Carlone & Johnson, 2007, Malone & Barabino, 2008). Therefore, attention was directed to the ways that multiple dimensions of students' and instructors' lived experiences played out to shape the ways they saw themselves in relation to science.

Focal students: Focal student interview transcripts were coded separately for science practices, conceptions of *who* does/can do science, and intersections of students' science and racial identities but were also explored holistically. As described above, interviews were coded inductively and all categories *emerged* from the data and were not predetermined. Coding categories were constructed through an iterative process (Miles & Huberman, 1994) to examine how different aspects of students' identities (e.g. racial, science) developed together.

Science & racial identity. To explore intersections of students' science and racial identities, transcripts were coded for the ways that students talked about science in relation to themselves. This research explores how students' science and racial identities develop together, therefore, these components are explored holistically. Transcripts were read and coded for statements of science identity that included interests in science and participation in science activities in and outside of school. In addition, transcripts were also coded for statements of racial identity that included racial group affiliation and centrality of this affiliation to students, and intersections of students' science and racial identities.

Conceptions of who does & can do science. To capture students' ideas about who does and can do science and how they saw themselves in relation to scientists, transcripts were coded for different aspects of how students characterized scientists as well as their sense making about racial/ethnic underrepresentation in science. To determine they ways that students characterized scientists transcripts were coded for three main components: 1) characteristics, 2) race and 3) gender. In each case, categories of ideas were divided into subcategories. Students' ideas in each category were explored across and within programs to determine patterns and differences in the ways students' commonly described scientists. This data was then examined in conjunction with other aspects of students' science and racial identities to determine how they saw themselves in relation to scientists. In addition, interviews were analyzed in conjunction with survey data to determine patterns between different components (e.g. perceived ability in science).

Sense making about racial/ethnic underrepresentation in science. In order to further explore intersections of race and science, transcripts were coded to determine students' sense making about racial/ethnic underrepresentation in science. Initial analyses revealed that in many cases racial narratives emerged during students' reasoning. In these cases, racial narratives were further analyzed for where students located the "issue" of racial/ethnic underrepresentation in science (e.g. individual, racialized structures). From this process, two broad subcategories of location were determined: 1) individual, one's culture/race (i.e. individual choice, deficit-oriented views), 2) racialized structural inequities (i.e. racial discrimination, educational opportunities). Categories for racial narratives were then examined in conjunction with characteristics, gender and race above to determine how the narratives "functioned" for students.

Science practices. Interviews were coded for the types of science practices that students' used to "do" science in school and the practices they thought scientists used to "do" scientific research. In all cases, categories emerged from the data and were not predetermined. Interviews were coded to capture students' ideas about the scientific research process and the practices scientists used in three ways: 1) the *types* of science practices students thought scientists utilized to conduct scientific research (pre program) and that they utilized to "do" science during program participation (post program), 2) the *meaning* students' associated with the science practices/work of scientists (pre and post program). This included their ideas about the scientific research process and *outcomes* of the process, discussed in detail below, and 3) uses for scientific research: utility and purpose of research, as well as who might find the research useful (pre and post program). To gauge shifts in students' views of science practices, interviews were analyzed for the types and meaning of science practices and uses for scientific research that students discussed before and after program participation. To determine post program shifts in students' ideas about the scientific research process, during post program interviews students were asked to describe their research project, what they did to conduct research on their topic, and changes in their ideas about the scientific research process.

Two broad categories of *meaning* for the practices of scientists and the scientific research process emerged through initial analysis of pre program interviews. Students described the science process as prescribed and static where answers are known or as constantly changing, evolving and unknown. The lead author initially coded these categories as traditional (i.e. prescribed) and authentic (i.e. unknown) and subcategories were defined. Disagreements arose about the meaning of practices that the codes represented. Multiple coders had difficulty differentiating between several codes within this original coding scheme. In addition, since students held multiple ideas about science practices that often fell into more than one category, this added to the complexity of the coding task. Disagreements regarding application of the codes led to further discussion of the coding categories, re-analysis of the data, and refinement of the coding scheme (Hammer & Berland, 2013) (see Appendix 8 for final coding scheme). This process resulted in the final broad categories of meaning: restrictive and expansive. These two broad categories are defined as follows:

Restrictive views of science practices describe the scientific research process as prescribed, known, static, rigid, and linear. Restrictive practices involve finding facts and known answers. This involves a view that there is one correct way of doing things in order to arrive at the correct answer. In addition, stereotypical images of science (e.g. mixing chemicals in a lab) and power differentials between what scientists do and what students have access to were categorized as restrictive because these views limit students' ideas about their abilities to engage with science. Restrictive practices are often based on students' experiences with labs and experiments in school that do not reflect authentic forms of science as conducted by scientists. Restrictive science practices limited opportunities for participation in science (e.g. one way to do things) and/or students' ideas about their ability to engage with the science process in a meaningful way (i.e. based on how they see themselves in relation to the practice).

Expansive views of science practices capture the explorative, non-linear, iterative, flexible, constantly changing/evolving, and problem solving aspects of the scientific research process. Expansive practices involve the generation of new knowledge and following flexible/non-linear paths where tangents are often explored. In addition, multiple ways of approaching research are utilized. Expansive science practices align with and map onto the work of real scientists and what they actually do to conduct scientific research. This view of science practices broadens opportunities for participation in science and expands students' ideas about their abilities to engage with the process (e.g. multiple ways to engage with science are accepted). These definitions were used to capture a baseline (pre) and shifts (post) in the *meaning* students associated with scientist practices and the scientific research process.

It is important to note, that often the science practices *themselves* were not restrictive or expansive in nature. It was the *meaning* associated with the science practices or the *outcome* of the practices that made them restrictive or expansive. For example, following a science procedure, often associated with cook-book/prescribed science can also be a part of the authentic work of real scientists (i.e. scientists may follow a lab protocol). If the meaning associated with a scientific procedure was rigid/prescribed and the goal (i.e. outcome) was to arrive at the correct answer this was considered a restrictive view of this science practice. If the outcome of engaging in the practice was to generate new knowledge, then this was considered an expansive view of this practice.

Linking identity statements & science practices. Through the analysis process above, it emerged that in some cases direct links could be made between science practices (e.g. collecting data) and identity statements (e.g. I am good at science). Exploring this further, certain questions (i.e. tell me about a time you felt good at science this summer) allowed for an exploration of the relationships between science practices and aspects of students' science/racial identity construction. During analyses, when a science practice could be directly linked to an identity statement (e.g. collecting data made me feel good at science) this was coded together as an identity/practice statement. Analyses revealed that these identity/practices statements were an important aspect of an *identity generative process* that emerged during this study that linked engaging in science practices and the accompanying program resources to the generation of new possibilities for students.

Practice/identity statements were analyzed as a *unit* to determine how engaging in science practices "functioned" for students with regards to identity construction. In order to determine patterns between science practices and identity statements, science practices and identity statements were aligned and sorted into groups by science practice and by identity statement. When there was overlap between the same identity statement (e.g. change agent) and the same science practice (e.g. present research) this was considered a significant aspect of students' identity generative process. Identity statements were counted once per science practice but explored across science practices and counted each time they could be directly linked to a different science practice.

To determine if and how program resources facilitated links between identity statements and science practices, identity/practice statements were explored throughout interview transcripts. Program resources that were connected to the science practices were coded and analyzed together with the identity/practice statements. Program resources from interviews were then examined in conjunction with observational field notes to gain a more holistic understanding of the complete identity generative process.

Scientist instructors. Instructor interview transcripts were read and coded for: 1) perspectives of science (e.g. utility), 2) instructional goals and general approach, 3) science practices promoted, 4) their approach to engaging students in the scientific research process, 5) perspective of students (e.g. racial background), 6) ideas about racial and gender disparities in the professional science community, and 7) types of program resources they made available. Coding categories were analyzed individually and for patterns between categories (e.g. perspective of students/science and resources made available). In addition, categories for instructor's ideas about science practices and their students were analyzed in conjunction with the types of program resources they made available. This analysis was used to determine how an instructor's "pedagogical vision" shaped the program resources they discussed. Interviews were triangulated with program observations to determine the mechanisms of how an instructor's pedagogical vision played out in real-time.

Observational field note analysis. Field notes were recorded during program observations and were used to capture the mechanisms associated with program participation and the types, availability and uptake of resources in real-time. Field note coding was done inductively and through an iterative process to remain open to novel constructs, interactions, and resources that appeared outside of the guiding framework (Miles & Huberman, 1994). Field notes were coded for types of program resources made available (e.g. instruction) and how the resources were taken up and utilized or resisted by participants. In addition, field notes were coded to capture social interactions and moments of positioning between students and instructors in the science program spaces. This process provided empirical evidence for the types of program resources (e.g. ideational, material, relational) made available in the science programs and the *mechanism* associated with how they were made available and exchanged among participants in those spaces. Coding and analysis of material resources included: a) curriculum resources, instruction, scaffolding of scientific processes made available by the instructor, and b) student engagement in the data collection process (e.g. using/reading science equipment). Coding for relational resources included positioning of students by instructors and peers during research, groups discussions and other program components. Coding for ideational resources included: a) how an instructors' perspectives of science, race, and their students shape their instruction and the types and approach for promoting science practices, and b) students' ideas about science practices, who can do science, and their place in science. Intersections among resources and unique resources outside of the framework that were made available were also explored.

Program observations were triangulated with focal student interviews and student surveys in order to gain a holistic understanding of students' experiences in the programs and how new possibilities were generated for students. Specific episodes were selected that addressed engagement or resistance of resources while students conducted scientific research. Focal students were asked about these episodes during post program interviews. This allowed for triangulation of students interviews with observations made in real-time and allowed for an exploration of how different identity constructing resources interact. Program observations were also coded in conjunction with instructor interviews to determine how aspects of an instructor's pedagogical vision and their perspectives of science and their students shaped the resources they made available and played out in real-time in the science program contexts.

Chapter 4. *Who* Does & Can Do Science?
Exploring Intersections of Students' Science & Racial Identities

Introduction

Case Example

> People are still racial…and think white people are better than Black people, or Mexican, or that they are smarter, and I guess, we are good for like hands on, the dirty work.

Serena is a 12th grade student who identifies racially as Mexican. She participated in the Westport summer science research program where she and her peers conducted a seven-week long air quality research project involving a local transportation agency. Like many of her peers in the program, Serena entered the program with a very low perceived ability in science. She describes experiencing little success in science class and in school: "I'm not really that good at science...science is not really my strong subject in school. Like, its bad. I never really got it." Her feelings of not being good at science fit into her broader sense of how she sees herself academically and the messages she receives about her ability to succeed: "I wanted to drop out and stuff. I wasn't that bright. People would just say she's going to mess up." During pre program interviews I asked Serena to describe how she thinks of scientists: "I think of them like in labs, very smart people, in the labs…and they know everything". Through further discussion she added that she views scientists racially as "white" and "guys more than girls." In many ways, Serena sees herself in opposition to how she conceptualizes scientists: scientists = smart, white, men; Serena = not "bright", Mexican and a girl. Serena says she notices racial disparities in *who* is a scientist and in the opening excerpt above, she reasons that this is because of racial discrimination. During her reasoning a racial narrative emerges: white people are "smarter" and people from her racial group are seen as good for "the dirty work". Though this racial narrative does not directly connect to science, it reinforces her conceptions about *who* is smart in society and that scientists are "white" and "smart". In addition, this narrative illustrates how options are placed upon students. Serena does not state this racialized perception as her own beliefs, but rather as a societal expectation that is assigned to her and members of her racial group. Serena's experience illustrates the importance of looking at issues of equity in new ways and from the perspective of students' science experiences. In addition, it underscores the importance of exploring how students' science and racial identities develop together in science learning environments.

Rationale

The underrepresentation of African American, Latino, Pacific Islander and other high school students of color in advanced science courses and the need to increase diversity in science fields is widely agreed upon (Oakes, Ormseth, Bell & Camp 1990; Darling-Hammond, 2010). Throughout this dissertation, I argue that the challenge of increasing racial/ethnic diversity in science is complicated by two dominant representations: 1) *what* science is (i.e. what gets counted as science practices), and 2) *who* can do science (i.e. who gets to be a science person). These representations too often provide narrow images of science (e.g. prescribed labs) and scientists (e.g. white, male) that are problematic for youth of color who don't see themselves within the bounds of these narrowly defined categories. From this perspective, classrooms and schools are embedded in systems of power and privilege that shape these representations as well as students' ideas about science. Thus, equity in science education is both about access to authentic science experiences (i.e. *what*) and opportunities to see oneself as a capable science learner (i.e. *who*). A typical solution to increasing diversity in science is to focus on reframing *what* science is through curricular and policy reforms (e.g. National Research Council, 2012) that promote authentic and inquiry-based approaches to instruction. Yet African American and Latino students continue to lag behind their white and Asian peers and race-based achievements gaps are persistent (National Science Board, 2012). While instructional reforms and expanding students' ideas about what counts as science are an important part of the solution (see Chapter 5), conversations with students such as Serena above suggest that a focus on *what* science is alone is insufficient for dismantling persistent issues of equity in science education. I argue that in order to make progress towards increasing diversity in the sciences, we need to extend beyond this focus and pay equal attention to the messages youth of color receive in science learning environments about *who* can be a capable science learner.

This research builds on and extends the argument that in order to increase diversity and broaden learning opportunities in science for racially/ethnically underrepresented youth, we must understand how the resources made available in science learning environments mediate relationships between race, culture, learning and identification processes in science. I *define identity* as how youth of color perceive science, how they see themselves in relation to science, and how the interactions they have and believe they can have shape *who* they become in science. This involves their ideas about *who* does science (e.g. characteristics, race; this chapter) and their ideas about *what* scientists do (i.e. science practices; see Chapter 5). I explore youth of colors' science identities (e.g. interest, views of science) in relation to their racial identities (e.g. membership in a racial/ethnic group) and examine how they develop *together* through participation in summer science programs.

This chapter focuses on students' ideas about *who* does and can do science. I pay particular attention to how students of color see themselves in relation to science and how their science and racial identities develop together in science programs. I *define race* as socially constructed, historically embedded categories of power and privilege (Omi & Winant, 1994). This research views meanings of racial categories as determined by social, political and economic forces that create hierarchies with tangible outcomes for inequity and access (Omi & Winant, 1994). The term *racial narrative* is used to describe statements such as the opening excerpt to capture the active nature of stereotypes and racialized societal perceptions that are invoked, used and kept alive in everyday contexts (Nasir & Shah, 2011).

Objective

This chapter explores youth of colors' incoming ideas about *who* does and can do science, how they see themselves in relation to science, and how their ideas shift following participation in summer science research programs designed for racially/ethnically underrepresented youth. I pay particular attention to the aspects of students' racial and science identities that emerge as most salient in the science programs and examine how these dimensions impact their ideas about belonging or not belonging in science. In addition, I examine students' sense making about racial/ethnic underrepresentation in science and the role of racial narratives that emerge during these discussions. Finally, I examine shifts in students' ideas about *who* does and can do science following program participation. In the next chapter, I explore how engagement in science practices can help make new possibilities available for youth of color (see Chapter 5).

This chapter has three main goals: 1) To better understand relationships between how youth of color view scientists (e.g. race, characteristics) and see themselves in relation to science; 2) to explore students' sense making about racial/ethnic underrepresentation in science, the racial narratives that emerge during these discussions, and how this shapes the possibilities youth of color view as available to them in science; and 3) to determine shifts in students' ideas about *who* can do science following program participation. I ask the following research questions:

- What are students' incoming ideas about *who* does and can do science (e.g. characteristics, race)? How do youth of color see themselves in relation to science?
- How do youth of color make sense of racial/ethnic underrepresentation in science? What is the role of racial narratives that emerge during these discussions?
- How do students' ideas of *who* can do science shift following program participation?

Next, I discuss the foundational scholarship in the areas of race, stereotypes and racial narratives, and science identity construction for racially/ethnically underrepresented youth that support this inquiry.

Theoretical Framework

Scholars examining racial/ethnic underrepresentation, learning, and identity construction in science provide important insights into the types of identities offered in science classrooms and across formal and informal contexts (Aschbacher, 2010; Brickhouse, 2001; Calabrese Barton, 2009; Polman & Miller, 2010; Tan & Calabrese Barton 2010). While research shows that racial positioning matters for women of colors' long-term science trajectories (Carlone & Johnson, 2007; Johnson et al, 2011, Malone & Barabino, 2008) and that disciplinary-specific stereotypes can limit the subject positions available to youth (Nasir & Shah, 2011), treatments of race in relation to science are limited (Parsons, 2014). Research is needed that directly addresses race when exploring identity construction for racially/ethnically underrepresented youth. In addition, research is needed that explores how youth of colors' science and racial identities develop *together* through participation in the practices of science. Encouraging this more holistic approach, researchers posit a theoretical framework that considers relationships between science learning and multiple aspects of identity construction (racial, disciplinary, academic) when examining learning and identity construction in science for youth of color (Varelas, Martin, Kane, 2012).

Building on ideas above, research involving racial narratives and stereotypes further underscores the need to re-center race in research exploring science identity construction for youth of color. Foundational research illustrates the ways racial constructions inform relationships between learning and identification processes and the identities made available and taken up by youth of color (Nasir 2012; Nasir & Hand, 2006; Nasir & Shah, 2011). Race is conceptualized as socially constructed, historically embedded categories of power and privilege (Omi & Winant, 1994). This research views the meaning of racial categories as determined by social, political and economic forces that create hierarchies with tangible outcomes for inequity and access (Omi & Winant, 1994). Foundational work on stereotype threat illustrates the pervasiveness of racialized stereotypes in our society and that these stereotypes have negative psychological consequences that impact performance in numerous domains (Steele, 1997; Steele & Aronson, 1995). This research suggests that racialized experiences and stereotypes matter for processes of learning and identity construction for youth of color and should be attended to when conducting research in this arena (Steele, 1997; Steele & Aronson, 1995).

Research provides empirical evidence that gender-based stereotypes and racial narratives effect disciplinary self-concepts and long-term trajectories in mathematics (Cvencek et al., 2011; Nasir & Shah, 2011). Research in developmental psychology illustrates how relationships between different aspects of identity (e.g. gender identity) and math-specific stereotypes operate at a cognitive level to impact self-concept and desire for future participation in math (Cvencek et al., 2011). For example, Cvencek et al. (2011) found that adult women who identify strongly as "female" are more likely to internalize math-gender stereotypes (i.e. women are bad at math). The cognitive discontinuity between identifying strongly as female, pursuing math, and the internalization of negative stereotypes about women in math leads to the development of negative attitudes and self-concepts in math and may impact future participation (Cvencek et al., 2011). Of particular significance is that researchers found that for children, boys have a higher math self-concept than girls and these gender differences in math self-concept *preceded* actual differences in math achievement. In other words, stereotypes function in relation to cognitive factors to shape one's trajectory in a discipline well *before* differences in academic performance exist (Cvencek et al., 2011). While this work does not address race-based stereotypes, it is plausible that similar relationships would apply in that context.

Research at the intersections of race and mathematics illuminates how discipline-specific racial narratives can shape the subject positions or possibilities that African American young men view as available to them in math. Researchers utilize the term, "racial narratives" to emphasize the lived and invoked nature of racialization in our society (Nasir & Shah, 2011). Research shows that the internalization of negative racial narratives about math competence may impact African American males' discipline-specific trajectories by limiting the *types* of subject positions available to them (Nasir & Shah, 2011). In addition, racial narratives often render some positions (i.e. as a capable doer of math) unavailable to African American young men (Nasir & Shah, 2011). Of particular significance is that youth are "hailed" into subject positions. In addition, racialized structural inequities limit access to particular options (i.e. capable math learner). Once hailed, students are forced to respond by taking up/confirming, or resisting the positions by modifying, repurposing or deploying counter narratives (Nasir & Shah, 2011). Findings emphasize the power dynamics associated with this type of positioning and identity work. In addition, it points to disparities in the distribution of *who* is required to do this work based on race.

I build on this work to explore relationships between students' conceptions of *who* does science (e.g. characteristics, race) and how they see themselves in relation to these conceptions (Figure 1, blue, A). Likewise, I explore how students make sense of racial/ethnic underrepresentation in science (i.e. racial disparities in *who* is a scientist) and the racial narratives that emerge during these discussions. I examine how racial narratives that emerge function for youth of color and impact how they see themselves in relation to science (Figure 1, blue, B). In addition, I examine how racial narratives link students' conceptions of science people (e.g. smart, white) to race and confirm racialized societal perceptions (e.g. *who* is smart) in ways that may limit the possibilities they view as available to them in science (Figure 1, blue, C). I explore the different types of relationships that emerge across the three programs, and illustrate how they function differently for different types of students (e.g. low vs. high perceived ability).

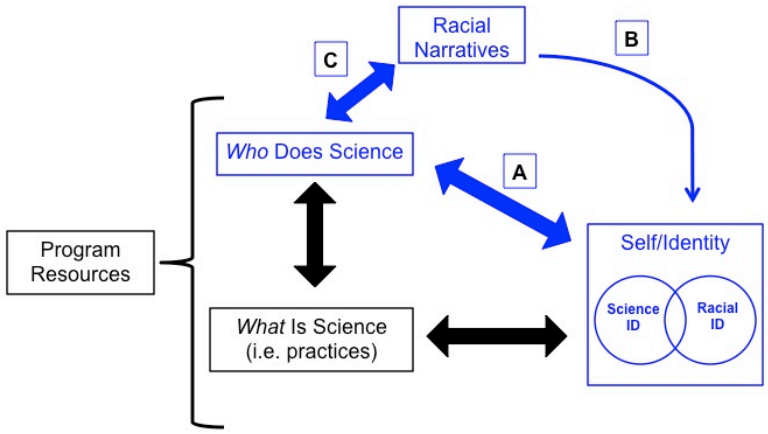

Figure 1. Relationships between students' conceptions of science people, how they see themselves in relation to science (A) and how racial narratives operate in conjunction with these conceptions (B, C). (Note: chapter focus = blue section of diagram).

In this chapter I make four main arguments: 1) Focal students' incoming conceptions of *who* does science serve a relational function, in that students view their conceptions of "science people" (i.e. characteristics, race) in relation to themselves (i.e. science *and* racial identity); 2) For focal students in this study, a relationship exists between how students characterize scientists, their sense making about racial disparities in *who* is a scientist, and how they see themselves as science learners (e.g. "good" or "bad" at science); 3) Racial narratives that emerged during focal students' sense making about racial disparities in *who* is a scientist served two overlapping functions: a) indirectly linked characteristics students associated with scientists to race, and/or b) confirmed youths' ideas about racialized societal perceptions (e.g. *who* is smart); 4) Post program shifts in *who* can do science are related to what students are able to *do* as scientists during the programs.

Findings suggest that resources are needed that help students move beyond resisting racial narratives in order to make *new possibilities and identities available* to them and to create shifts in their ideas about *who* can do science. In Chapter 5, I explore how engagement in science practices can help make new possibilities available for youth of color in science.

Overview of Methods

Data Sources

This study utilized two main data sources: 1) Pre and post student surveys, and 2) Pre and post program focal student interviews.

Pre & post program student surveys. 41 students total completed pre and post program surveys across the three summer science programs. The goal of pre and post program surveys was to establish a baseline (pre) and determine changes (post) in students' attitudes towards, ideas about, and perceptions of ability in science. Pre program surveys were administered on the first day of the program. Post program surveys were administered on the last day of the program. All surveys were administered and completed on paper copies during class time and turned in together.

Validated scales that measured students' interest, attitudes towards, and perceptions of ability in science were used to create Likert scale items. Validated scales measured: science identity (Girod, 2005), perceived ability: self-concept in science (Kind, Jones & Barmby, 2007), interest in science (Girod, 2005), relevance and utility of science/scientific research in life (Siegel & Ranney, 2003), and work of scientists (Aschbacher, Ellen & Roth, 2010). From these validated scales, 37 Likert scale items were constructed in check box format with choices that ranged from strongly agree to strongly disagree.

Post program surveys mirrored the pre program version and were designed to capture changes in students' attitudes towards, ideas about, and perceptions of ability in science following program participation. In addition, questions were added that asked students to describe changes in their ideas about who does science and the work of scientists. Pre program surveys in combination with pre program interviews (described below) created a baseline for students: 1) science identity and 2) perceived ability in science.

Pre & Post Program focal student interviews. 18 focal students total across programs completed pre and post program interviews. 7 students total completed follow-up interviews during the school year following program participation. Pre program interviews were conducted on the first day of the program with approximately six focal students per program (Bayside (n=6), Redwood (n=5), Bayside (n=7). Post program interviews took place on the last day of instruction with the same set of focal students. Interviews were conducted during program time but outside of the main program activity area. Follow-up interviews were conducted with as many focal students as possible (n=7) at the student's school site or a public location near their home (e.g. library).

Pre program interviews were designed to capture students' ideas about *who* does/can do science, how students saw themselves in relation to science and other aspects of their science and racial identities. *Identity* is defined as how youth of color perceive science and scientists, how they see themselves in relation to science/scientists, and how the interactions they have and believe they can have with science shape *who* they become in science.

Conceptions of who does & can do science. In order to gain an understanding of how students' characterizations of scientists, pre program interviews were designed to capture how students envisioned scientists. This included the skills, characteristics, gender and race that students associated with scientists. Post program interviews asked students to describe someone they had met during the summer that they considered a scientist and the skills and characteristics they associated with this person.

Science & racial identity. Pre program interviews were designed to explore aspects of students' science and racial identities and how they saw themselves in relation to their conceptions of scientists. Questions captured students' backgrounds and experiences with science, their conceptions of their abilities in science (e.g. tell me a time that you felt good at science), and their interests in science. To capture intersections of race and science and how students saw themselves in relation to science, questions captured disparities that students noticed in *who* is a scientists by race and gender and their sense making about racial/ethnic underrepresentation in science. During interviews, racial narratives commonly emerged during students' sense making about racial/ethnic underrepresentation in science. *Racial narratives* are defined as raced-based narratives that capture how racialized societal perceptions and stereotypes are invoked, kept alive, and used in everyday contexts (Nasir & Shah, 2011). As a result, questions were asked to probe about racial narratives that emerged. Post program interviews captured shifts in students' science and racial identities, how aspects of their identities developed together, and if and how their pursuit of science as youth of color was supported during the program.

Analysis

Survey analysis. Of the 52 students involved in this study, 41 students completed pre and post program surveys across programs. Students with missing data were excluded from pre to post program comparisons. The number of total students that completed pre and post program surveys differed by program: Redwood: 14/19, Bayside: 18/22, Westport: 9/11.

Attitudinal questions appeared as Likert scale items on pre and post program surveys. Likert scale items were scored from 1-5 with 5 representing the most positive response and 1 representing the most negative response. All items for a validated scale were considered a subcategory (e.g. science identity). To determine differences between students, data was averaged by subcategory for individual students and compared within and across programs. To determine differences between programs, student data was averaged by program and compared across programs. Plots were created to determine patterns between different groupings of students that included: 1) high vs. low perceived ability, 2) high vs. low science identity, and 3) male vs. female students. Findings were reported as within and between program differences.

All student pre and post program surveys included Likert scale items that measured perceived ability in science (e.g. I am good at science) (Likert scale). Preliminary analyses revealed that this measure was a salient aspect of students' identities in the science programs and is therefore described in greater detail. It is important to note that perceived ability in science scores were not designed to assess students' *actual* ability in science, but rather served as a measure for how students' viewed themselves as science learners (i.e. view themselves as "good" are "bad" at science). Students' scores were averaged for all perceived ability items, arranged from high to low scores and divided into quartiles across programs. Students in the top quartile were labeled "high perceived ability students" and students in the bottom quartile were labeled "low perceived ability students". To determine relationships between perceived ability in science and students' incoming ideas about *who* does/can do science, survey data was analyzed in conjunction with interview data for focal students who fell into the top (i.e. high) or bottom (i.e. low) quartiles.

Interview analysis. All student interviews were transcribed using InqScribe transcription software. Coding was done inductively and categories for the emergent ways students described their ideas about *who* can do science and aspects of their science and racial identities were constructed through an iterative process (Miles and Huberman 1994). Coding categories *emerged* from the data and were not pre-determined. Focal student interview transcripts were coded separately for students' conceptions of *who* does/can do science and intersections of students' science and racial identities but were also explored holistically. Previous research shows the importance of examining intersectional aspects of identity (e.g. race, gender) to capture the experiences and long-term trajectories of women of color in STEM (e.g. Carlone & Johnson, 2007, Malone & Barabino, 2008). Therefore, attention was directed to the ways that multiple dimensions of students' lived experiences played out to shape the ways they saw themselves in relation to science. Analyses for this chapter focused on the following aspects of focal student interviews:

Science & racial identity. To explore intersections of students' science and racial identities, transcripts were coded for the ways that students talked about science in relation to themselves. This research explores how students' science and racial identities develop together, and therefore, these components are explored holistically. Transcripts were read and coded for statements of science identity that included interests in science and participation in science activities in and outside of school. In addition, transcripts were also coded for statements of racial identity that included racial group affiliation and centrality of this affiliation to students, and intersections of students' science and racial identities.

Conceptions of who does & can do science. To capture students' ideas about *who* does and can do science and how they saw themselves in relation to scientists, transcripts were coded for different aspects of how students characterized scientists as well as their sense making about racial/ethnic underrepresentation in science. To determine they ways that students characterized scientists transcripts were coded for three main components: 1) characteristics, 2) race and 3) gender. In each case, categories of ideas were divided into subcategories. Students' ideas in each category were explored across and within programs to determine patterns and differences in the ways students' commonly described scientists. This data was then examined in conjunction with other aspects of students' science and racial identities to determine how they saw themselves in relation to scientists. In addition, interviews were analyzed in conjunction with survey data to determine patterns between different components (e.g. perceived ability in science).

Sense making about racial/ethnic underrepresentation in science. In order to further explore intersections of race and science, transcripts were coded to determine students' sense making about racial/ethnic underrepresentation in science. Initial analyses revealed that in many cases racial narratives emerged during students' reasoning. In these cases, racial narratives were further analyzed for *where* students located the "issue" of racial/ethnic underrepresentation in science (e.g. individual, racialized structures). From this process, two broad subcategories of location were determined: 1) individual, one's culture/race (i.e. individual choice, deficit-oriented views), 2) racialized structural inequities (i.e. racial discrimination, educational opportunities). Categories for racial narratives were then examined in conjunction with characteristics, gender and race above to determine *how* the narratives "functioned" for students. From the different types of identity statement described above, holistic portraits of focal students were constructed.

Contrasting Cases. This research utilizes contrasting cases of two students: one with a high perceived ability in science and one with a low perceived ability in science to provide an example of how conceptions of *who* does/can do science play out differently within these two groups of students. Serena has a low perceived ability in science, views herself as "bad" at science, and attends the Westport program. Carlos has a high perceived ability in science, sees himself as "good" at science and attends the Redwood program. Both students are rising 12^{th} graders and identify racially as Mexican. These representative cases illustrate how students' conceptions of scientists (e.g. characteristics, race) and how they see themselves in relation to science play out differently for different "types" of students.

Findings: Incoming Conceptions of *Who* Does Science

In order to gain an understanding of students' incoming ideas about *who* does and can do science, I examined students' conceptions of scientists in three main ways: 1) characteristics students associate with scientists or "science people", 2) the race and gender they associated with scientists, and 3) students' sense making about racial disparities in *who* is a scientist. The goal of establishing this understanding is to then examine how students see themselves in relation to these conceptions (see Figure 1, A). In the next section, I focus on the *characteristics* students associate with scientists.

Focal Students' Characterizations of Scientists

In this section, I explore the most common characteristics students' associated with scientists across programs. These characteristics serve as a baseline for one aspect of how students' conceptualize scientists. I then examine how students' see themselves in relation to these characterizations. During pre program interviews, the most common characteristics that focal students associated with scientists were those related to knowledge (i.e. "smart", "know material"), and those grouped as "stereotypical images" (e.g. goggles, lab coat) (see Figure 2).

When combined, describing scientists as "smart" and "knowing material" were the most common characteristics that focal students associated with scientists. Characteristics were categorized as "smart" when students specifically used this term to describe scientists, while the category "knowing material" grouped different expressions of knowledge together. This distinction is important because "smart" is often conceptualized as innate (Leonardo & Broderick, 2011) and fixed while gaining knowledge may be seen as malleable. Serena, the 12th grade Westport student from the opening excerpt provides an example of using both of these terms to describe scientists:

> I think of them like in labs, very smart people, in the labs, and tests, and stuff, and they know everything, and the, whatever the chart (periodic table).

Serena associates characteristics such as a high level of knowledge (i.e. "very smart", "know everything") with scientists. This was common across focal students who often described scientists as having more knowledge than the average person. In addition, students commonly described scientists in stereotypical ways, reflecting images that are ubiquitous in the media (i.e. glasses, lab coats) (see Figure 2). Melanie, a 10th grade student from Westport who identifies racially as Filipina provides an example:

> I think of them in white gowns with clipboards and really high tech equipment and computers, and like people with glasses on and goggles and stuff.

Melanie describes a stereotypical image both of what scientists look like (e.g. "goggles") and what they do (e.g. "use high tech equipment"). Finally, students often described scientists as people who are interested in science, and hard working (see Figure 2).

The range of characteristics described above portrays scientists in different ways. This may impact students' ideas about *who* they need to be in order to do science and how they see themselves in relation to science. As mentioned above, some of the characteristics are viewed as innate/fixed (e.g. smart) or unfamiliar and inaccessible (e.g. stereotypical images). These types of characteristics may provide students with a narrow image of *who* does science and therefore who they need to be in order to do science. In addition, these characteristics, when considered fixed and innate, may seem unattainable for some students. In contrast, some characteristics can be considered more accessible (e.g. curious) and attainable (e.g. hard working). For example, arguably anyone can be hard working if they put in the effort. These types of characteristics may broaden students' ideas of *who* can do science. These characteristics may seem more attainable for students. This has implications for how students see themselves in relation to science, discussed in detail below.

It is important to note that students have complex repertories and often described multiple characteristics that were assigned to different categories. However, interesting patterns emerged between the most common characteristics that students used to describe scientists (i.e. “smart”, “knowing material”) and other characteristics. In the next section, I explore relationships between these characteristics in order to illustrate students’ complex repertoires and how characteristics operate together to shape students’ views of scientists.

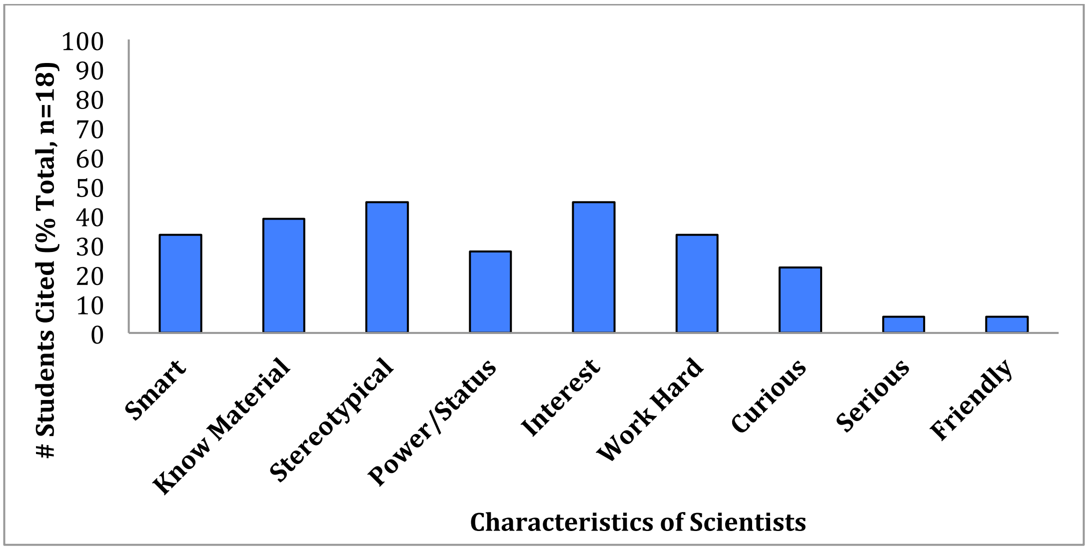

Figure 2. Pre program characteristics that focal students associated with scientists *across* programs.

Scientists as smart & stereotypical images. In this section, I explore how the knowledge students attributed to scientists (i.e. “smart”, “knowing material”) worked in concert with other common characteristics students associated with scientists to shape their conceptions of science people. Almost all of the students who described scientists specifically as “smart” also described them in stereotypical ways making this the most common combination of characteristics. Fernando, a 12th grade student from Westport who identifies racially as Latino provides an example: “I think of scientists as hella smart in a lab… white lab coats, glasses…mixing chemicals”. Fernando describes the knowledge he associates with scientists (i.e. “hella smart”) as well as stereotypical images of what they look like (e.g. “glasses”) and what they do (i.e. “mix chemicals). This illustrates how students commonly made links between the “smartness” of scientists and stereotypical images. Both of these characteristics may make scientists seem inaccessible and unattainable and together impact how students see themselves in relation to science.

Scientists as smart and powerful. Some focal students described scientists as high status and powerful. These ideas were categorized as “power”. These students often described a power differential between scientists and the average person in society and/or themselves. Interestingly, this differential was often based on the knowledge or “smartness” of scientists. In this way, students made links between power and knowledge. Melanie, the 10th grade student from above provides an example. During a pre program interview we discussed her ideas about how science knowledge is constructed and what information is written in science textbooks. When I asked her how they decide what to write in textbooks she responded:

> M: I feel like sometimes maybe they can just do it because they have the power to.
> Interviewer: Who?
> M: The scientists.
> Interviewer: And what do you think gives them power?
> M: That they're like labeled *scientist* and it makes them smarter then everyone because they're scientists.

Here, Melanie views scientists as having the power to write what they want in science textbooks (i.e. "do it") because of their "label" as scientists. Melanie describes the power she associates with scientists and how this power is linked to knowledge (i.e. smart). During our discussion, Melanie also describes scientists as "high" status. Together these statements suggest that she views a power differential between scientists and other people in society.

Gabriella, a 10th grade student from Bayside who identifies as Chicana makes a similar association between being smart and the positioning she associates with scientists. When I asked her to describe how she views scientists she says: "They already know their stuff. They don't need to go up to someone that's like above them, because they're already the ones that are like smart." Here, Gabriella suggests that because scientists "know their stuff" and are "smart" they are in a high status position and don't need to answer to someone above them. In these examples, Melanie and Gabriella link the knowledge/smartness of scientists to having power or being high status. In this way, some students conceptualize scientists in the following way: scientists = smart → powerful. These findings highlight the importance of understanding students' ideas about how scientists are positioned in society relative to how they might see their own positioning.

Knowing materials & hard working. Many students who described scientists as "knowing material" (discussed above) also characterized scientists as hard working, dedicated and persistent (see Figure 2). Nathan an 11th grade African American student from Westport provides an example. He states that doing science requires hard work: "Definitely a lot of hard work and a lot of like thinking over years, and years." Here, Nathan suggests he thinks of scientists as both knowledgeable and hard working, or perhaps hard working in order to become knowledgeable. This perspective suggests that if you work hard you can become knowledgeable – which may seem more attainable for some students. Again, this has implications for how students see themselves in relation to science.

In summary, being "smart" and knowledgeable are common characteristics that focal students associated with scientists. Students often make links between the knowledge of scientists and other characteristics such as stereotypical images and power. In the "identity implications" section below, I discuss how the salience of these characteristics impacts different types of science learners. Next, I examine differences in how students characterized scientists across programs.

Characteristics of scientists: Significant differences by program. Findings show that there were significant differences in how students characterized scientists across programs. Westport students, more commonly characterized scientists in stereotypical ways, viewed scientists as "smart" (e.g. Serena, Fernando), and described scientists as powerful due to their knowledge (e.g. Melanie). In this way, Westport students comprised the majority of students who described scientists as: smart/stereotypical, and smart/powerful. As described above, these characteristics may limit students' ideas about *who* can do science. In contrast, while half of Bayside students mentioned the knowledge they associate with scientists (e.g. know material) only one student from this program described scientists specifically as "smart" (i.e. see Gabriella above). No students from Redwood described scientists as either "smart" or "knowing material" (see Figure 3). Redwood students commonly characterized scientists as "curious", "creative" and "hard working". As described above, these characteristics may seem more attainable and broaden students' ideas about *who* can do science. Finally, almost half of the focal students from Westport and two students from Bayside described scientists as powerful or high status in ways that linked knowledge (or smartness) to this power/status. However, no students from Redwood characterized scientists in this way. These program differences suggest Westport students may experience science and view scientists in more inaccessible and unattainable ways than students from other programs.

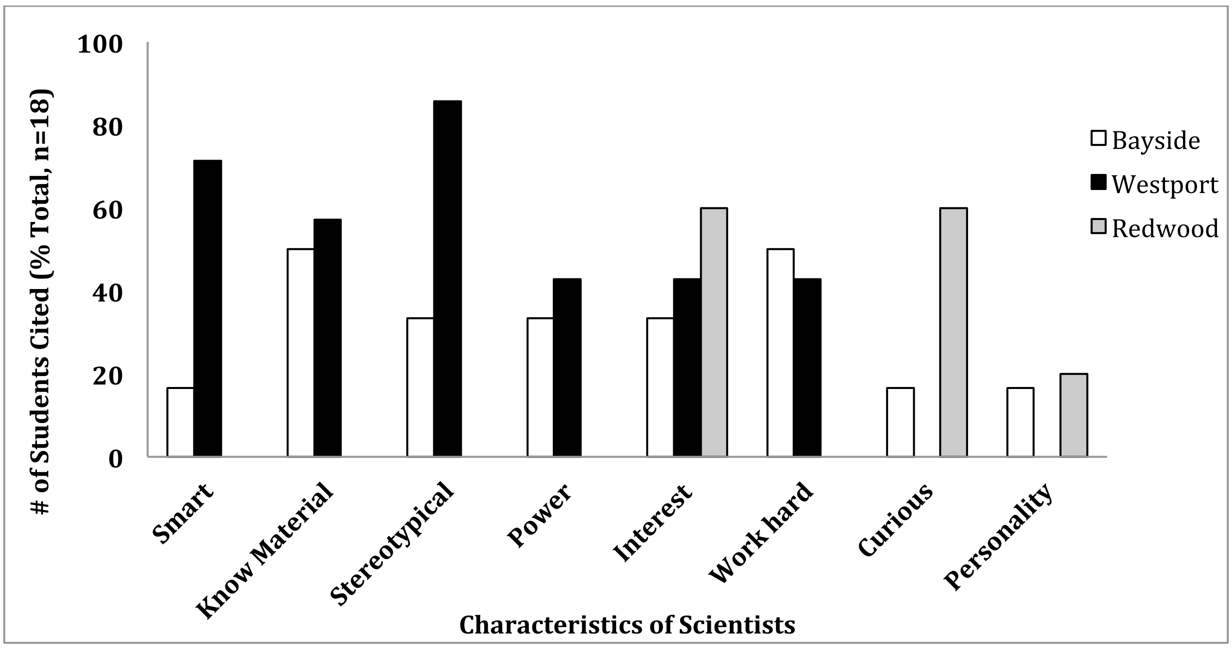

Figure 3. Pre program differences in characteristics focal students associated with scientists by program.

Why does this matter for how students see themselves in relation to science and the possibilities students' view as available to them? What are the identity implications of this work? In many ways, the most common characteristics that focal students associated with scientists are not new. While research with high school aged youth is limited, findings align with research involving children's conceptions of scientists (e.g. Tucker-Raymond, Varelas, Pappas, 2007). What has not been explored is how these conceptions of "science people" function relationally for students and impacts the ways they see themselves in relation to science. How do students' characterizations of scientists compare to how they describe themselves in relation to science? How does this inform the options they view as available to them in science?

As one aspect of identity, during analyses, perceived ability in science emerged as a salient aspect of focal students' identities in the science programs. Therefore, in the next section, I pay particular attention to the relationship between students' perceived ability in science and the characteristics they associate with scientists and how these dimensions inform each other. I discuss identity implications and how these relationships may impact the options students view as available to them in science. To do this, I use the contrasting cases of Serena, who views herself as "bad" at science and Carlos, who sees himself as "good" at science to show how these dynamic relationships play out for different "types" of students.

Identity implications: Characteristics of scientists & perceived ability. In this section, I explore relationships between students' incoming perceived ability in science (i.e. feeling "good" at science (or "bad" at science) and the characteristics that they associated with scientists. Findings suggest that for focal students in this study, a relationship exists between the characteristics students associate with scientists and how they view themselves as science learners. Interestingly, the characteristics students' associated with scientists aligned with or contrasted to how they saw themselves as science learners. Low perceived ability students (i.e. students who feel "bad" at science) more commonly described scientists as smart in in stereotypical ways compared to high perceived ability students (see Figure 4). In this way, the knowledge and "smartness" that low perceived ability students associated with scientists directly contrasted with how they viewed themselves as science learners. In contrast, high perceived ability students (i.e. view themselves as "good" at science) commonly described scientists as curious and hard working and were able to identify similar characteristics in themselves (see Figure 4). Though sample sizes are small (high: n=5; low: n=7), this finding is important because it suggests that a relationship exists between how the focal students in this study characterize science people and how they see themselves as science learners in ways that may impact their ideas about *who* they need to be in order to do science. As described above, characteristics such as "smart" and stereotypical images (e.g. goggles, lab coats) may be viewed as innate or make science seem inaccessible and limit the options that low perceived ability students' view as available to them in science. In contrast, characteristics such as "curious" may make science seem more attainable and broaden high perceived ability student's ideas about *who* can do science.

Interestingly, both high and low perceived ability students described scientists as "knowing material" at almost equal rates. The focus on the "smartness" of scientists by low perceived ability students, but an equal focus on knowing material by high and low students suggests that there may be distinctions in the meaning students associate with being "smart" and "knowing material". As described above, being smart has an innate and fixed connotation while knowing material may be viewed as malleable and therefore attainable. Findings show how students' characterizations of scientists and how they see themselves as science learners (i.e. aspect of identity) inter-relate in dynamic ways. In addition, findings suggest that low perceived ability students view scientists in ways that may seem unattainable them. This potentially limits the possibilities they view as available to them in science.

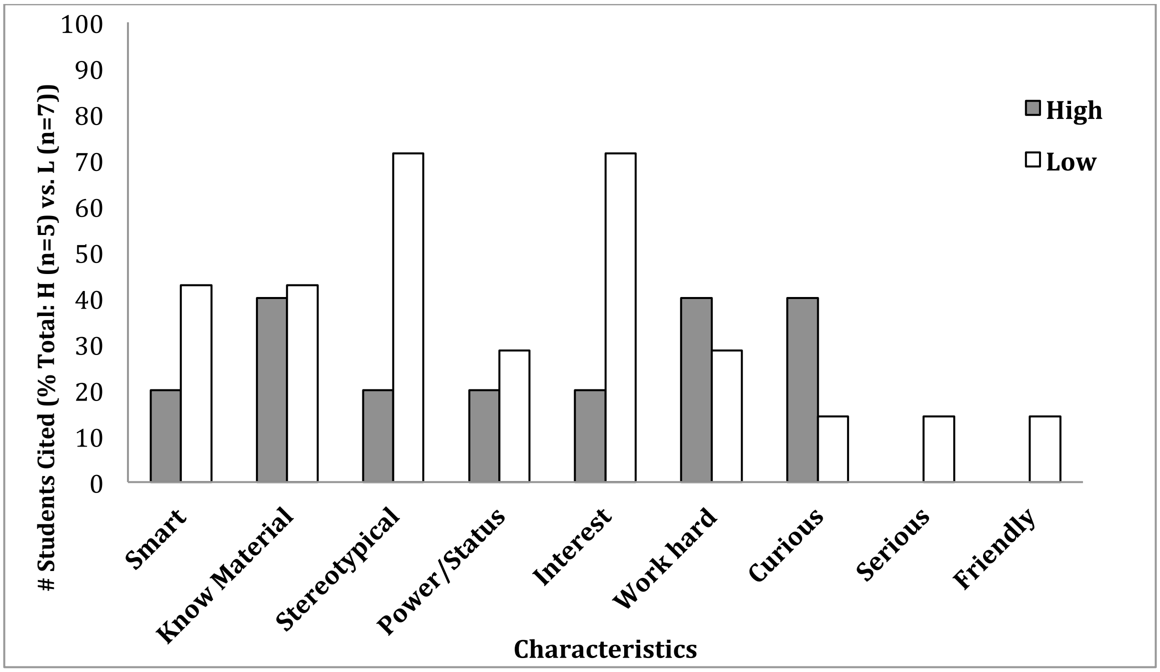

Figure 4. Pre program characteristics high vs. low perceived ability focal students' associated with scientists.

Program differences: Characteristics of scientists & perceived ability. As described above, there were significant between program differences in the common characteristics that students associated with scientists (see Figure 3). Interestingly, these program differences reflect the relationship between perceived ability and the characteristics associated with scientists as described above. Westport students entered the program with the lowest average perceived ability in science scores across programs (i.e. all students from Westport fell into the bottom 50% of perceived ability in science scores across programs). As described above Westport students more commonly characterized scientists in stereotypical ways, and viewed scientists as "smart" and powerful due to their knowledge compared to students from other programs. In contrast, Bayside and Redwood students entered the program with similarly high average perceived ability in science scores. Students from these programs focused less on the knowledge of scientists and only one student from Bayside described scientists specifically as "smart". Redwood students, who entered the program with the highest average perceived ability in science scores, commonly characterized scientists as "curious/creative" and "hard working". Overall, between program differences in the characteristics students' associated with scientists can be explained by differences in average perceived ability in science scores by program.

It should be noted that these relationships are complex and there are exceptions. For example, describing stereotypical images of scientists was common for Westport students regardless of incoming perceived ability in science. Melanie from Westport provides an example. She enters the program with higher perceived ability in science scores than the majority of Westport students, yet, she also describes scientists in stereotypical ways. This suggests that students' across the range of incoming perceived ability in science from Westport may have conceptualized scientists in ways that were unfamiliar or different than how they viewed themselves. Next, I illustrate these differences using contrasting cases of different types of students.

Contrasting Case: Belonging vs. not belonging in science. I utilize contrasting cases of a student who feels "good" at science (i.e. Carlos, Redwood) and a student who views herself as "bad" at science (i.e. Serena, Westport) to illustrate the dynamic relationships between the characteristics students associate with scientists and how they see themselves as science learners (see Table 1, left columns). Serena and Carlos are both rising 12th grade students and identify racially as Mexican. Serena is representative of students who entered their science program with a low perceived ability in science. Like other low perceived ability students, Serena views herself as "bad" at science and describes experiencing little success in science. Carlos is representative of students who entered their program with a high perceived ability in science. Like other high perceived ability students, Carlos is confident in his science abilities, sees himself as "good" at science, and experiences success in science in school. In the next section, I examine how Serena and Carlos describe themselves in relation to science and compare this to the characteristics they associate with scientists (see Table 1, characteristics columns). These comparisons reveal how low perceived ability students often see themselves in opposition to scientists (e.g. scientists = smart; I am bad at science) while high perceived ability students are able to identify characteristics similar to those they associate with scientists in themselves.

Table 1. Comparison of self to characteristics, race, and gender of scientists by perceived ability in science. (Note: Similarities or differences between self and scientist in *italics*)

Student	**Perceived Ability**	**Characteristics**		**Race & Gender**		**Identity Outcome**
		Self	**Scientists**	**Self**	**Scientist**	
Serena	Low	• *"Bad" at science* • *Slow processor* • Desire to "get" it	• *Very Smart* • *Know material* • Stereotypical images • Enjoy it	• *Mexican* • *Girl*	• *White* • *Men*	• Uncertain; Does not want to pursue science
Carlos	High	• "Good" at science • *Inquisitive* • *Desire to learn* • Persistent	• Creative • *Inquisitive* • *Desire to learn*	• *Mexican* • Boy	• *Not Mexican* • No specific gender	• Motivated by lack of racial representation in science

Low perceived ability: Scientists as "very smart people". Serena, from the opening excerpt, is a rising 12th grade student from Westport who identifies racially as Mexican. She is representative of low perceived ability students. Serena joined the summer science program because she "needed to redo science" and expresses experiencing very little success in science class in school. As described above, when I asked her how she envisioned scientists she says she think of them as "very smart people in labs" who "knowing everything". In addition, she describes scientists as people in "white jackets". As was common with low perceived ability students, Serena associates characteristics such as a high level of knowledge and stereotypical images with scientists. Both of these types of characteristics are often viewed as innate (i.e. "smart) or unfamiliar (i.e. white jackets) and may make science seem inaccessible.

This contrasts to how Serena views her own capabilities in science. Serena has one of the lowest incoming perceived ability in science scores of students across all programs. She describes how she sees herself in relation to science: "I'm not really that good at science...science is not really my strong subject in school. Like, it's bad. I never really got it." Serena's description of herself in relation to science contrasts to her characterization of scientists as "very smart people" who "know everything" (see Table 1). In this way, Serena, provides an example of how students see themselves in relation to scientists.

Broadening our scope, we see that Serena's ideas of her abilities in science are embedded in a broader constellation of how she sees herself academically. During pre program interviews she expresses struggling in school and receiving messages about her abilities to succeed academically:

> I didn't want to be in school anymore I wanted to drop out and stuff. I wasn't that bright. So uh, people would just say she's going to mess up. People just doubted me, I guess. And nobody in my family has ever been to college, so I guess I would be the first one.

Here, Serena describes being positioned as not "bright" based on the messages she receives from "people who doubted" her and her struggles to succeed academically. Her statement suggests that this, in combination with her positioning as a first generation college-bound student may create unique challenges for her. Taken together, Serena doesn't see herself as "good" at science or in school. The way she views herself is validated by people who "doubt her" and contrasts to how she characterizes scientists. Serena expresses a desire to be "good" at science:

> I really want to learn more and get it. Like how I am in my other classes. Like math, once the teacher tells me, I get it, I do it all, and I get it done fast. That's how I want to be in science too….But just for me, it takes time. You tell me once, its like, no. I process things slow.

Here, Serena expresses a desire to learn and makes an interesting connection between what it means to be good at math (i.e. "get it done fast") and how she sees herself in general as a learner (i.e. "processes things slow"). In her statement above, she equates doing things "fast" with being good at a subject. In this way, she illustrates how her desire to be good at science is linked to her perceptions of what it means to be "good" at a subject. In addition, she expresses how her belief about her abilities (i.e. process things slow) factors into her ideas about whether or not she can gain the knowledge necessary to be good at science based on this perception.

In summary, the characteristics that Serena associates with scientists directly contrast to the characteristics she associates with herself in relation to science (see Table 1). This view of scientists (e.g. as smart, stereotypical images) connect to her perception of what it means to be good at science and may limit the possibilities she can imagine for herself in science.

High perceived ability: Scientists as "inquisitive" like me. Carlos, a 12th grade student from Redwood who identifies racially as Mexican is representative of high perceived ability students. This expands the possibilities that he can imagine for himself in science. Carlos, enters the program with very high identity and perceived ability scores in science placing him in the top quartile across programs. Carlos joins the Redwood science program because as he states: "I'm really interested in science and the environmental aspect of science". He wants to pursue environmental science in college and thinks that the summer program will be a good way to "get exposed" to this aspect of science. He describes science as a "top interest" in school and throughout the interview expresses a strong desire to pursue science in college.

When asked to share a time he felt "good" at science he describes his experiences in both his Biology and Chemistry classes at school: "I felt confident in class, like I understood everything and I also enjoyed it. It was challenging but enjoyable." Here, Carlos expresses "confidence" and "understanding" all of the material as well as being "challenged" but "enjoying" this challenge. He builds on this to express that he felt confident in class because he "understood everything". He can't think of a time that science has been difficult for him.

When I asked Carlos to describe the characteristics he associates with scientists he states: "They're um, creative and inquisitive, so they like want to learn more and study, research." Here, Carlos describes scientist in ways that may seem more accessible or attainable (i.e. arguably anyone can be inquisitive). His characterization of scientists is typical of high perceived ability students who commonly described scientists as curious and hard working compared to low perceived ability students who characterized scientists as smart and knowing material (see Figure 4). Later, when asked to describe how he sees himself in relation to science he says: "Inquisitive, like I just want to learn different things, that's why I'm here. I want to learn more, get experience." In this way, Carlos describes characteristics of a scientist that align with how he sees himself in relation to science (see Table 1). Some of the characteristics Carlos uses to describe himself in science are the same characteristics he associates with scientists (i.e. inquisitive).

Carlos is able to identify aspects of himself that are aligned with his characterizations of scientists (e.g. inquisitive). In addition, Carlos describes himself as "hard working". This aligns with how high perceived ability students described scientists. When I ask him to expand on this he says: "I accomplish what I want to do, not like, just let it go by, I just work on it, keep working on it, even if I make mistakes or fail I try again." Here, Carlos describes a particular confidence in his abilities to succeed if he puts in the effort. This may make it more likely for students like Carlos to view pursuing science as a possibility.

The examples of Serena and Carlos illustrate the relationship between how students characterize scientists and how they see themselves as science learners. In addition, the contrasting case of Serena and Carlos provides an example of how these relationships play out for students in different groups (e.g. high vs. low perceived ability). Students like Serena, who do not see themselves good at science commonly focus on the knowledge and smartness of scientists in ways that contrast to how they see themselves as science learners. Students like Carlos, who view themselves as good at science are able to identify similar characteristics that they associate with scientists in themselves (see Table 1).

Summary: Characteristics of scientists. Findings show that students' incoming conceptions of *who* does science serve a relational function, in that students view the characteristics they associate with "science people" in relation to themselves. For the focal students in this study, perceived ability in science (i.e. seeing oneself as "good" or "bad" at science) was a salient aspect of their identities in the science programs. Findings show that a relationship exists between the characteristics students associated with scientists and how they see themselves as science learners. Students with low perceived ability more commonly described scientists as "smart" and in ways that contrasted to their own perceived ability in science compared to high perceived ability students. In addition, low perceived ability students more commonly described scientists in stereotypical ways. There were considerable differences among programs that aligned with the findings above. Students from Westport, who on average entered the program with a lower perceived ability in science than students from Bayside and Redwood described scientists in stereotypical ways and as "smart" and knowledge more commonly than students from other programs.

The examples of Serena and Carlos show that when focal students talked about themselves in relation to science, they did so in ways that reflect or contrast with how they imagine scientists. In addition, the contrasting case illustrates how ability is built into students' understandings of *who* scientists are and what it means to be "good" at science. In this way, students' characterizations of scientists and their perceptions of their abilities as science learners are intimately linked. These examples underscore the importance of examining the messages youth of color receive about *who* can do science based on their experiences. In addition, findings suggest that broadening students' ideas about *what* science is and what it means to be good at science may expand the possibilities they imagine for themselves in science. In the next section, I build on the characterizations of scientists above to examine the race and gender that focal students associate with scientists and how this intersects with the ways they see themselves in relation to science.

Race & Gender of Scientists

To construct a broader understanding of focal students' conceptions of scientists, in this section, I explore the *race* and *gender* that students associate with scientists. I explore how experiencing a lack of racial representation in science intersects with students' science and racial identities and revisit the cases of Serena and Carlos to illustrate these intersections. Referring back to the model, this builds on our understanding of students' ideas about *who* does science and how they see themselves in relation to science (Figure 1, A).

Scientists as "not my race". Findings show that students commonly experienced a lack of racial representation in science. During pre program interviews, I asked students to describe the race and gender they associated with scientists. Students described scientists in three main ways: 1) "not my race", 2) white, and 3) Asian (see Figure 5). Across programs, focal students most commonly described scientists as people who were not from their racial background (e.g. not Latino). These ideas were categorized as "not my race". In some cases, students described scientists as people from a specific racial group (e.g. white) and these racial groups were categorized individually (see Figure 5). In contrast, the majority of students didn't associate any specific gender with scientists. However, some students described scientists more commonly as men, and some as white men in particular (see Serena, opening excerpt). There were no major differences for the race or gender students associated with scientists across programs.

Why does this matter for relational work of examining how youth of color view scientists in relation to themselves? As described above for students' characterizations of scientists, in many ways these findings are not new. However, what is not explored is how experiencing a lack of racial representation shapes the ways youth of color see themselves in relation to science. In the next section, I examine relationships between viewing scientists as "not my race", the characteristics students associated with scientists and their perceived ability in science.

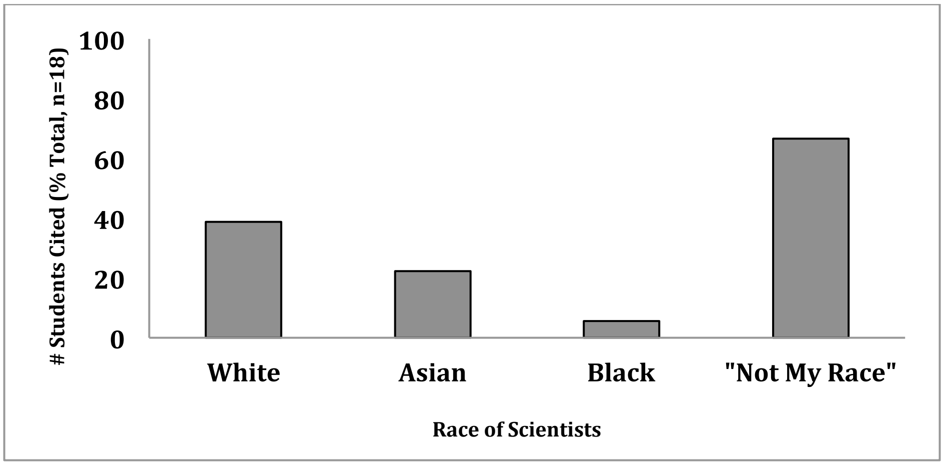

Figure 5. Focal students' pre program ideas about the race of scientists across programs.

Identity implications: Lack of racial representation, characteristics & perceived ability. In this section, I examine how experiencing a lack of racial representation in science works in concert with the characteristics students associate with scientists and their perceived ability in science to further enhance feelings of belonging or not belonging in science. Findings show that students' experienced a lack of racial representation in science regardless of their incoming perceived ability in science. That is, students across the range from high to low perceived ability described this awareness. However, findings suggest that there may be a cumulative relationship between experiencing a lack of racial representation, the characteristics students associated with scientists, and how they see themselves as science learners. I revisit the cases of Serena and Carlos to illustrate how experiencing a lack of racial representation in science can operate collectively with characterizations of scientists to impact high and low perceived ability students differently to further shape how they see themselves in relation to science (see Table 1, right columns).

Low perceived ability: Further distanced from scientists. Recall from above the Serena enters the program seeing herself as "bad" at science, "not bright" and generally unsuccessful academically. Racially, Serena identifies as Mexican and describes this as a central aspect of her identity: "yeah it is a big part of me, that's part of who I am." She describes her culture as shaping her family's "perspective and how they do things", something she deeply respects. When asked to describe the race and gender she associates with scientists she said: "white and guys more than girls" (see Table 1). She expands on this to say that this view of scientists is partially informed by the science teachers she's had in school who have all been white men.

When combined with the characteristics she associates with scientists above, experiencing a lack of racial representation in science further distances Serena from how she conceptualizes scientists. She views scientists as: "very smart", white, and male. In contrast, she sees herself as: "not bright", Mexican, and a girl. In many ways, she sees scientists in opposition to how she views herself (e.g. gender, race, characteristics) (see Table 1). She views herself as motivated to learn science but also as a "slow processor". When asked if she could see herself doing science in the future she says: "I don't think I would want to be. It's interesting to me, well maybe, later on, who knows… I don't think I would want to do that all the time". Here, Serena expresses reservations about becoming a scientist because she doesn't think she'd want to do what they do all the time. It is plausible that *who* she sees doing science (i.e. smart, white, men) may add to the ways she doesn't see herself belonging in science and limit the options she views as available to her.

High perceived ability: Lack of representation as a motivator. Recall from above that Carlos enters the program very confident in his abilities in science and aspiring to pursue science in college. Like Serena, Carlos identifies racially as Mexican. When I ask him if being Mexican is a big part of how he identifies himself he states: "Yeah! Because I want to be a scientist and there's not a lot of Mexican scientists." Here, Carlos describes a significant overlap between his science and racial identities. Carlos is enthusiastic about pursuing science in general but here expresses a desire to pursue science specifically because he does not see himself racially represented in science. Carlos views scientists as "not Mexican" (i.e. "not my race"), yet describes this as further motivation to pursue science.

As described above, Carlos expresses a strong interest in science and desire to pursue science in the future. He associates certain characteristics with scientists that he is able to identify in himself (e.g. inquisitive) (see Table 1). This may broaden the possibilities Carlos views as available to him in science. Though he does not see himself racially represented as a scientist he takes this as a challenge. Because he views himself as good at science he may experience greater agency to reposition himself and feel more equipped to take on this challenge. The enthusiasm he expresses suggests that a lack of racial representation further motivates his desire to pursue science.

Summary: Lack of racial representation. Findings show that across programs, students overwhelmingly express awareness of a lack of racial representation in science. This was common across the range of perceived ability in science. However, findings suggest that there may be a cumulative relationship between experiencing a lack of racial representation, the characteristics students associated with scientists, and how they see themselves as science learners. The contrasting cases of Serena and Carlos show how this awareness plays out differently for high and low perceived ability students. For students like Serena that don't see themselves as good at science, and can't identify characteristics that they associate with scientists in themselves, the lack of representation may add to the ways they see themselves as not belonging in science. For Carlos, a lack of Mexican scientists provides an additional motivator for pursuing science. High perceived ability students, like Carlos, who view themselves as a capable science learners may be able to identify other ways that they *do* belong in science (e.g. similar characteristics). In this way, high perceived ability students may experience greater agency to reposition themselves and to view science as a possibility despite not seeing people who look like them doing science. The cases illustrate the dynamic ways that different aspects of focal students racial and science identities inter-relate to shape the possibilities they feel as available to them in science.

To further explore how focal students see themselves in relation to science, in the next section, I examine students' *sense making about racial disparities* in *who* is a scientists. I examine how students' sense making about racial/ethnic underrepresentation in science shapes and is shaped by their perceptions of themselves as science learners. In addition, I examine racial narratives that emerged during students sense making and how they impact the ways students see themselves in relation to science.

Sense Making: Racial Disparities in *Who* is a Scientist

To further explore the complexity of intersections between students' science and racial identities, in this section I examines students' sense making about racial/ethnic underrepresentation in science and the role of racial narratives that emerged during these discussions. As described above, the majority of students express an awareness of a lack of racial representation in science. During pre program interviews, I asked students to describe how they made sense of the racial disparities they noticed in *who* is a scientist. Across programs, students' sense making about racial/ethnic underrepresentation was categorized in four main ways: individual choice, deficit-oriented views, racial discrimination and educational opportunities. In addition, some students described "immigration issues" and "science not made relevant" as reasons for racial disparities, but at much lower rates (see Table 2 for categories and descriptions). Interestingly, the categories that emerged differ by *where* the "issue" of racial/ethnic underrepresentation is located. For example, ideas that were categorized as "individual choice" and "deficit-oriented " views (Table 2, gray shading) suggest that the problem lies within the *individual/self* or one's *race/culture* respectively. In contrast, ideas that were categorized as "racial discrimination", "educational opportunities", and "immigration issues" locate the issue in *structural inequities*, social/racial hierarchies and suggest there are larger structural and societal barriers in place determining *who* becomes a scientist. These represent ideas to build on throughout the programs. Finally, ideas in the "science not relevant" category present a critical perspective of science and suggest that if science was taught in ways that was more relevant to people of color they might be more interested in pursuing science.

Table 2. Students' Sense Making About Racial/Ethnic Underrepresentation in Science by Program (Note: major program differences in bold).

Sense Making: Racial Disparities	**Definition**	**Bayside** (n=6)	**Redwood** (n=5)	**Westport** (n=7)
Individual Choice/ Motivation	Individuals can choose to pursue science or not; personal motivation determines if pursue science	3	2	1
Deficit	See racial group as inhibiting, deterrent from becoming a scientist	2	2	**5**
Racial Discrimination	Positioning of racial groups/racial hierarchies in society determine *who* becomes a scientist	**4**	1	2
Education/Opportunities (*race-based*)	Race-based disparities in access to education/resources creates barriers to pursuing science	**4**	**5**	
Immigration Issues	Issues with citizenship create barriers to pursuing science	2	1	
Science Not Relevant	Science not taught in a way that is relevant to people of colors' lives			2

In the next section, I explore how students' reasoning about racial/ethnic underrepresentation and *where* they locate the "issue" is impacted by how they see themselves as science learners.

Identity implications: Perceived ability & racial disparities in *who* is a scientist. Similar to characteristics discussed above, findings show that a relationship exists between students' sense making about racial/ethnic underrepresentation in science and their perceived ability in science. Specifically, findings show that how students see themselves as science learners impacts *where* they locate the "issue" of racial/ethnic underrepresentation. High perceived ability students more commonly located the issue in racialized structural inequities (e.g. educational opportunities) and therefore made sense of racial disparities in more critical ways than low perceived ability students (see Figure 6). In contrast, low perceived ability students more commonly located the issue in their race/culture and therefore internalized deficit-oriented reasoning about racial/ethnic underrepresentation in science compared to high perceived ability students (see Figure 6). Fernando, a 12th grade student from Westport who identifies as Latino provides an example of the sense making of low perceived ability students. During pre program interviews, Fernando is unable to think of anything he likes about science. He expresses experiencing little success in science class and in school. This is reflected in his low grade point average (self reported: 1.6). When I ask him about his experiences in science class he says: "I get distracted a lot. And then I get frustrated if I don't answer it right.…dumb decisions." As described above, Fernando views scientists as "hella smart in a lab mixing chemicals" (see characteristics). He also describes scientists as "hard working". In this way, he views himself (i.e. "distracted", "bad" at science) in opposition to scientists (i.e. "hard working", "hella smart"). The stereotypical ways he views scientists as "in labs mixing chemicals" may further distance him from how he conceptualizes scientists. Fernando says he doesn't notice Latino scientists or know any scientists in general: "I don't really know scientists. I don't even know one scientist's name." When I ask him why he might not notice many Latino scientists he reasons:

> What I say is just, colored people, put it that way, they slack off a lot, don't try to pay attention, like, 'whatever I don't really care this and that'. But, I guess you could say in reality, we do care, cause they try to complain about it…well, do something to change that, stop troubling about it.

Here, Fernando asserts a racial narrative – that people of color "slack off" and therefore are not represented as scientists. In addition, he expresses a tension "in reality we do care". Fernando describes himself as "distracted" and not applying himself in science class in school. In this way, Fernando takes up or internalizes this racial narrative of "slacking off" and a racialized societal frame (i.e. "cultural racism", Bonilla-Silva, 2006). Because Fernando has a low perceived ability in science and does not see himself belonging in science he may not be positioned to resist the identities he is "hailed" into and that are placed upon him by society (Nasir & Shah, 2011). This is supported by the tension he expresses – that in reality he (and other people of color) really does care – suggesting he may not have the resources to push back against this racial narrative. The racial narratives such as this that emerged during students sense making and the role of these narratives are discussed in greater detail in the next section.

In contrast, high perceived ability students more commonly located the issue of racial/ethnic underrepresentation in the individual ("individual choice") and in racialized societal inequities ("racial discrimination", "educational opportunities"). The biggest difference between high and low perceived students occurred in the "individual choice" category. High perceived ability students described the pursuit of science as an "individual choice" at much higher rates than low perceived ability students (see Figure 6). This may be because high perceived ability students experience success in science and as a result perceive that they have greater agency to make a "choice" to pursue science or not. Ronald, a 10th grade Bayside student who identifies racially as Black provides an example of high perceived ability students. When asked to describe a time he felt good at science he states:

> On like a regular basis I'm usually really good at science, but the time that I felt like I was jus like crazy the *best* was when I was at the end of 8th grade when I got my CST scores back….I was in the top for almost my whole school.

Here, Ronald describes feeling very confident in his science abilities and suggests that he often experiences success in science class. In addition, he describes science as something he could pursue if he decides to do so. Ronald notices a lack of people of color in science. When I ask him what might help to increase racial diversity in science he says: "Between the different races…it all comes down to the individual like, if they're more motivated to do it, their number can rise as well." Here, Ronald makes a connection between personal "motivation" and increasing racial representation in science. In this way, he locates the "issue" in the individual who has a choice to be "motivated" or not. Like other high perceived ability students, because Ronald sees himself as good at science, he may experience more agency to make this "choice" despite experiencing a lack of racial representation in science. Taking up this type of framing is described as "abstract liberalism" or viewing racialized societal framing of opportunity as a choice (Bonilla-Silva, 2006). Ronald may also take up this type of framing as a way of pushing back/resisting the societal positioning he has been hailed into (Nasir & Shah, 2011).

In addition, high perceived ability students were more likely to locate the "issue" of racial/ethnic underrepresentation in racialized societal structures compared to low perceived ability students. In this way, students who have more agency to push back and resist show greater awareness of the structural inequities at play. In contrast, low perceived ability students who have the least ability to resist and reposition themselves show greater internalization of deficit-oriented views. Enhancing students' sense making about racialized structural inequities and increasing the visibility of these structures represent ideas to build on throughout the programs. In this next section I examine how differences in where students locate the "issue" of racial/ethnic underrepresentation differs by program.

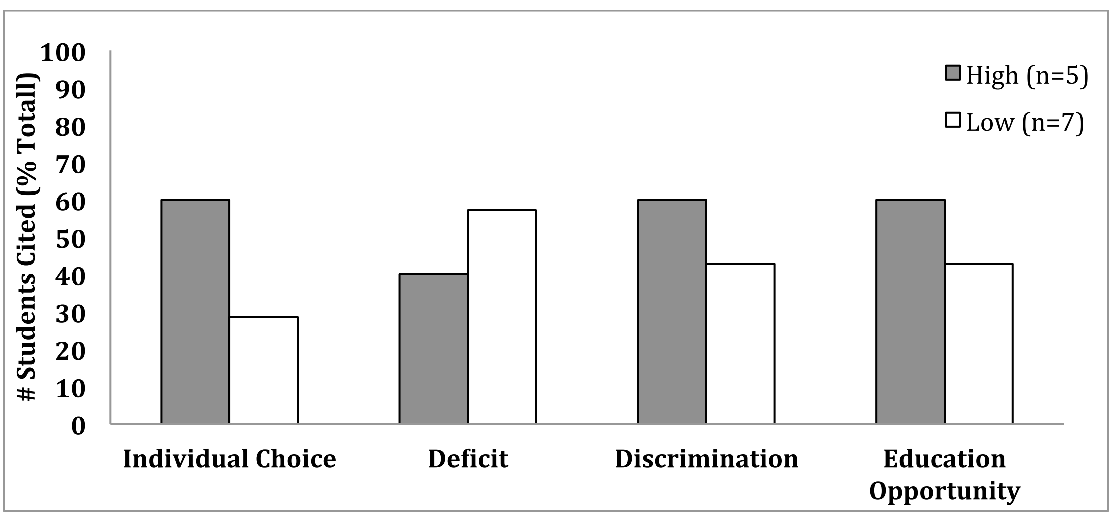

Figure 6. Focal students' pre program sense making about racial/ethnic underrepresentation in science.

Differences by program: Sense making of racial disparities. Findings show that there were significant differences in *where* students located the issue of racial/ethnic underrepresentation in science across programs. Findings map onto the relationship between perceived ability and sense making about racial/ethnic underrepresentation in science described above. Students from Bayside and Redwood who entered the program with similar and high average perceived ability in science scores described sense making suggesting that racialized structural inequities create disparities in *who* gets to become a scientist. Students in these program most commonly described "racial discrimination" and "educational opportunities" as reasoning for a lack of people of color in science (see Table 2). Carlos, the case study student from earlier provides and example. Recall that Carlos is confident in his science abilities. He recalls seeing a lack of Mexican scientists and when I asked why he says: "Maybe a lot of (Mexican) people just don't get the opportunity to go to college? Maybe that's the main reason." He continues: "We could all be good at it (science), it's just the opportunities we get." Here, Carlos reasons that racial disparities in access to educational opportunities shapes *who* gets to pursue science. In contrast, Westport students, who entered the program with the lowest average perceived ability in science scores across programs, more commonly located the "issue" of racial/ethnic underrepresentation in one's culture/race (i.e. deficit orientations) compared to students from Bayside and Redwood (see Table 2, bold). See the example of Fernando above.

It should be noted that many Westport students describe experiencing little success in science class in school and these students disproportionately represent the low perceived ability students. As described in Chapter 2: Methods, Westport students commonly joined the program because they needed to make up science credits and/or had failed science class. In contrast, though students from Bayside and Redwood also covered the range from high to low perceived ability, they had applied to participate in these programs. Findings suggests that for the focal students involved in this study, those from Westport may have experienced a higher level of marginalization and/or lack of access to high quality science instruction and opportunities to experience success in science compared to students from Bayside and Redwood. Combining this with findings in the characteristics sections above, it is significant that students who are most marginalized and have the least agency to resist and reposition themselves more commonly described scientists as "smart" and in stereotypical ways and located the issue of racial/ethnic underrepresentation in one's culture/race (i.e. deficit orientations). This may impact the options that all students, but especially those from Westport may view as available to them in science.

Complex repertoires: Multiple ideas & overlap. Findings illustrate the complexity of students' sense making about issues of racial/ethnic underrepresentation in science. It's important to note that though patterns emerged between programs and high and low perceived ability students, these relationships are complex. Students across programs hold tensions in their reasoning about racial/ethnic underrepresentation in science. Some students described multiple ideas that were assigned to different categories (e.g. ideas about racialized societal structures and deficit-oriented views). Melanie provides an example. She describes a deficit-oriented idea about her culture: "I feel like our culture doesn't really go for scientists. I've never heard of a family that was like you need to become a scientist, it's good." Here, she locates the "issue" of racial/ethnic underrepresentation in her culture. At the same time, she identifies structural issues:

> I've never heard of a professional Filipino scientist. Maybe it's just a lot of the other races don't feel comfortable. Here, it's a lot of low-income or working class people and they probably don't feel like they're good enough to become a scientist, cause it's like *high*.

Here, she illuminates intersections of race, class and positioning suggesting that people of certain races (e.g. Filipino) and classes (e.g. low income) might now feel good enough to become scientists because it's "high" status.

The fact that students hold tensions suggests that their ideas about *who* can do science interact with societal perceptions, positioning, and aspects of their racial and science identities in complex ways. In addition, these tensions suggest that disruption of sense making that locates the "issue" of racial/ethnic underrepresentation in science in the individual or one's race/culture are possible. In this way, there is room for empowering students who have internalized deficit-oriented views and for productive reframing of the possibilities youth of color view as available to them in science.

In the next section, I further examine the racial narratives that emerged during student's sense making (e.g. Fernando: "people of color slack off"). First, I explore how these racial narratives functions for students. Then I illustrate how they function differently for different types of students through examples of high and low perceived ability students.

Emergence of racial narratives: Linking characteristics, race & science. In this section, I explore how students' conceptions of science people (i.e. characteristics, race) operate in conjunction with racial narratives (see Figure 1, C) to shape how they see themselves in relation to science (see Figure 1, B). As described above, racial narratives often emerged during students' sense making regarding racial/ethnic underrepresentation in science. Racial narratives most commonly emerged when students' sense making about racial/ethnic underrepresentation in science was categorized as "deficit-oriented" (e.g. Fernando) or "racial discrimination". In this section, I examine the role of these racial narratives and how they impact the way focal students see themselves in relation to science.

Findings show, that the racial narratives that emerged during students' sense making about racial disparities in *who* is a scientist serve two overlapping functions: 1) indirectly link characteristics of scientists to race, and 2) confirm youth of color's ideas about racialized societal perceptions (e.g. who is smart). In addition, findings show that for focal students in this study, racial narratives may impact high and low perceived ability students differently. However, findings show that racial narratives impact *all* students across the range of incoming perceived ability in science. This demonstrates the disproportionate identity work that *all* youth of color need to do (Nasir & Shah, 2011) in order to navigate productive pathways in science.

Identity implications: Perceived ability & racial narratives Interestingly, findings show that while the racial narratives that emerged during students sense making were not often directly linked to science, in some cases they became linked *relationally* through the content of the narratives and the characteristics students associated with scientists. That is, the content of the racial narratives that emerged often linked the characteristics students' associated with scientists (e.g. smart) to race. Next, I illustrate how racial narratives become linked to science through the characteristics students associate with scientists and how this may differentially impact high and low perceived ability students.

Who is smart in society: white = smart = scientists. Racial narratives in the "racial discrimination" category commonly linked the characteristics involving knowledge (i.e. smart, know material) that students associated with scientists, as described above, to race. In this way, these narratives provided students with particular messages about *who* is smart in our society and therefore who can do science. The contrasting cases of Serena and Gabriella illustrate how these racial narratives impact high and low perceived students in different ways.

Low perceived ability: white = smarter. Serena, the 11th grade Mexican student from Westport (case study above) provides an example. Recall that Serena enters the program with a very low perception of her ability in science. She characterizes scientists in stereotypical ways, as "very smart" and says that she sees more "white men" in science than other racial groups. In many ways, she sees herself in opposition to how she views scientists (e.g. race, gender, characteristics). She says she doesn't know of any Mexican scientists and, as described in the opening excerpt, when I ask her why that might be she says:

> People are still racial…and think white people are better than Black people, or Mexican, or that they are smarter, and I guess, we are good for like hands on, the dirty work.

Here, Serena expresses a racialized societal perception that she experiences: "white people" are "smarter" and "better" than people who are Black or Mexican. In addition, she expresses a racialized perception that people from her race (i.e. "we", Mexican) are "good for the dirty work" or labor. She builds on this further to say "I know a lot of people think that." Serena's statement is powerful on many levels, illustrating the impact of racial narratives and how societal perceptions becomes linked to and validate who she sees doing science – white, smart men. In this way, this racial narrative indirectly links characteristics she associates with scientists (i.e. smart) with race (i.e. white). This racialized societal perception (i.e. white = smart) aligns with her conceptions of scientists (i.e. white, smart, men) and works in opposition to how she sees herself in science (i.e. Mexican, "not bright", girl). It is important to note that while she does not take up this narrative directly (i.e. she does not think that white people are better or smarter than Black and Mexican people), this narrative informs her ideas about *who* is smart (in society) and confirms how she sees herself in relation to science. In addition, this racial narrative describes a societal expectation that she experiences as assigned to her and members of her racial group.

High perceived ability: Stereotypes "hold you back". Gabriella, the 10th grade Chicana student from Bayside mentioned above, describes a narrative that suggests a similar type of racial hierarchy and societal positioning. However, Gabriella differs from Serena in important ways. She enters her program with a high perceived ability in science and describes science as her favorite subject. When I ask her to tell me a time she felt good at science she says: "Good at science? I've been good, since I was little actually." She describes scientists as "smart", high status and "not my race". When I asked Gabriella how being Chicana affects her experiences in science she says:

> It kinda depends on where you fall in because if you're Mexican you'll be told to get out of school and work, and if you're Black then you'll be told that you're gonna like go on the corner, and if you're white you're told…like all these stereotypes effect you. So if you're white, then you're most likely to be told you're gonna do good in school, you have a lot of money you can go (to college).

Here, Gabriella describes a racial narrative that she experiences that positions people from her race (e.g. Mexican) and Black people in lower societal tiers – as people who are good for "work" and who do not belong in school. In addition, this narrative positions people of different races by racialized perceptions of ability and income – white people are more likely to "do good in school" and "have a lot of money". Like Serena, Gabriella describes this racial narrative not as her own beliefs but as placed upon her and people from her racial group by society. Gabriella explicitly states that the stereotypes effect her and later builds on this: “it’s just those stereotypes that kind of hold you back”. This demonstrates that even though Gabriella views herself as “good” at science (and presumably school) she experiences the impact of these racial narratives. This is an important example of how racial narratives operate to hold students back, even those that are high perceived ability in science.

At the same time, Gabriella expresses a tension – that it’s an individual can choose to pursue science or not. She describes this idea: “It's really your choice if you want to engage in studies or not…because some people can be lazy and just slack off, but in reality it's whether they want to or not.” Here, Gabriella suggests that if people do not make a choice to “engage in studies” it may be because they are “lazy” or “slack off”. While she describes experiencing inequities based on racial positioning she also asserts an idea that individuals have agency to make decisions within the bounds of these hierarchical structures. Gabriella is much more confident about her ability in science than Serena. She feels marginalized by racial narratives, but may be able to resist to some extent by being good at science. In this way, Gabriella may experience more agency to resist the racial narrative and assert an alternative option to the one made available to her (Nasir & Shah, 2011). However, her ideas above and statement of being held back by stereotypes demonstrates the disproportionate work that youth of color need to do to navigate pathways in science.

Matter of motivation: “Don’t do work” vs. hard working scientists. Racial narratives in the “deficit-oriented” category commonly drew on racialized generalizations about the value different racial groups place on learning and personal motivation. Focal students described either internalizing or pushing back on these racial narratives depending on how they saw themselves as science learners. The contrasting examples of Fernando and Vincent illustrate how a similar racial narrative can be taken up and resisted differently for high and low perceived ability students.

Low perceived ability: “Slack off”. As described above, Fernando, the 12th grade Latino student form Westport enters the science program experiencing little success in science class and in school. Fernando describes scientists as “applying themselves”, and “hella smart”. He describes himself as getting distracted in science class and reasons that there might be less Latinos in science because “people of color slack off”. In this way, he internalizes this racialized conception of people of color “slacking off” and validates it by getting “distracted” in class. In addition, this puts him at odds with how he conceptualizes scientists. The questions becomes why is Fernando “distracted” in class? Often these issues are framed as a lack of motivation or effort on the part of the individual. While Fernando suggests in an earlier statement that he makes “dumb decisions”, this research aims to broaden the scope to more holistically explore these issues. What role do racial narratives, societal positioning, and marginalization play in creating a “lack of motivation”? How do these issues become magnified for students who don’t see themselves as good at science? What messages do students like Fernando received about where they belong and don’t belong and *who* they need to be in order to do science?

High perceived ability: “I’m achieving stuff”. Vincent, a 10^{th} grade student from Westport presents a contrasting example. Vincent is a high achieving, high perceived ability student who is passionate about science. He describes science as his favorite subject in school. He describes scientists as “smart” and views himself similarly in science. When describing how being Latino affects his experiences in science he expresses a similar racial narrative: “I guess by people saying that, some, like all Latinos don't work.” This is a narrative Vincent resists. He pushes back on this narrative: “I actually went over and did all my work, and like I'm doing good now, and I'm really achieving stuff." Vincent describes a narrative that he resists by asserting that "he does his work". While he pushes back on this narrative, similar to Gabriella, he also expresses a tension. He suggests that one reason he notices fewer Latinos in science is because "they don't stay in class". He feels that if they did it would help them get interested in science. In this way, he negatively applies this narrative to other members of his racial group (i.e. students like Fernando who get distracted in class), but not to himself. He views scientists as "smart". He describes himself as "good" at science and motivated to do his work. In this way, he may be able to resist this racial narrative and to assert an alternative position to the one made available to him (Nasir & Shah, 2011).

In summary, this research illustrates the constellation of factors that play into students' ideas about *who* they need to be in order to do science, how racial narratives shape the messages students receive about where they do and don't belong and the options that are made available to them in science and in society. Findings suggest that low perceived ability students may not see themselves belonging in science in a multitude of ways. For these reasons, racial narratives may be difficult for these students to resist or push back against because they have little leverage to do so. In contrast, high perceived ability students experience some of the same levels of not belonging in science (e.g. lack of racial representation) but can also find ways they *do* belong in science (e.g. share common characteristics with scientists). This may provide high perceived ability students with some leverage to resist racial narratives and reposition themselves. However, *it's complex*. The example of Gabriella demonstrates how racial narratives operate to "hold back" even students who are confident in their science abilities. In addition, the example of Fernando (i.e. "distracted" in class) demonstrates what is often thought of as an issue of individual motivation. This research seeks to expand our understanding of the factors that may contribute to "motivation" and the role of racial narratives in shaping students the messages students receive about where they do or don't belong (in science and society) and *who* they need to be in order to do science. How do these messages and the options students view as available play into the outcomes we observe (i.e. getting "distracted")?

In the next section, I build on the example of Gabriella to raise caution to the notion that students who are confident and good at science will be able to navigate productive routes into science on their own. Instead, I propose that *all* students need science and racial resources to support them on their pathways.

It's complex*: *Racialized societal perceptions & "expectations". In this section, I build on the example of Gabriella above to make the case that *all* students, regardless of how they view themselves as science learners, need resources to navigate productive pathways in science. Naomi, a 10^{th} grade student from Bayside is representative of high perceived ability students. She identifies racially as African American. Naomi enters the program with a very high perceived ability in science and exudes enthusiasm for science. She describes herself as a "knowledge seeker", is confident in her abilities in science and expresses often experiencing success in science class in school. Naomi describes science as central to her identity: "I really like seeing the world through science eyes…part of the way I see the world is science, and so it's a really cool world that way." Naomi describes scientists as "curious" and "wondering" about things and identifies these same characteristics in herself. She wants to pursue a career in science: "I really love biology. I want to be a surgeon…cause I really love that kind of explorative aspect."

As was common across focal students, Naomi describes scientists as "not her race". She says she sees "a lot of people from Eastern Asia" in science and describes the pictures at the doctor's office as evidence to support this idea. When asked why she think there might be more Eastern Asian people in science she reasons that it is a matter of societal expectations: "Even *you* kind of expect them to (become scientists). If you aren't expected to do something chances are you're probably not going to do it." Here, Naomi describes a complex relationship between race and societal expectations. Despite this, when asked if she wants to be a science person she says: "I do!" And when asked if she thinks she can be she says "Yeah!" with confidence. This suggests that despite experiencing a lack of racial representation, Naomi is confident she can pursue science.

However, she builds on her experiences to describe how racial narratives involving racialized societal expectations impact her. When I asked her if being African American has impacted her experiences in science at all she says:

> I think at first glance people would not expect me to be interested in science, but you know, once people get to know me, it's kind of more, like 'oh obviously'. I don't really know what people would think of me, but I feel like it's probably not really who I actually am.

Here, Naomi describes an experience of being perceived as not interested in science because of her race. This perception sharply contrasts to "who she is", and the excitement she exudes for science. She feels that because she is African American, people at "first glance" would not "expect" her to be interested in science. Though she is confident in her science abilities the racialized societal perceptions she experiences impact her – people have to "get to know her" to understand she is passionate about science. This is unique to her positioning in society as an African American student. This example illustrates the disproportionate distribution of identity work that students of color, like Naomi, need to do in order to pursue their passions in science – constantly redefining and presenting alternative subject positions from the one's that she is "hailed" into by society (Nasir & Shah, 2011). In addition, it points to the choices that students of color must make about how they will "show up" in a system that often does not recognize this disproportionate identity work and the aspects of their authenticity and identities that they need to relinquish in order to be successful.

Summary: Sense making about racial disparities & racial narratives. Findings illustrate how the racial narratives that emerged during students' sense making about racial/ethnic underrepresentation in science operate for the focal students in this study. Findings show that the racial narratives that emerged served two overlapping functions for focal students: 1) indirectly linked the characteristics students associated with scientists to race, and 2) confirmed racialized societal perceptions (e.g. who is smart). In this way, students' conceptions of who does science ("science people") becomes an axis point, and the racial narratives serve overlapping functions that inform how they see themselves in relation to science (see Figure 2). Findings show that while the racial narratives that emerged during discussion of racial/ethnic underrepresentation in science were not often directly linked to science, they became linked *relationally* through the content of the narratives and the characteristics students associated with scientists. This is supported by research that shows that racial narratives are the mechanism through which math achievement and ability are linked to race (Nasir & Shah, 2011).

In addition, findings show that there is a relationships between perceived ability and: 1) students' sense making and where students locate the "issue" of racial ethnic underrepresentation in science, and 2) the ways they take up, resist, and internalize racial narratives. Low perceived ability students more commonly located the issue of racial/ethnic underrepresentation in their race/culture and therefore internalized deficit-oriented reasoning about racial/ethnic underrepresentation in science compared to high perceived ability students. In addition, racial narratives often validated low perceived ability students' ideas that they don't belong in science. This may contribute to the outcomes we observe (i.e. "distracted" in class) and pushes back against the perception that these outcomes are an issue of personal motivation. In contrast, high perceived ability students more commonly located the issue in racialized structural inequities (e.g. educational opportunities) and in some cases expressed more agency to resist an reposition themselves against racial narratives placed upon them. However, findings demonstrate how racial narratives operate to impact even students who are confidence in their science abilities (e.g. Gabriella, Naomi). For example, Naomi exudes confidence and passion for science, but experiences racialized societal perceptions (e.g. not interested in science) and expectations because she is African American. Findings suggest that racial narrative (e.g. who is smart or good in school) might have different impacts on students based on particular aspects of their identities (e.g. perceived ability). At the same time the examples illustrate the disproportionate identity work that *all* focal students of color need to do in science in order to resist and reposition themselves (Nasir & Shah, 2011). This underscores the importance of providing youth of color with productive resources to navigate pathways in science.

Summary: Incoming Ideas About *Who* Does Science

This research illustrates the constellation of factors that play into how youth of color see themselves in relation to science (and scientists), how racial narratives shape the messages students receive about where they do and don't belong and the options that are made available to them in science and in society. Findings from pre program analyses show that students' incoming conceptions of *who* does science serve a relational function, in that students view their conceptions of "science people" (i.e. characteristics, race) in relation to themselves (science, racial identity). Students commonly describe scientists as smart and knowledgeable and often make links between the knowledge of scientists and other characteristics such as stereotypical images and power. In addition across programs, students overwhelmingly express awareness of a lack of racial representation in science. The cases illustrate how ability is built into students' understandings of *who* scientists are and what it means to be "good" at science. The examples of Carlos and Serena underscore the importance of examining the messages youth of color receive about *who* can do science based on their experiences with science and broadening their ideas about what it means to be good at science in order to expand the possibilities they imagine for themselves in science.

Findings suggest that a relationship exists between how focal students characterize scientists, their sense making about racial disparities in *who* is a scientist, and how they see themselves as science learners. For the focal students in this study perceived ability in science (i.e. seeing oneself as "good" or "bad" at science) was a salient aspect of their identities in the science programs that shaped how they see themselves in relation to scientists. For example, low perceived ability students more commonly attributed characteristics associated with knowledge such as "smart" to scientists, in ways that contrasted with their own perceived abilities in science. In addition, low perceived ability students more commonly internalized deficit-oriented reasoning about racial disparities in who is a scientist compared to high perceived ability students.

In addition, findings suggest that there may be a cumulative relationship between experiencing a lack of racial representation, the characteristics students associated with scientists, and how they see themselves as science learners. Findings show how experiencing a lack of racial representation in science works in concert with the characteristics described above to further enhance some students feeling of belonging or not belonging in science. The cases of Serena and Carlos illustrate how experiencing a lack of racial representation in science can operate collectively with the characteristics students' associate with scientists to impact high and low perceived ability students differently.

Finally, findings show that in this study, racial narratives that emerged during students' sense making about racial/ethnic underrepresentation in science served two overlapping functions for focal students: a) linked characteristics associated with scientists to race, and b) confirmed students' ideas about racialized societal perceptions (e.g. *who* is smart). Though the racial narratives that emerged were not often directly linked to science, in some cases they became linked *relationally* through the content of the narratives and the characteristics students associated with scientists. That is, the content of the racial narratives that emerged often linked the characteristics students' associated with scientists (e.g. smart) to race. This is supported by research that shows that racial narratives are the mechanism through which math achievement and ability are linked to race (Nasir & Shah, 2011).

This research illuminates the multitude of factors that play into the messages students receive about *who* they need to be in order to do science and the role of racial narratives in shaping students ideas of belonging or not belonging in science based on how they see themselves as science learners. Findings suggest that racial narrative might have differential impacts on students based on how they see themselves as science learners. At the same time, findings illustrate the impact of racial narratives on focal students across the range of perceived ability in science and the identity work that *all* youth of color need to do to resist and reposition themselves in science (Nasir & Shah, 2011). Low perceived ability students may not see themselves belonging in science in a multitude of ways. For these reasons, racial narratives may be difficult for these students to resist or push back against because they have little leverage to do so. In addition, this research pushes back on the notion that a perceived "lack of motivation" is an individual choice. This research illustrates the ways students are positioned by racial narratives, the options made available to them, and how this may be magnified for students who don't see themselves as good at science in the first place. In contrast, high perceived ability students experience some of the same levels of not belonging in science (e.g. lack of racial representation) but can also find ways that they *do* belong in science (e.g. share common characteristics with scientists). This may provide high perceived ability students with some leverage to resist racial narratives and reposition themselves. However, findings illustrate that *all* focal students are effected by racial narratives, even those that are confident in their science abilities (e.g. Naomi, Vincent). The examples illustrate the disproportionate distribution of identity work that focal students of color need to do in order to pursue their passion in science; constantly redefining and presenting alternative subject positions from the one's that they are "hailed" into by society (Nasir & Shah, 2011).

Post Program Shifts in *Who* Does & Can Do Science

Significant shifts occurred in focal students' ideas about *who* does and can do science following program participation. In this final section, I highlight the main shifts that occurred, the nature of the shifts, and illustrate the ways that students' ideas about *who* can do science expanded (or in some cases remained the same) after program participation. The goal of this section is to document the main shifts that occurred and to provide examples of why focal students of color need program resources that support their science *and* racial identities in order to create new possibilities for *who* they can be in science. I demonstrate that the biggest identity shifts occurred for Westport students. Findings here, suggest that Westport students identified themselves and their peers as scientists more commonly than students from other program because of what they were able to *do* as scientists and because their science and racial identities were supported while engaging in science practices. Therefore, this program provides a unique case of further analysis in later chapters. In the next chapter (i.e. Chapter 5), I explore how students' construct new possibilities and identities through the *doing* of science. In addition, I show how students' ideas about *what* science is and *who* can do science shift together while engaging in scientific research. In Chapter 6, I focus on the Westport program and provide a detailed analysis of the program resources made available and the social context of the program that supported holistic identity construction and the shifts documented here.

Next, I highlight the main shifts that occurred following program participation and how Westport provides a unique case for further analysis in later chapters.

Identifying Themselves/Peers & Youth of Color as Scientists

During post program interviews, I asked students to describe someone they met that summer that they considered a scientist. Findings show that while students across programs made gains in seeing themselves as scientists, Westport students made the greatest shifts following program participation (see Figure 7). Almost all of the focal students from Westport (6/7) identified themselves as scientist following program participation (see Figure 7). In this way, Westport students made significant identity gains compared to students from other programs (see Figure 7). Natasha, a 12th grade student provides an example:

> I think just doing the research in general makes everybody a scientist, because I mean we took data and we did all the research, and did all of that so.

Natasha expresses a view that because they did "research" and "took data" she and her peers are scientists. In this way, she identifies herself and her peers as a scientist because of what they were able to *do* as scientists. In addition, her statement suggests that students' ideas about *what* science is (i.e. science practices) and *who* can do science develop and shift together. It is important to note, that for Westport students, this type of identity shift was commonly described in conjunction with *doing* scientific research.

In addition, some students from Westport specifically described youth of color as scientists following program participation. This finding was unique to Westport students (see Figure 7). James, an 11th grade African American student from Westport provides an example. During a post program interview, I asked James if he learned anything during the summer about what it meant to be a person of color in science and he responded:

> J: Um, yeah, it shows that other people of color could do it, it's like, you could just do it.
> Interviewer: Yeah, and what showed you that would you say?
> J: I guess, well I did it!

Here, James describes an important shift in his ideas about *who* can do science specifically based on race. During pre program interviews he said he didn't notice many African Americans or other people of color in science. Here, he describes a shift in this idea based on the empirical evidence that he "did it" and "other people of color" did it. In addition, James' statement suggests that it was significant to him that he conducted scientific research with a group comprised of all students of color. Describing youth of color specifically as scientists following program participation was a finding unique to Westport students.

Perceived ability gains & identifying as a scientist. In addition, Westport students who entered the program with the lowest perceived ability in science made the greatest gains following program participation. Findings show that increases in perceived ability and identifying as a scientist may be linked. Westport students made significant gains in perceived ability compared to students from Bayside and Redwood who showed little to no change. When divided into low vs. high students, low Westport students made a 48% increase from pre to post compared to low students from Bayside (8.2%) and Redwood (6.3 %). Interestingly, all low perceived ability students from Westport moved inbound towards seeing themselves as scientists. That is, they identified themselves and their peers as scientist following program participation. This was unique to Westport students. Low perceived ability students from Bayside and Redwood either showed no pre to post program shifts in seeing themselves in science or moved outbound and found even more ways they felt that they did not belong in science following program participation.

Serena, the case study student from Westport provides an example of low perceived ability students moving inbound. Recall that Serena entered the program struggling in science and expressing a view that she was "bad" at science, and a "slow processor". In addition, a racial narrative emerged during her sense making about racial/ethnic underrepresentation in science: a societal perception that "white people are smarter" and people from her race (i.e. Mexican) are good for "the dirty work". This validated her ideas about scientists being smart, white, and men. During post program interviews she described a shift in her ideas about her ability to do science: "Well this type of science, I get it, like it's easier now." This shift in ability was reflected by a pre to post program gain in perceived ability based on post program surveys. Serena's statement and survey scores indicate that she left the program feeling more confident in her science abilities. This suggests that conducting research provided an opportunity for Serena to feel successful in science and helped to at least partially disrupt the racial narrative she described about *who* can be smart in science. In addition when I asked who she had met during the summer that she considered a scientists she responded: "Well, I guess we are all scientists....doing this, cause I researched, kept going out and collecting data, and yeah.. we found out results from the air." This suggests that conducting air quality research over the summer allowed Serena to identify *herself* as a scientist. The shift Serena described in her perceived ability may have contributed to this expansion of her ideas about *who* can do science.

The unique identity shifts that occurred for Westport students suggest that important and holistic program resources were made available to students in this program. In the next chapter (i.e. Chapter 5), I provide an in-depth analysis of *how* engaging in science practices and *doing* scientific research can create new roles and possibilities for students across programs. In Chapter 6, I provide an in-depth analysis of the program resources made available and the social context of the Westport program that may have supported the holistic identity construction described above for Westport students.

Shifts in Characteristics, Race and Gender of Scientists

Some students' conceptions of scientists (e.g. characteristics, race) shifted following program participation. In this section, I highlight the nature of the shifts that occurred and how some students experienced an increased awareness of a lack of racial representation in science following program participation. Findings underscore the need for program resources that support students' science and racial identities in science programs.

Scientists as "not my race": A need for holistic program resources. Following program participation students across programs expressed an expansion of their ideas about *who* does science based on race. Recall that during pre program interviews students across programs most commonly described scientists as "not my race" (i.e. not Latino or their particular race) or specifically as white and/or Asian. Following program participation, there was a decrease in the number of focal students across programs that described scientists as white, Asian, and "not my race". However, the most interesting shifts occurred in the category of "not my race".

While students across programs were less likely to described scientists as "not my race" following program participation, Westport students made the most significant shifts. During pre program interviews, the majority of Westport students described scientists as "not my race". Interestingly, no Westport students described scientists as "not my race" following program participation (see Figure 7). In contrast, Redwood students showed a slight decrease in describing scientists as "not my race" while Bayside students showed no pre to post differences (see Figure 7). Furthermore, some students from Redwood and Bayside stated that they became more aware of a lack of racial representation in science as a result of program participation. Developing an awareness of a lack of racial representation was most common for focal students from Redwood. Interestingly, the majority (i.e. 4/5) of focal students from Redwood expressed a greater awareness of being racially underrepresented in science following program participation. Alejandra, a 12th grade student who identifies racially as Mexican provides an example. During a post program interview, when I asked her what she learned about being Mexican and pursuing science during the summer she said:

> I don't really see many people my….I actually saw this guy…he presented once in the meetings and I was like whoa this is the first one I see! I was like now I found a Mexican person that is actually a scientist!

Here, Alejandra describes a greater awareness of lack of Mexican scientists. She expresses excitement about meeting a Mexican scientist during a lab meeting, but her statement suggests that this encounter was rare. This contrasts to James from Westport above who learned that people of color could do science as a result of program participation.

In addition, students from Redwood described a lack of racial representation based on the student population participating in their program. While the Bayside and Westport programs served all youth racially/ethnically underrepresented in science, the student population of the Redwood program was racially mixed. While the five focal students from Redwood all identified racially as Latino or Mexican, they were the only Redwood students who identified racially this way. In addition, the focal students attended the same predominantly Latino high school. Jasmine a 12th grade students from Redwood who identifies racially as Hispanic provides an example. She describes her program experience:

> J: I just noticed this when I was in the program, that it's very rare, that Hispanics are in science. Cause, I mean, me and a few others were like the only ones that are Hispanic and the rest are Asian and Indian, and like um, I don't know. And they all go to private schools.
> Interviewer: are you talking about the other students (in the program)?
> J: Yeah…just like me and four others, and we go to the same high school and I think that maybe, …coming from my school, many people wouldn't know what an internship *is*….Maybe we don't get those opportunities at our school….they do all sorts of stuff. I mean stuff that I never heard happen at my school.

Here, Jasmine describes noticing that the only other Hispanic students in the program were those from her school. She builds on this to state that she noticed a lack of Hispanic scientists in the lab she worked in. Together these experiences provide evidence for Jasmine that it's "rare" for Hispanics to be in science. She also describes a difference between the opportunities she has at her public high school, and the opportunities that she heard other students discussing at their often private schools – opportunities she had never heard of before.

The experiences of Alejandra and Jasmine illustrate how students in Redwood became more aware of a lack of racial representation following program participation. Neither Alejandra nor Jasmine identified as a scientist following program participation. In addition, Jasmine, entered the program with a low perceived ability in science and did not see herself as "good" at science. She entered the program to decide if science was something she wanted to pursue during her upcoming freshman year at community college. Following program participation, Jasmine shifted out of science and decided to pursue her other interest of journalism in college. Though there are likely a multitude of factors that informed this decision, experiencing a lack of racial representation as a student in the program and in the scientists she observed at the lab may have limited the options she viewed as available to her in science and been a factor that contributed to this decision. Findings from Redwood suggest that the population of students participating in science programs may influence how some students see themselves in relation to science, especially if they view themselves as different (in this case based on race). In addition, while science programs can't control the racial/ethnic background of scientists that commonly work in science spaces, findings here point to the need for programs to provide resources that address issues of racial/ethnic underrepresented in science and support youth of color as they navigate pathways in science.

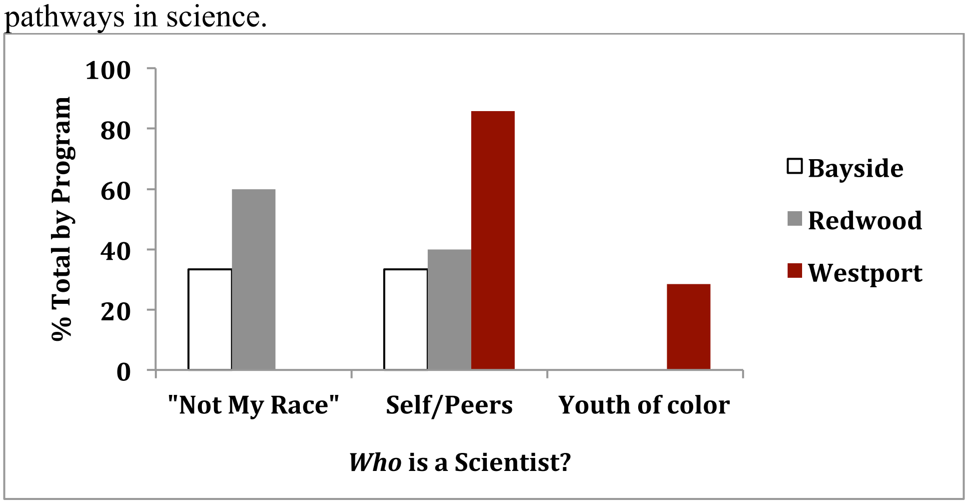

Figure 7. Post program shifts in focal students' ideas about *who* is a scientist by program.

Accumulating dimensions: Shifting characteristics, race & gender. The characteristics that focal students associated with scientists shifted across programs following program participation. Findings show that multiple dimensions shifted together (e.g. characteristics, race) in order to broaden students' ideas about *who* can do science. As illustrated with the example of Melanie above, this makes sense when students meet and interact with scientists. Recall that during pre program interviews, students commonly described scientists as "smart" and "knowing material". In addition, Westport students often described scientists in stereotypical ways. Following program participation, no students associated stereotypical images with scientists. In addition, across programs, students were less likely to describe scientists specifically as "smart" during post program interviews, while there was an increase in students describing scientists as "knowing material".

Disrupting who can be smart. Some students described ways that characteristics, race, and/or gender they associated with scientists shifted together through program participation. Gabriella, a 10th grade Chicana student from Bayside provides an example. Recall that during pre program interviews, Gabriella described scientists as "not my race" and described a racial narrative involving racialized societal positioning and *who* belongs in school. During post program interviews, when asked to describe someone she had met during the summer that she considered a scientist she named her Biology instructor, an enthusiastic African American young woman. When I asked if meeting this instructor changed her ideas about *who* does science she responded:

> A little bit, knowing that she's African American, or Black and she's smart and she's a female…I know that people can do like certain things and everyone has the same mind or, whatever. It's just like me saying that, 'oh you could be this you could be that', but then like actually seeing it, like that's cool.

Here, Gabriella expresses how having the experience of engaging with and learning from a science instructor of color, provided empirical evidence about *who* can do science in ways that cut across intersections of race and gender. It should be noted, that this instructor was an amazing instructor; she was passionate about teaching and engaged the students in culturally relevant Biology instruction. Like Gabriella, focal students from Bayside commonly described her as a scientist following program participation. Interestingly, Gabriella describes the instructor specifically as "smart" – a characteristic that students commonly associated with scientists during pre program interviews. In addition, she says she knows "everyone has the same mind" but that "actually seeing it" was "cool". This statement cuts across issues of race, gender, and societal perceptions about being "smart". Gabriella's statement of knowing we all have the same mind, but appreciating the empirical evidence suggests that her experiences during this summer and with this instructor in particular, helped disrupt this racial narrative about *who* is smart.

The example of Gabriella illustrates how some students from Bayside broadened their ideas about who can do science by seeing their instructors as scientists. While expanding students' ideas of *who* can do science in these ways is important, findings show that unique shifts occurred for Westport students who were able to see *themselves* as scientists because of what they were able to *do* as scientists.

Shifting race & power. During pre program interviews, some students described scientists as powerful because of their knowledge (i.e. Melanie). Recall that during pre program interviews Melanie described scientists as “high” status and “powerful” because they were “smarter” than everyone else. She describes how her ideas evolved during program participation:

> I thought scientists were like legit more old, like old people, and all high class and what not. Going to this program, changed my mind about what a scientist looked like because I think “Matt” (instructor) is a scientist, and he's like young and not hella fancy.

In this way, Melanie describes how working with her science instructor and viewing him as a scientist disrupted the status (and age) she previously associated with scientists.

In addition, Melanie describes a significant shift in her ideas about *who* is powerful. Interestingly, during post program interviews, Melanie builds on her idea that scientists are powerful because of their knowledge: “I feel like the title of a scientist comes with like hella knowledge that people expect...I think scientist are pretty powerful.” However, following program participation, Melanie describes an important shift in her ideas about *who* is powerful: “I think we're pretty powerful this summer as scientist.” She builds on this to describe how this shift specifically connects to youth and people of color:

> I think its really important to represent and show people that scientists aren't powerful because of their race, but because of who they are and what they want to accomplish as a scientist and what they want to contribute to their community so I feel like its really important for people of color to represent scientist.

Here, Melanie describes how power and race are linked for her and the significance of this shift of power to herself and her peers particularly as youth of color. She extends her ideas about how she views power, science and race as connected:

> I mean coming from like a history of like colored people being the bottom of the food chain and white people being at the top I think that still is incorporated with like everything there is today...I mean its not as harsh but you still kinda see it. Positions as high as a scientist like a lawyer, doctors, titles like that are still high…

She describes the position of scientist as still high, but not she and her peers occupy this high status and powerful position. Findings show that Westport students made the biggest and unique identity shifts following program participation. This suggests that unique resources were made available that supported these important shifts. This is discussed in detail in Chapter 6.

In this final section, I revisit the examples of Carlos and Naomi – students who are both confident and passionate about science and express a strong desire to pursue science. These examples illustrate the complexity of identity work that students need to do in order to pursue their passions in science.

Complex identity work & need for holistic program resources. The goal of this last section is to illustrate the identity work that youth of color must do, even when they strongly identify with science. Findings underscore the importance of providing all students with resources that support their science *and* racial identities in science programs. As described above, some students expressed a greater awareness of lack of racial representation in science *following* program participation. Carlos, the 12th grade Mexican case study student from Redwood enters the program with a very high interest and ability in and identification with science (as described earlier). When asked I asked him if he learned anything through the program about what it means to be Mexican and pursuing science, he said:

> One thing I seen is that I don't really see a lot of Mexican like in here (lab), like not a lot, so…cause there's only a few of us, like Mexicans in the program, and then, also like scientists and like graduate students.

Here, Carlos expresses awareness of a lack of racial representation in all aspects of the program: in the students that are part of the program and in the scientists and graduate students at the lab. This confirms his ideas about Mexican people being underrepresented in science that he stated during pre program interviews. When I asked Carlos how he reasoned about this he said:

> Well, in a way its like encouraging because I want to do science so like, you know, like be, I guess just encouraging myself to become a scientist because I know, not a lot of people are.

Similar to his response during pre interviews, Carlos expresses awareness of a lack of racial representation in science as a motivator. While Carlos describes this lack of representation as an "encouragement", he doesn't describe access to resources outside of his own goals that support his pathway in science. Research shows that racial positioning impacts the pathways and long-term trajectories of women of color in STEM field (Carlone & Johnson, 2007; Johnson et al., 2011, Malone & Barabino, 2008). In addition, this research points to feelings of being "the only one" as both common, isolating and alienating (Carlone & Johnson, 2007; Johnson et al., 2011, Malone & Barabino, 2008). This suggests that student like Carlos could use resources that support their science and racial identities to help navigate productive pathways in science.

Similar to Carlos, Naomi, the 10^{th} African American student from Bayside enters the program extremely passionate about science. Recall that during pre program interviews, she mentions feeling that people don't perceive her as interested in science based on her race. Following program participation, she describes a greater awareness of racial underrepresentation in science:

> Well, I'd say that (pause), it's not super common for people of my major part of my ethnicity to be involved in science, but I feel in no way does that mean that I can't be involved in science...I feel like maybe a little societally held back but not at all in personal motivation, definitely not.

She identifies strongly as a science person and is determined to pursue science. While Naomi is definitive in her pursuit of science, and her passion for science increases over the summer, her experiences as an African American girl in science and society significantly shape how she is positioned. She describes how she experiences the significance of race in our society:

> Well, I mean it will affect your self-image, it will affect where you can get, it will affect, you know, *what* you can get. It's just like where society puts you kind of majorly determines where you're going to end up.

Naomi describes the widespread impact of race on her lived experience and other people of color and how structural inequities shape where people "end up." She struggles with trying to understand inequities based on racial difference – and more specifically why certain races and racial differences are seen as "bad". I asked her to describe what she meant above about being "societally held back" and she explains that she blames society, but also that it is "natural" to single out people who are "different". She uses her science background and ideas about evolution to reason about why race is so significant in our society:

> Nobody really cares what skin color people have, that's not going to affect us, but it seems we've started to believe it *has* or something….there must be something inside us that sees those differences, I just don't really know what exactly it is that makes some people think it's *bad*.

Naomi's statement is powerful on several levels and underscores the significance of students' sense making around racial narratives that shape racialized societal perceptions. She says she uses her strong science background to reason about racism and racial inequities. She says she draws on ideas of "Darwin": natural selection, and "population differences", to try and understand people's reasoning about what will affect the human "species moving forward". She describes skin color as a difference that does not negatively impact the species but feels that for reasons she can't understand, people see this difference as "bad". Furthermore, Naomi isn't given the opportunity to see how racial difference can be an *attribute* that she brings to her understanding of science.

Naomi's reasoning about race, and its significance in shaping her lived experience and what is possible suggests that racialized perceptions and narratives deeply impact students at the intersections of their science and racial identities. Like Carlos, Naomi expresses a strong desire to pursue science. It is plausible that the challenges associated with fulfilling their dreams may impact their long-term trajectories in science. They may receive continual messages about *who* belongs in science (and who doesn't) (Carlone & Johnson, 2011). At a minimum, the examples of Carlos and Naomi illustrate the complex and profound identity work that all students need to do, even those that find themselves very much in line with becoming a scientist. Carlos and Naomi will continually need to reposition themselves and assert alternative subject positions to the options made available to them (Nasir & Shah, 2011) in order to pursue science as youth of color.

Summary: Post program shifts. Post program findings show that shifts occurred in students' ideas about *who* does and can do science. Interestingly, students from Westport, who entered the program with the lowest average perceived ability in science scores made the greatest post program identity shifts. Students from Westport identified themselves and their peers as scientists more commonly than students from other programs following program participation. In addition, some Westport students specifically identified youth of color as scientists, a finding unique to this program. Findings suggest that Westport students made gains in perceived ability (i.e. saw themselves as capable science learners) and identified themselves and their peers as scientists because of what they were able to *do* as scientists. This is discussed in detail in Chapters 5 and 6.

Findings suggest that in some cases simultaneous shifts in multiple dimensions (e.g. characteristics, race, perceived ability) occurred through program participation. This led to an expansion of students' ideas about *who* can do science. For example, findings show that increases in perceived ability and identifying as a scientist may be linked. Conducting research provided an opportunity for students like Serena to feel successful in science and helped to disrupt the racial narrative she described about *who* can be smart in science. In addition, findings suggest that Westport students made gains in perceived ability (i.e. saw themselves as capable science learners) and identified themselves and their peers as scientists because of what they were able to *do* as scientists. Westport students' ideas about *who* does science and the characteristics they associated with scientists shifted together. In this way, engaging in scientific research allowed Westport students to construct new ideas about *who* does science that included *themselves*.

Findings also underscore the importance of providing resources in science programs that support *all* of who youth of color are in science learning environments. Findings show that some students experienced a greater lack of racial representation following program participation. In addition, the examples of Naomi and Carlos, (i.e. high perceived ability students) illustrate the identity work that even students who are high perceived ability in science and highly passionate about pursuing science must do in order to navigate a productive pathway forward in science. In next chapter (see Chapter 5), I explore how engaging in science practices helped create new possibilities for who students can be in science.

Discussion & Conclusions

This research illustrates the constellation of factors that play into how youth of color see themselves in relation to science (and scientists), how racial narratives shape the messages students receive about where they do and don't belong and the options that are made available to them in science and in society. In this chapter, I make four main arguments: 1) Focal students' incoming conceptions of *who* does science serve a relational function, in that students view their conceptions of "science people" (i.e. characteristics, race) in relation to themselves (i.e. science *and* racial identity); 2) For focal students in this study, a relationship exists between how students characterize scientists, their sense making about racial disparities in *who* is a scientist, and how they see themselves as science learners (e.g. "good" or "bad" at science); 3) Racial narratives that emerged during focal students' sense making about racial disparities in *who* is a scientist served two overlapping functions: a) indirectly linked characteristics students associated with scientists to race, and/or b) confirmed youths' ideas about racialized societal perceptions (e.g. who is smart); 4) Post program shifts in *who* can do science are related to what students are able to *do* as scientists during the programs.

Findings show that students' incoming conceptions of *who* does science serve a relational function, in that students view their conceptions of "science people" (i.e. characteristics, race) in relation to themselves (science, racial identity). This suggests that there may be a cumulative relationship between experiencing a lack of racial representation in science, the characteristics students associated with scientists, and how they see themselves as science learners. Post program findings from Westport illustrate how multiple dimensions (e.g. characteristics, race, perceived ability) shift together. In addition findings show how racial narratives and ideas about characteristics can be disrupted and reframed in productive ways based on students' experiences in summer science research programs. Findings suggest that Westport students made gains in perceived ability (i.e. saw themselves as capable science learners) and identified themselves and their peers as scientists more commonly than students from other programs because of what they were able to *do* as scientists. In this way, engaging in scientific research allowed Westport students to construct new ideas about *who* does science that included *themselves*. This suggests that students' ideas about *what* science is and *who* can do science shift together. How engaging in science practices made new possibilities available for Westport students is explored in Chapter 5.

Findings show that students' conceptions of *who* can do science and perceived ability in science are further complicated by racial narratives that emerged during students' sense making about racial/ethnic underrepresentation in science. Findings show that racial narratives that emerged during focal students' sense making about racial/ethnic underrepresentation in science served two overlapping functions for focal students: a) linked characteristics associated with scientists to race, and b) confirmed students' ideas about racialized societal perceptions (e.g. *who* is smart). The racial narratives that emerged were not often directly linked to science, in some cases they became linked *relationally* through the content of the narratives and the characteristics students associated with scientists. That is, the content of the racial narratives that emerged often linked the characteristics students' associated with scientists (e.g. smart) to race. This is supported by research that shows that racial narratives are the mechanism through which math achievement and ability are linked to race (Nasir & Shah, 2011). Research in developmental psychology shows how different aspects of students' identities inter-relate with broader discipline-specific stereotypes (e.g. gender-math stereotypes) which impacts students' disciplinary self-concepts and perceptions who they can become, orientations towards a discipline etc. (Cvencek, et.al., 2011). In addition, this research shows how the strength of certain aspects of students' identities (in this case gender identity) informs the level at which a stereotype is internalized, which has implications for one's self concept in a discipline.

Foundational work on stereotype threat suggests that racialized experiences and stereotypes matter for processes of learning and identity construction for youth of color (Steele, 1997; Steele & Aronson, 1995). Findings from this dissertation build on this work to show *how* racial narratives operate for the focal students in this study. Findings build on previous literature involving stereotypes and racial narratives in two ways: First, they extend this important work to the science discipline. Second, findings extend our understanding of how racial narratives operate collectively with different aspects of students' identities and their conceptions of *who* does science to shape the options they view available to them in science.

Findings from this study suggest that racial narratives operate collectively with different aspects of students' science and racial identities in a similar way to gender-math stereotypes (Cvencek, et.al, 2011). However, findings from this dissertation suggest an expansion of how racial narratives function in two ways. First, findings suggest that racial narratives don't have to be discipline-specific (i.e. about science) in order to operate in conjunction with student's conceptions of scientists. Interestingly, though the racial narratives that emerged were not often directly linked to science, in some cases they became linked *relationally* through the content of the narratives and the characteristics students associated with scientists. For example, the racial narrative "white people are smarter than Mexican people" became linked to science through the characteristics and race that Serena associated with scientists: "white" and "smart". In this way, the content of the racial narratives that emerged often linked the characteristics students' associated with scientists (e.g. smart) to race. This builds on previous literature that shows that racial narratives are the mechanism through which math achievement, ability, and motivation are linked to race (Nasir & Shah, 2011). Findings here broaden our understanding of how racial narratives operate by extending this body of work to the science discipline. In addition, findings show how racial narratives operate collectively with different aspects of students' identities and their conceptions of *who* does science to impact their sense making and science experiences. Second, findings suggest that racial narratives can shape students' ideas about their place in science (i.e. self-concept), but also that students conceptions of scientists and how they see themselves in relation to scientists shapes their sense making around racial narratives. In other words, for students who don't see themselves as good at science or racially represented in science, and view scientists as smart and "not their race", racial narratives can validate their conceptions about *who* is smart in science-specific ways (i.e. scientists = white = smarter).

Findings here extend our understanding of how racial narratives operate in the science discipline and in conjunction with other relational aspects of how students' see themselves in relation to science (e.g. perceived ability) to impact their science experiences. Together these findings further develop our understandings of how race matters when considering science identity construction for youth of color and the complex ways that racial narratives impact students' ideas about *who* belongs in science as well as the options they view as available to them in science.

Significant shifts occurred in focal students' ideas about *who* does and can do science following program participation. Findings suggest that Westport students made gains in perceived ability (i.e. saw themselves as capable science learners) and identified themselves/peers and youth of color as scientists because of what they were able to *do* as scientists. The unique identity shifts that occurred for Westport students suggest that important and holistic program resources were made available to students in this program. In the next chapter (i.e. Chapter 5), I provide an in-depth analysis of *how* engaging in science practices and *doing* scientific research can create new roles and possibilities for students across programs. In Chapter 6, I provide an in-depth analysis of the program resources made available and the social context of the Westport program that may have supported the holistic identity construction described above for Westport students.

Findings underscore the importance of providing resources in science programs that support *all* of who youth of color are in science learning environments. Findings show that some students experienced a greater lack of racial representation following program participation. In addition, the examples of Naomi and Carlos, (i.e. high perceived ability students) illustrate the identity work that *all* students of color must do – even those who are highly confident and passionate about pursuing science – in order to navigate a productive pathway forward in science. Findings suggest that for focal students in this study, resources that support students' science *and* racial identities are necessary in order to create new possibilities for *who* youth of color can be in science. Findings also point to the need for science programs to reflect on their own capacity, limitations, and willingness to support youth of color in program spaces. The types of program resources made available to Westport students that may have supported the shifts described in this chapter are explored in Chapter 6.

In summary, the experiences of the students in this study illustrate the complex ways that students' conceptions of scientists, their perceived ability in science and the racial narratives that emerge during their sense making about racial/ethnic underrepresentation operate together to shape: 1) students ideas about who they need to be in order to pursue science, and 2) the possibilities they imagine for themselves in science. Findings show that *all* students are impacted by racial narratives regardless of incoming orientations to science (i.e. high *and* low perceived ability students) and need sufficient science *and* racial resources with which to reposition themselves and to navigate productive pathways in science. In addition, findings illustrate the ways that students' science and racial identities are inter-related. As a result we must consider how they *develop together* in science learning environments.

Chapter 5: *What* Is Science?
Supporting Youth of Colors' Identities as Learners & Doers of Science

Introduction

Case Example

> I thought science was just like scientists, heavy, hella smart in a lab, mixing chemicals...but here we just walk around…taking air samples with a machine, just writing everything down, and learning how to make graphs and how to present, and talking about what we learned.

To illustrate the dynamic relationships between students' ideas about the practices of science, *who* does/can do science, and how these ideas evolve together through participation in authentic scientific research, I start with the experience of a summer science program participant involved in this study. Fernando is a rising 12th grade student from the Westport program who identifies racially as Latino. Like many of his peers in the Westport program, he enters the program experiencing little success in science class and views himself as not good at science. He says he often gets "distracted" in science class. As a result he struggles academically in science class and in school. As expressed in the opening excerpt, Fernando enters the program with particular ideas about *who* does science (e.g. hella smart people) and *what* scientists do (e.g. mix chemicals in a lab). In addition, the expression above suggests that his ideas about *what* science is and *who* does/can do science are interconnected. Along with his peers, Fernando conducts a seven-week long air quality research project. During this time, his ideas about science practices, *who* can do science, and how he sees himself in relation to science develop together. Following program participation, Fernando expresses an overall shift in his ideas about what counts as science as documented in his statement above. In addition, through engaging in scientific research he adds new practices to his repertoire. He describes an expansion in his ideas about types of science practices (e.g. making graphs) and the meaning he associates with particular practices. In addition, he expresses a shift in agency. His statement: "we just walk around taking air samples," suggests that science became more accessible to Fernando. In this way, his conceptions of who is a scientist shifted from smart people in a lab to something he and his peers could do in their community. Through engaging in scientific research he is able to identify as a capable science learner and construct a conception of a scientist that includes himself and his peers. Fernando's statement suggests that shifting students' ideas about the practices of science and their abilities to participate in these practices has the potential to create new possibilities for *who* students can become in science.

Rationale

The underrepresentation of African American, Latino, Pacific Islander and other high school students of color in advanced science courses and the need to increase diversity in science fields is widely agreed upon (Oakes, Ormseth, Bell & Camp 1990; Darling-Hammond, 2010). In addition, developing the next generation of innovators in science, technology, engineering, and math (STEM) is deemed essential because it is linked to the nation's economic prosperity (National Research Council (NRC), 2011). This highlights two issues: a need to increase diversity and the necessity to create innovators in STEM. A typical solution to increasing diversity in science is to focus on reframing *what* science is through curricular and policy reforms (e.g. National Research Council, 2012) that promote authentic and inquiry-based approaches to instruction (e.g. NRC 2012). However, the U.S. continues to lag behind other developed nations in producing scientifically literate citizens. In addition, racially based achievement gaps are persistent (National Science Board, 2012). These statistics suggest need for more expansive instructional reforms that address *what* science is and *who* can do science together. In addition, Fernando's experience illustrates the value and potential of programs that provide this holistic support.

The Next Generation Science Standards (NGSS, 2013) promote an integration of science practices and content through curricular and instructional reforms. As California and other states adopt these standards, a unique opportunity exists to develop educational resources that engage students in science practices and support identity construction for youth of color in holistic ways. In this chapter, I aim to contribute to this conversation by illuminating how engagement in science practices supports processes of learning and identity construction for the youth of color in this study. In addition, I aim to document the types of opportunities that support students' science *and* racial identities while engaging in science practices. I build on findings from *Chapter 4: Who Does and Can Do Science* that show that students who identified themselves and their peers as scientists did so because of what they were able to *do* as scientists. In this chapter, I turn my attention to how identities are constructed through participation in the practices of science. I examine how conducting research with scientist instructors can expand students' ideas about what counts as science. Finally, I examine how students' ideas about *what* science is (i.e. practices) and *who* can do science shift together through participation in the practices of science.

Chapter Objective

This chapter explores students' incoming ideas about science practices, how they see themselves in relation to these practices, and how their ideas shift following participation in summer science research programs. Students conduct scientific research alongside scientist instructors as part of program participation. This chapter has three main goals: First, to better understand students' *incoming ideas* about the types and meaning of science practices that they associate with "doing" science. This involves their experiences with science in school and their ideas about what scientists "do" to conduct scientific research. In addition, I examine how students see themselves in relation to these science practices. Second, to determine shifts in students' ideas about science practices (i.e. types, meaning) after engaging in scientific research during the science programs. I also examine, how these shifts impact the ways students see themselves in relation to science. Third, to explore how scientist instructors' perspectives of science and race shape the resources they make available and how this impacts focal students' identity construction.

I ask the following research questions:

- What are students' incoming ideas about science practices and how do they see themselves in relation to these practices?
- How do students' ideas about science practices shift following program participation? How does this impact the options they view as available to them in science?

- How do scientist instructors' perspectives of science and race shape the program resources they make available while engaging youth in scientific research?

Next, I discuss the previous scholarship that supports this inquiry.

Theoretical Framework

This research draws on socio-cultural theories of learning, identity and positioning (e.g. Harre, 2008, Holland et al., 1998, Wenger, 1998). I view learning as a process of becoming and imagining of possible futures (Nasir & Hand, 2006). I utilize the "practice-linked identity" framework (viewing participation in a practice as central to who one is) (Nasir, 2012) in order to explore *how* learning, positioning and engagement in science develop *in* the science programs.

Science identity literature offers insights into the types of identities offered to underrepresented youth (e.g. Polman & Miller, 2010; Tan & Calabrese Barton, 2010). While research shows that racial positioning matters for women of colors' long-term science trajectories (Carlone & Johnson, 2007; Johnson et al., 2011, Malone & Barabino, 2008) and that disciplinary-specific stereotypes can limit the subject positions available to youth (Nasir & Shah, 2011), treatments of race in relation to science are limited. More research is needed that examines how students' science and racial identities develop together through participation in the practices of science.

Previous science education literature highlights some of the potential identity constructing resources that support the development of practice-linked identities in science. Research shows that engaging with science practices and the sense making and analytical work involved can help expand students' ideas of what counts as science practices (Warren, Ballinger, Ogonowski, Rosebery & Hudicourt-Barnes , 2001). In addition, student-designed investigations provide unique opportunities for students to develop deep understanding of science content (Lehrer, 2009) and construct unique epistemological stances (Metz, 2004; Sandoval, 2005; Lehrer, Schauble & Lucas, 2008). Building on this further, research shows that engaging with science practices through investigations has positive impacts on identity construction. Findings from previous studies show that conducting investigations increases interest and engagement in science (Linn & Hsi, 2000) and allows students to perceive themselves as real scientists and identify as capable learners (Barab & Hay, 2001; Bouillion & Gomez, 2001; Bowen & Roth, 2007, Lehrer, 2009).

I build on this work to examine how participation in scientific research can expand students' ideas about *what* science is and *who* can do science. I explore how youth of colors' science and racial identities develop *together* through engaging in scientific research. As described in Chapter 4, I *define identity* as how youth of color perceive science, how they see themselves in relation to science, and how the interactions they have and believe they can have shape *who* they become in science. This involves their ideas about *who* does/can do science (e.g. characteristics, race) discussed in Chapter 4, and their ideas about *what* scientist do (this chapter). Chapter 4 explores students' ideas about *who* does and can do science and how students of color see themselves in relation to science (see Figure 1, black). Here, I explore students' ideas about *what* science is (i.e. practices: school, scientist) and how they see themselves in relation to these practices (e.g. ability to engage with practices) (see Figure 1, green). Taken together, I illustrate how, for focal students in this study, ideas about *what* science is and *who* can do science are inter-related in dynamic ways (see Figure 1).

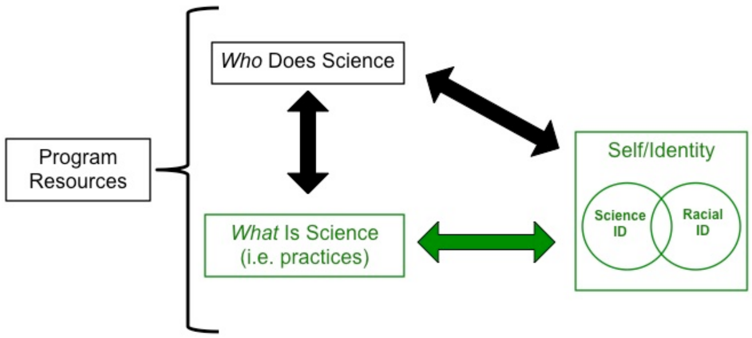

Figure 1. Focus on how students view practices of science (*what*) in relation to themselves (see green portion of overall diagram).

In this chapter *I make three main arguments*: First, focal students' ideas about science practices serve a relational function, in that students view their conceptions of science practices in relation to themselves. Some students compared what *they* do in science class with what scientists do, and/or questioned their ability to engage in the types of science practices they viewed as central to the work of scientists. In addition, a relationship exists between the meaning students associate with science practices (i.e. restrictive or expansive) and how they see themselves as science learners. Second, engaging in scientific research can expand students' ideas about what counts as science practices. In addition, engaging in scientific practices broaden the meaning students associate with the scientific research process from restrictive to expansive. This can help makes science more accessible and allow students to identity as capable doers of science. Third, for focal students in this study, program resources that supported students' science *and* racial identities created new possibilities for *who* they could become in science.

Findings show that expanding students' ideas about science practices can broaden students' ideas about what counts as science and create shifts in their ideas about *who* can be a capable science learner. However, findings also show that pedagogical and instructional resources are needed that attend to both the types of science practices that are promoted and the messages youth of color receive about *who* can do science while engaging in scientific research in order to make new possibilities available in science for youth of color. When combined with findings from Chapter 4, this research shows that while reforms that focus on promoting authentic science practices are an important part of the solution, a focus on shifting *what* science is (i.e. practices) alone is insufficient for dismantling persistent issues of equity in science education.

Methods

Data Sources

This study utilized three main data sources: 1) Pre and post program student surveys 2) Pre and post program focal students interviews, and 3) Scientist instructor interviews.

Pre & post program student surveys. 41 students total completed pre and post program surveys across the three summer science programs. The goal of pre and post program surveys was to establish a baseline (pre) and determine changes (post) in students' attitudes towards, ideas about, and perceptions of ability in science as well their ideas about the scientific research process. Pre program surveys were administered on the first day of the program. Post program surveys were administered on the last day of the program. All surveys were administered and completed on paper copies during class time and turned in together.

Attitudes & perceived ability in science. Validated scales that measured students' interest, attitudes towards, and perceptions of ability in science were used to create Likert scale items. Validated scales measured: science identity (Girod, 2005), perceived ability: self-concept in science (Kind, Jones & Barmby, 2007), interest in science (Girod, 2005), relevance and utility of science/scientific research in life (Siegel & Ranney, 2003), and work of scientists (Aschbacher, Ellen & Roth, 2010). From these validated scales, 37 Likert scale items were constructed in check box format with choices that ranged from strongly agree to strongly disagree.

Ideas about the scientific research process. Questions were designed to capture students' ideas about the process of conducting scientific research. Items contained a check box portion (i.e. how much do you agree or disagree with the following statement) and an open-ended response section that asked students to explain their choice. Two main items were used for analysis in this study: Item #1: "In order to do good work, scientists need to closely follow the steps of the scientific method"; Item #2: "Scientists rarely stray from their plan when they do experiments". In addition, survey items asked students ideas about uses for and the importance of scientific research.

Post program surveys mirrored the pre program version and were designed to capture changes in students' attitudes and ideas about science and the scientific research process following program participation. Additional questions were added that asked students to describe how their ideas about the scientific research process and uses for scientific research changed following program participation.

Interviews. ***Focal students***.18 focal students total across programs completed pre and post program interviews. 7 students total completed follow-up interviews during the school year following program participation. Pre program interviews were conducted on the first day of the program with approximately six focal students per program (Bayside (n=6), Redwood (n=5), Bayside (n=7). Post program interviews took place on the last day of instruction with the same set of focal students. Interviews were conducted during program time but outside of the main program activity area. Follow-up interviews were conducted with as many focal students as possible (n=7) at the student's school site or a public location near their home (e.g. library).

In order to gain an understanding of students' ideas about science practices and how they see themselves in relation to these practices, pre program interviews were designed to capture students' ideas of what scientists "do" to conduct research. *Science practices* are defined as the types of activities utilized to conduct scientific research and/or produce scientific knowledge through the research process. This definition is intentionally broad in order to holistically capture students' ideas about and experiences with "doing" science. Interviews were designed to capture two types of science practices (school and scientist) defined as follows: a) School science practices: the types of activities students participate in during science class in order to "do" science in school; b) Scientist practices: the types of activities utilized by scientists to conduct scientific research and/or produce scientific knowledge through the research process. Pre program interview questions asked students to describe what it "looked like" to do science in school and their ideas about what they thought scientists did to conduct scientific research. Post program interviews asked students to describe their research projects and what *they* did to conduct scientific research during the summer science programs.

Scientist Instructors. 10 instructors total across programs completed interviews. Interviews were conducted at or near the end of the summer science program at the program site. Interviews were designed to capture instructors' perspectives of science and their students as well as their sense making about racial/ethnic underrepresentation in science. Interview questions captured instructors' ideas about science that included: goals for instruction, utility of scientific research, science practices that they used and found important to promote, ways that they used science in their own lives and how they hoped students would use science in their lives. Interviews also captured instructors' ideas about their students that included: racial backgrounds, societal positioning. Finally, interviews captured instructors' sense making about racial disparities in the professional science community.

Analysis

Pre & Post Program Surveys. Of the 52 students involved in this study, 41 students completed pre and post program surveys across programs. Students with missing data were excluded from pre to post program comparisons. The number of total students that completed pre and post program surveys differed by program: Redwood: 14/19, Bayside: 18/22, Westport: 9/11.

Attitudinal survey items. All student pre and post program surveys included items that measured perceived ability in science (e.g. I am good at science) (Likert scale). It is important to note that perceived ability in science scores were not designed to assess students' *actual* ability in science, but rather served as a measure for how students' viewed themselves as science learners (i.e. view themselves as "good" are "bad" at science). Students' scores were averaged for all perceived ability items, arranged from high to low scores and divided into quartiles across programs. Students in the top quartile were labeled "high perceived ability students" and students in the bottom quartile were labeled "low perceived ability students".

Science process questions & open-ended responses. Pre and post program surveys contained items that assessed students' ideas about and understanding of the scientific research process. Questions about the scientific research process contained a statement (e.g. scientists closely follow the steps of the scientific method), a check box portion that asked students how much they agreed or disagreed with the statement, and an open response section for students to explain their answer. Check box items were scored from 1= strongly agree to 5 = strongly disagree. A scoring rubric was created to assess students' open-ended responses for two assessment items. The rubric was designed to capture a range of responses that described prescribed to more authentic views of the scientific research process. The scoring rubric was scored on a scale from 1-5 for item #1 and 1-6 for item #2 with the highest score indicating the most authentic views of science (see Appendix 6 and 7). Check box and open-ended response scores were analyzed separately. Scores were averaged and analyzed across programs. Similar to the Likert scale items described above, patterns were assessed for different groupings of students (e.g. high vs. low perceived ability) and to determine pre to post program changes.

Interview analysis. Interviews were coded inductively and all categories *emerged* through students' and instructors' conceptions, descriptions and sense making (i.e. coding categories were not pre-determined). All interviews were coded through an open and iterative coding process (Miles & Huberman, 1994).

Focal students: Science practices. Interviews were coded for the types of science practices that students' used to "do" science in school and the practices they thought scientists used to “do” scientific research. In all cases, categories emerged from the data and were not predetermined. Interviews were coded to capture students’ ideas about the scientific research process and the practices scientists used in three ways: 1) the *types* of science practices students thought scientists utilized to conduct scientific research (pre program) and that they utilized to “do” science during program participation (post program), 2) the *meaning* students’ associated with the science practices/work of scientists (pre and post program); discussed in detail below, and 3) uses for scientific research: utility and purpose of research, as well as who might find the research useful (pre and post program). To gauge shifts in students’ views of science practices, interviews were analyzed for the types and meaning of science practices and uses for scientific research that students discussed before and after program participation. To determine post program shifts in students’ ideas about the scientific research process, during post program interviews students were asked to describe their research project, what they did to conduct research on their topic, and changes in their ideas about the scientific research process.

Two broad categories of *meaning* for the practices of scientists and the scientific research process emerged through initial analysis of pre program interviews: Restrictive and expansive. Restrictive views of science practices describe the scientific research process as prescribed, known, static, rigid, and linear. Restrictive practices involve finding facts and known answers. This involves a view that there is one correct way of doing things in order to arrive at the correct answer. In addition, stereotypical images of science (e.g. mixing chemicals in a lab) and power differentials between what scientists do and what students have access to were categorized as restrictive because these views limit students’ ideas about their abilities to engage with science. Restrictive practices are often based on students’ experiences with labs and experiments in school that do not reflect authentic forms of science as conducted by scientists. Restrictive science practices limited opportunities for participation in science (e.g. one way to do things) and/or students’ ideas about their ability to engage with the science process in a meaningful way (i.e. based on how they see themselves in relation to the practice).

Expansive views of science practices capture the explorative, non-linear, iterative, flexible, constantly changing/evolving, and problem solving aspects of the scientific research process. Expansive practices involve the generation of new knowledge and following flexible/non-linear paths where tangents are often explored. In addition, multiple ways of approaching research are utilized. Expansive science practices align with and map onto the work of real scientists and what they actually do to conduct scientific research. This view of science practices broadens opportunities for participation in science and expands students’ ideas about their abilities to engage with the process (e.g. multiple ways to engage with science are accepted). These definitions were used to capture a baseline (pre) and shifts (post) in the *meaning* students associated with scientist practices and the scientific research process (see Appendix 8 for coding scheme).

It is important to note, that often the science practices *themselves* were not restrictive or expansive in nature. It was the *meaning* associated with the science practices or the *outcome* of the practices that made them restrictive or expansive. For example, following a science procedure, often associated with cook-book/prescribed science can also be a part of the authentic work of real scientists (i.e. scientists may follow a lab protocol). If the meaning associated with a scientific procedure was rigid/prescribed and the goal (i.e. outcome) was to arrive at the correct answer this was considered a restrictive view of this science practice. If the outcome of engaging in the practice was to generate new knowledge, then this was considered an expansive view of this practice.

Scientist Instructors. Instructor interview transcripts were read and coded for: 1) perspectives of science (e.g. utility), 2) instructional goals and general approach, 3) science practices promoted, 4) their approach to engaging students in the scientific research process, 5) perspective of students (e.g. racial background), 6) ideas about racial and gender disparities in the professional science community, and 7) types of program resources they made available. Coding categories were analyzed individually and for patterns between categories (e.g. perspective of students/science and resources made available).

Contrasting cases: High & low perceived ability students. I use contrasting cases of four students (Lorenzo, Fernando, Melanie and Naomi) to illustrate how experiences with science practices play out differently for different "types" of students. The case study students are representative of two different types of students: 1) low perceived ability students: students that don't see themselves as good at science. These students have sophisticated ideas about science but struggle to do well in science class and don't experience success in science (i.e. Lorenzo, Fernando), and 2) medium/high to high perceived ability students: those that experience success in science class and are confident in their science abilities (i.e. Naomi, Melanie). In addition, I include two students in each "type" (i.e. low vs. high perceived ability) because identity outcomes vary within and between groups following program participation. The case study students were selected to hold gender constant by perceived ability category and to have one representative from two of the three science programs (i.e. Bayside, Westport) in each category. In this study, boys were slightly over-represented in the low perceived ability group (i.e. boy: 7/12, girls: 5/12). Boys were also overrepresented and comprised the majority of the high perceived ability group (i.e. boys: 7/10, girls 3/10). The cases study students were selected to hold gender and program constant for low vs. high categories and are not representative of a gender bias within high vs. low categories.

Findings: Incoming Ideas About the Practices of Science

In order to gain a better understanding of students' experiences with and incoming ideas about the practices of science, I examine two types of science practices: 1) school science practices (i.e. the practices students engage with to "do" science in school) and 2) practices of scientists (i.e. students' ideas about the practices scientists use to conduct scientific research) as defined in the methods section above. Pre program focal student interviews and all student surveys were analyzed to establish a baseline for students' incoming ideas about science practices and the scientific research process. The purpose of this baseline is to better understand how students experience science and see themselves in relation to these science practices. I then determine shifts in students' ideas following program participation.

School Science Practices

In this section, I examine students' experiences with school science practices and how they see themselves in relation to these practices. During pre program interviews, focal students were asked to describe their experiences with "doing" science in school. Responses were coded as school science practices and were used to establish a baseline for students' school science experiences. Findings show that the school science practices focal students experienced are those commonly used to teach science in school (e.g. labs/experiments, learn vocabulary). There were no major differences in the types of school science practices students experienced by program. In addition, across programs, the meaning students associated with the most common school science practice of doing labs/experiments was prescribed, procedural and where results are judged as right or wrong. These findings align with typical school science experiences documented in the literature (Schweingruber et.al, 2005).

Across all three programs, the most common types of school science practices that focal students described (n=18 across programs) were: doing labs/experiments (13/18), reading from textbooks (10/13) learning vocabulary/concepts (7/18) and memorizing information (6/18) (see Figure 2). Serena, an 11th grade Mexican student from Westport provides an example of the common practices she experienced in science class: "In the end, my experience in science is off a book and worksheets and stuff like that." Serena's experience is representative of students across all three programs where school science practices such as reading textbooks, learning vocabulary words, and memorizing information are ubiquitous.

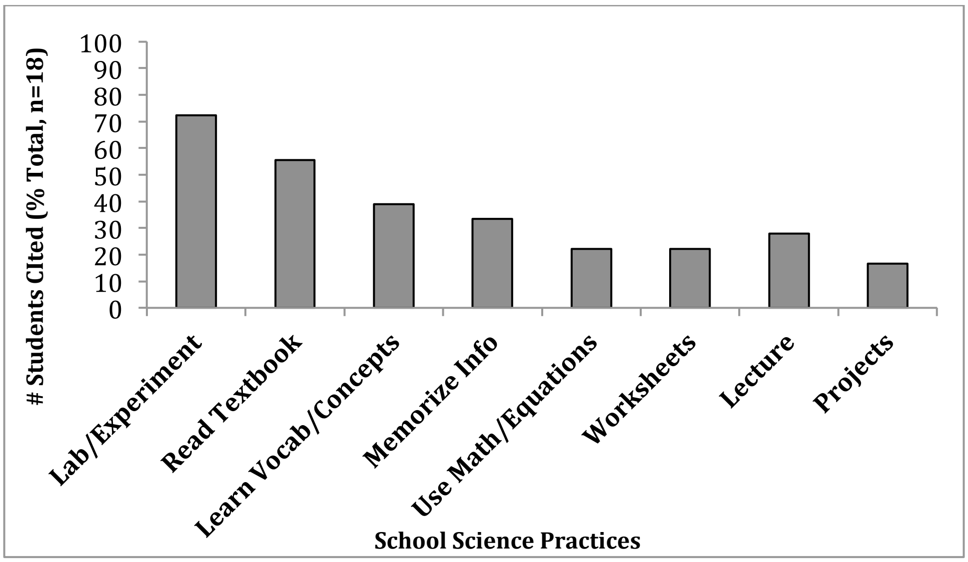

Figure 2. School science practices described by focal students *across* programs.

In addition, I examined the *meaning* students associated with these practices to determine how their experiences shaped their ideas about their ability to engage with school science. The meaning students' associated with the most common school science practice of "doing experiments/labs" suggests that students' often experienced prescribed and procedural approaches to science. Three themes emerged from students' descriptions of the practice of conducting experiments/labs: 1) scientific methods and the scientific research process are static, fixed, with one correct way to do things, 2) results are known and judged as right or wrong, 3) failure is not a natural part of the science process.

Students often described experiments/labs as following prescribed steps of a procedure in order to arrive at a known answer. This answer was assessed as "right" or "wrong". Naomi, a 10th grade student from Bayside describes the consequences for making a mistake during labs:

> In school, we kinda have to follow every single instruction and if you do something wrong they just make you start over. Like you can't find out how to fix it or, you know, if you want to do something else, they're like, 'you could totally do that on your own time, but we're not going to give you any supplies for it'. It's like you can't really do it on your own time because you don't really have a way to.

Naomi's statement illustrates the static/prescribed nature of school science commonly described by focal students. In addition, she describes a lack of opportunity to "find out how to fix things", suggesting there is no space in her science class for problem solving and making mistakes. This limits the opportunities that students have to participate in science because there is one way to do things. Finally, she expresses a lack of access to pursue science questions and ideas that interest her but are outside of the bounds of the school science curriculum.

Building on these experiences, Alejandra, a 12th grade student from Redwood describes how failure is framed through the practice of doing labs in school:

> Well in science (class) if you didn't do it right then you would fail the whatever you were doing….I mean the teacher has the results there herself she has the answers because, a lab, it has been done a lot before. It's even in the textbook like how to do it or, she already knows a lot of people have done it in like a lot of classes.

Here, Alejandra describes that failing is possible if you don't do the lab the "right" way. Her statement illustrates a scientific process where there is a known answer that has been achieved by many others in the past (i.e. the results are "even in the textbook"). She describes failure in school science as a result of not getting the known answer rather than a natural part of the science process.

Naomi and Alejandra's experiences with labs/experiments are representative of focal students across programs. They describe one correct way to do things and a lack of agency to problem solve and to work outside the confines of prescribed lab procedures. This may limit the opportunities students have to engage with and participate in school science because there is one accepted approach and little space to make and learn from mistakes.

Differences by program: School science practices. While focal students across programs expressed similar experiences with school science some differences were detected between programs. Focal students from Bayside and Westport described school science practices that reflected slightly more prescribed and procedural approaches to science instruction compared to students from Redwood. For example, listening to lectures was a practice associated with doing science for Bayside and Westport students but not mentioned for Redwood students (see Figure 3). In addition, students from Bayside placed a greater emphasis on memorizing information than students from other programs (see Figure 3). In contrast, students from Redwood described school science practices that indicated greater exposure to potentially more inquiry-oriented science practices. Two focal students from Redwood had the opportunity to design and conduct a year-long research project with an outside science program that served the sciences classes at their school. This experience was unique to Redwood students. Findings suggest that while students experienced school science practices in similar ways across programs, there may have been differences in the amount of exposure to inquiry-oriented instruction by program.

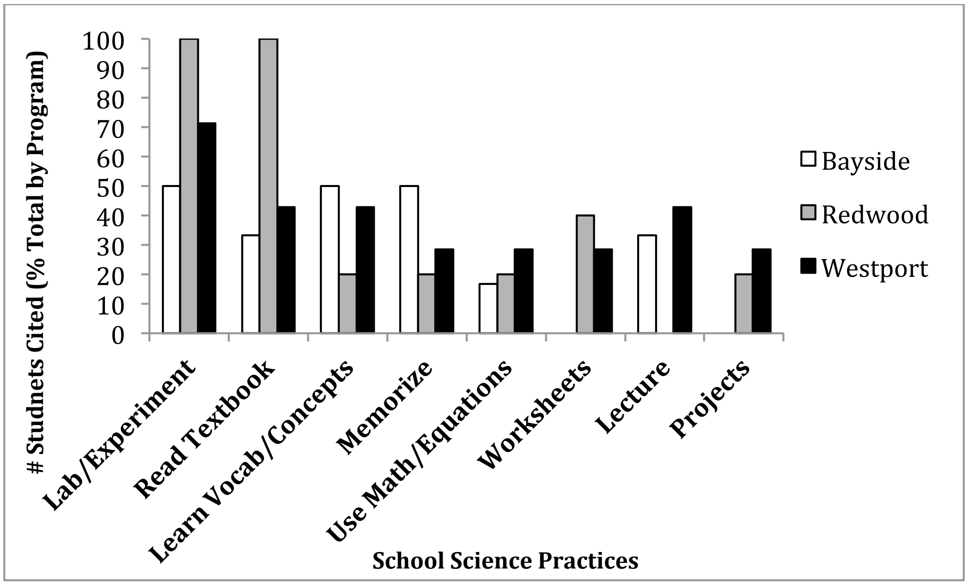

Figure 3. Differences in school science practices described by focal students by program.

Why does this matter for processes of learning and identity construction and the possibilities students' view as available to them in science? As described above, in many ways, the school science practices that focal students described above are not new. In addition, the prescribed nature of school science labs and experiments is well documented (Schweingruber, Hilton & Singer, 2005). What is not explored is the *relational* aspects of engaging in school science practices: how students see themselves as able to engage or not engage with school science practices and how this shapes they way they see themselves in relation to science. In the next section, I examine how students' experiences with school science practice can contribute to their feelings of belonging or not belonging in science.

Identity implications: School science practices. In this section, I utilize contrasting cases of students with low and high perceived abilities in science to illustrate how engaging with school science practices plays out differently for different types of students and shapes how they see themselves in relation to science. Lorenzo, a 10th grade student from Bayside, and Fernando, a 12th grade student from Westport, both enter their respective programs with a low perceived ability in science. Fernando and Lorenzo both have sophisticated ideas about science but struggle to be successful in science in school. This impacts how they see themselves as science learners (see Table 1). In contrast, Melanie, at 10th grade student from Westport, and Naomi, a 10th grade student from Bayside, enter their respective programs with medium/high to high perceived abilities in science. Both Melanie and Naomi describe science and math as their favorite subjects and experience success in science in school (see Table 1). The contrasting cases include two students in each category (i.e. low vs. high perceived ability) because identity outcomes vary within and between groups following program participation. Here, I start with students' experiences with school science practices and how they see themselves in relation to these practices. I then build on these examples throughout the chapter to show how ideas about and experiences with different types of science practices creates varying identity outcomes for different types of students.

Table 1. Contrasting Cases of High vs. Low Perceived Ability in Science Students: Incoming Ideas about Science Practices (School, Scientist) & Identity

Student	Perceived Ability	School Science Practices	Scientist Practices	Identity
Lorenzo *(Bayside)*	Low	• Struggles to be successful • Language an issue (English is second language) • Memorizing vocabulary, concepts is difficult	• Prescribed • Finding facts	• Struggles to engage with practices used by scientists • Continually questions if he belongs in science
Fernando *(Westport)*	Low	• Struggles to be successful • Gets "distracted" and "frustrated" in class	• Mix chemicals • Money/sponsors • Smart in lab • Apply themselves	• "Distracted" in class • Doesn't do anything that scientists do • Wants to be a Pharmacist
Melanie *(Westport)*	Medium/ High	• Science is favorite subject • Lack of access to high quality instruction	• Ask questions • Derive solutions • Smart, powerful	• Ask questions like scientists • Her experiments: small; scientists: advanced • Not sure if she could see herself doing science
Naomi *(Bayside)*	High	• Science is favorite subject • Applies science to life	• Curious, wonder • Figure out how things work	• Sees world through "science eyes" • Curious, wonder • Figure out how things work • Strongly identifies as science person

"I should stop this!": Questioning if he belongs in science. Lorenzo is a 10th grade student from Bayside. He identifies racially as Mexican and describes this as central to who he is. He describes himself as "good at math" and says he uses science and math in his life (i.e. playing card games). However, he expresses a continual struggle to succeed in science class in school. Throughout the interview, Lorenzo expressed sophisticated ideas about science, yet his experiences with science in school left him feeling not good at or belonging in science. This was common across low perceived ability students. Lorenzo came to the U.S. from Mexico in 3rd grade and recalls being held back a grade because he was too scared to speak even though he knew some English. He expresses that he struggles with language and that this carries over to his science experiences. He described the practices he experiences in school science: "I memorize…I go through process of like taking in information, memorizing key concepts, and then um, using those concepts later on, and it's like short term." Like Lorenzo, focal students commonly described learning vocabulary/concepts and memorizing information as common school science practices (see Figure 2). Lorenzo explains how these common practices intersect with his struggle with language:

> When I first started to get some of like the advanced words, and like I didn't know those concepts, I was like um, what am I doing? I should stop this! But then after that I got better…the big words were like a huge problem to me and especially pronouncing them.

Lorenzo's statement of "what am I doing? I should stop this" suggests that his struggles with the practices of memorizing advanced words/concepts made him question if he belongs in science. He continually framed himself as not "that bad" at science (vs. good at it). For example, he described a time he felt good at science: "I got a good grade on my science quiz…I was like, Oh! So I'm not that bad!" Throughout the interview, Lorenzo continually recounted receiving messages that made him question if he belongs in science.

As described above, Lorenzo identifies racially as Mexican and views this as a central aspect of his identity. He describes how his racial identity intersects with the common school science practices of reading textbooks. When we discussed science textbooks and the information contained in them, Lorenzo immediately said he didn't think all of the information in his science textbooks was true. I asked him to explain and he made a comparison to history books: "No, not all of it's true, that's like definitely one of the things I've always seen that's not true….if they do it in like the history books, then why wouldn't they do it again like in other papers?" I asked him to expand on what he meant by "do it":

> I guess lie about some things or leave out some things too. Like the Mexican or the Spanish and French Revolution they left out a lot of things, like a lot of information, so why would they put like all the information in science but not in this?

Here, Lorenzo expresses a sophisticated and critical idea that like history books, his science textbooks are written from a culturally biased perspective that excludes his racial group's perspective. This shows the complexity of how different aspects of students' science and racial identities inter-relate to shape how they see themselves in relation to science.

Lorenzo's example illustrates how students see themselves and aspects of their identity in relation to school science practices (e.g. learning vocabulary, textbooks). In addition, it shows that students may hold sophisticated ideas about science that are not valued in school. The initial hurdle of language and engaging with science practices such as memorizing words/concepts may have limited his ability to see science as a subject where he could experience success. Together these experiences may contribute to his continual questioning of whether he belongs in science.

Science as unnecessarily complicated: "Why can't you just say the easier word?"

Fernando is a 12th grade student from Westport. He identifies racially as Latino. He describes science as a "middle" interest in school but says he often gets "distracted" in science class and struggles in general academically. When asked, he can't think of anything he enjoys about science. During the interview, Fernando says he often gets "distracted" in science class and ends up leaving class because he gets frustrated:

> I get distracted a lot. And then I'm like, 'hold on, what are you guys talking about?' And then I get frustrated if I don't answer it right. Because I wasn't paying attention and getting everything that I should have got…dumb decisions.

Fernando has a low grade point average (1.6). This, in combination with his account of science class above suggests that he doesn't experience success at school very often.

He describes his experiences with science in school: "Lessons, PowerPoint, videos, just watch videos about what we are learning that day." When asked if there is anything he dislikes about science he says the "complicated words". In this way, like Lorenzo, he describes struggling with science vocabulary but instead of questioning if he belongs in science he expresses frustration at this practice: “It's so complicated when you have to use certain words for stuff...like what are you saying?” I asked him to expand on what he meant: “Some words are just...long, and they mean the basics things. It's like...why can't you just say the easier word?” Here, Fernando critiques the common practice of learning vocabulary words in science that really just mean the “basic things” and expresses frustration at making things unnecessary complicated. This critical idea in combination with the ways he learns science (e.g. videos) may be a reason he gets “distracted” and experiences a lack of success in science class in school and therefore does not see himself as good at science.

When asked to describe a time he felt good at science, Fernando says “right now, because I understand what he (the instructor) is talking about right now.” In this way, Fernando expresses a desire to understand science in the program and when he does that it makes him feel like he is good at it.

Limited by access to science instruction. Melanie is a 10th grade student from Westport. She identifies racially as Filipina. She describes science and math as her favorite subject in school and can’t think of a time that science class has been difficult for her. Though she enjoys science she expresses a lack of access to high quality science instruction: “I feel like my science class last year during freshman year was just not as informative as I wish it’d be.” She expands on this: “I don't remember me being involved in science as much, like in middle school and elementary…like we didn't have a lot of classes.” Here, Melanie expresses a desire to learn science but a lack of access to science classes. She describes how she learns science in school: “Not too many experiments. It’s just like a lot of reading out of textbooks and like a lot of structured type of teaching and stuff.” This contrasts to what Melanie describes as enjoying most about science: “Trying out different things, like experimenting, getting my hands on like test tubes and stuff, I like that.” She sees herself as good at science and needing to put in a “medium” amount of effort to do well depending on the topic. She can’t think of a time that science has been hard for her: “I don't recall any times where I've been frustrated with science”. Even though she expresses a lack of access to the types of science she likes to do (e.g. “experimenting”) she does well in science class and sees herself as an above average science student. Because Melanie is successful at school science practices, she may be able to look beyond the restrictive practices (e.g. “structured teaching”) she experiences. In addition, Melanie says she uses science in her life outside of school. When I asked her if she does science outside of school she says: “I feel like I do. Like when I'm just exploring outside of my apartment, looking at like different insects and picking at plants and stuff.” In this way, Melanie may be able to do some of the kinds of science she enjoys exploring things on her own time.

“Seeing the world through science eyes”. Naomi is a 10th grade student from Bayside. She identifies racially as African American. She exudes passion and enthusiasm for science and identifies strongly as a science person. Like Melanie, science and math are her favorite subjects in school. She describes herself as a “knowledge seeker” and expresses the central role of science in her life: “I don't know it's kind of just always been something I enjoyed, I can't really explain why it's just kind of my thing.” She is confident in her science abilities and expresses often experiencing success in science class in school. Naomi describes science as central to her identity: “I really like seeing the world through science eyes…part of the way I see the world is science, and so it's a really cool world that way.” Her mom and a few other family members are in the medical profession and she says that this has helped fuel her curiosity in science.

As described above, Naomi learns science in school through “lectures” and “labs”, common practices describes by focal students above (see Figure 2). Recall from above that

Naomi expresses frustration with the prescribed ways she does experiments and labs in school. In addition, she expresses a limitation in being able to go beyond the assigned lab due to a lack of access to supplies. However, she explains a strategy that may help her overcome these frustrations and limitations:

> I think it's really all about incorporating it into your life. Where you know its not just being in a classroom and you know learning stuff or like taking lecture or doing labs, it's about um, really using it to understand things about your world and that's what I like to use it for."

Here, Naomi says that she applies the science she learns through common practices of "lectures" and "labs" to her life. She says her teacher during the previous school year was "really great" and helped his students make these connections. In this way, she may leverage school practices in ways that have meaning for her. When asked if science is ever difficult for her, she says she struggles with memorizing terms (like Lorenzo and Fernando) but expresses confidence to overcome this challenge: "if you keep working at it you get it eventually and it all makes sense." In this way, she describes an ability to overcome frustrations. Because Naomi experiences success in science and has a teacher that helps make science relevant to their lives, Naomi may be able to see beyond the boundaries of restrictive school science practices. She also says she feels good at science: "whenever, I know something that the teacher doesn't, I feel like I've been doing my research and I feel like I've done something good." Her statement suggests that she does "research" and reads about science-related things on her own time. In combination with findings ways to incorporate things into her life, this may allow her to fill some of the gaps she experiences in school.

Summary: School science practices. Findings show that the types and meaning of school science practices focal students experienced are those commonly used to teach science in school (e.g. prescribed labs/experiments, learn vocabulary). There were no major differences in the types of school science practices students experienced by program. However, what has not been explored is how students' experiences with school science practices shape how they see themselves in relation to science and how this varies for different types of students. The contrasting cases of Lorenzo/Fernando, and Melanie/Naomi illustrate how high and low perceived ability students experience similar school science practices in different ways (see Table 1). For students who don't see themselves as good at or successful at science (i.e. Lorenzo, Fernando), certain practices (e.g. vocabulary) may create barriers to entry, limit opportunities to participate in these practices, and cause students to question if they belong in science (i.e. Lorenzo). Students who describe science as a favorite subject and see themselves as good at science (i.e. Melanie, Naomi) may be able to more easily look beyond the bounds of restrictive school science practices because they more readily experience success. In addition, they may be able to overcome frustrations of "structured teaching" and prescribed experiments and find ways to pursue passion in other aspects of life. Both Lorenzo and Fernando express sophisticated ideas that critique common school science practices (i.e. Lorenzo: textbooks, Fernando: vocabulary). This suggests their struggles to succeed in science class may be a result of *how* science is taught in school that limits opportunities to engage in science practices in a meaningful way. In addition, their complex ideas about science practices disrupt the idea that students' with a low perceived ability in science are not successful due to a lack of actual ability but rather as a result of a lack of opportunity to engage with science.

In the next section, I build on students conceptions of science practices by exploring their ideas about the practices scientists utilize in order to conduct scientific research.

Practices Used by Scientists to Conduct Research

In this section, I examine students' incoming ideas about science practices by exploring their ideas about what scientists "do" when conducting scientific research. During pre program interviews, students were asked to describe the practices they thought scientists used to "do" research. Interviews were analyzed for the *types* of practices students described to gain a better understanding of their ideas about what counts as science practices. In addition, interviews were analyzed for the *meaning* students' associated with science practices ranging from prescribed (similar to their school science experiences) to authentic (map onto the work of real scientists) in order to better understand their views of the scientific research process. The goal of establishing this understanding is to then explore how students see themselves in relation to these practices. In the next section, I start with the *types* of practices students thought scientists utilized to "do" scientific research.

Types of scientist practices. During interviews, I asked students to described the *types* of science practices they thought scientists utilized in order to better understand their ideas about what counts as science practices. Overall, students described general ideas about the types of science practices they thought scientists used to conduct research. Across programs, focal students most commonly described the following types of science practices: 1) conduct research/experiment (general), 2) scientific methods used to conduct research, and 3) use equipment/machine/technology (see Figure 4). Students described many other types of practices but at lower rates than those mentioned above (see Figure 4). Some practices involved steps of the scientific method commonly taught in school (e.g. methods, hypothesis, conclusion). These ideas map onto, and are likely informed by students' experiences with labs and experiments in school described above. Other practices represent more superficial or stereotypical ideas about the types of practices scientists use (e.g. use big words, mix chemicals) (see Figure 4, right side). These types of practices may be based on school science practices (e.g. Fernando: complicated words) as well as images of science ubiquitous in the media (e.g. mixing chemicals). In the next section, I examine how students see themselves in relation to these practices.

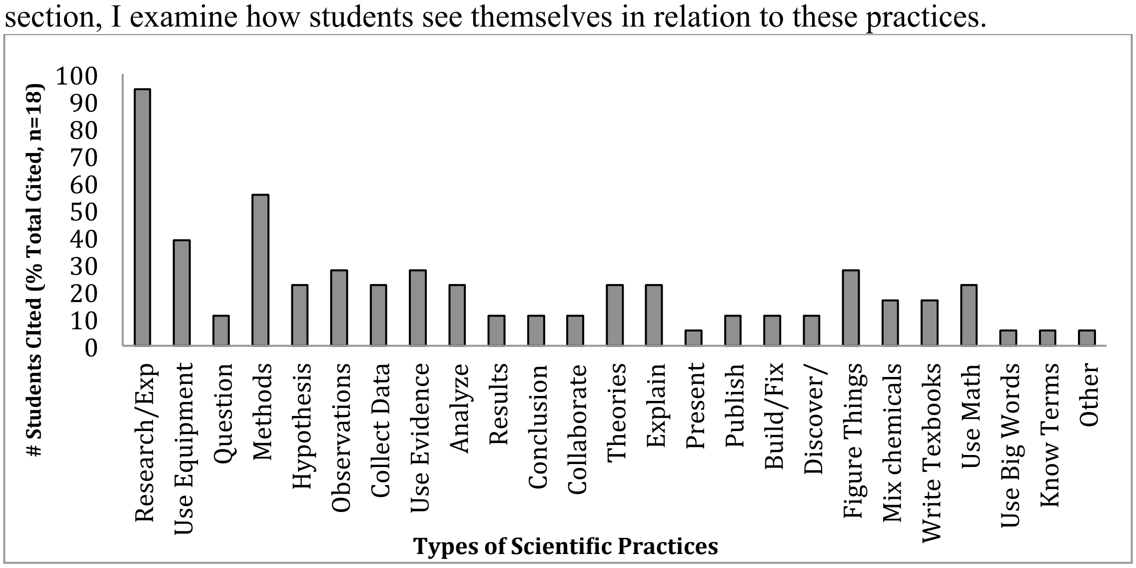

Figure 4. Focal students' pre program ideas about *types* of science practices used by scientists to conduct research *across* programs.

Comparing scientists to self. In this section, I illustrate the relational aspects of how students view certain types of science practices in relation to themselves. Interestingly, some students compared what *they* do in science class with what scientists do, and/or questioned their ability to engage in the types of science practices they viewed as central to the work of scientists.

Comparing their science to scientists. Melanie, the 10th grade Filipina student from the case study above compares *her* science and the types of practices she engages in during school to the types of practices she thinks scientists use:

> M: I feel like the science they (scientists) do is a little more advanced in a way…like my science is just like small things, I don't know.
> Interviewer: What do you mean by advanced and small things?
> M: Like advanced, they're finding solutions to issues with like people or health or stuff, or like, they're going to like the depth of astronomy and stuff. And like small stuff, for me, is just like doing small experiments with gas and little electronics and stuff.

Melanie expresses a view of science as involving "really high tech equipment" (above) in order to do "advanced" things (e.g. exploring the depths of astronomy). Her statement suggests that she may view what scientists do as more important and valuable (e.g. "finding solutions") compared to the science she does (e.g. "small stuff").

Ability to engage in central practices. In addition, some students expressed ideas about their ability (or lack of ability) to engage with the practices they viewed as central to the work of scientists. Elana, a 10th grade student from Bayside provides an example. She describes her ideas about what scientists do to conduct research: "Well they probably know the terms and stuff and then they also have machines, right? There's a bunch of, yeah, technology and everything cause that's like what scientists do." When I asked her if she could see herself doing anything like that she responded:

> I don't know, cause like, I'm not really, technology doesn't like me so, I don't think I... I don't know. Things always go wrong when I get a computer…like I always break it or something.

Elana views "knowing terms" and "using technology" as central to the work of scientists. She sees herself as having the bad memory (throughout the interview she says she has "the worst memory ever") and not good with technology. She expresses reservations at being able to become a scientist because of disparities between her own perceived abilities with remembering terms and using technology and the practices she thinks scientists do well. In this way, Elana may view certain science practices as inaccessible (e.g. using technology). This may limit the possibilities she views as available to her in science.

The examples of Melanie and Elana illustrate how some students view different types of practices in relation to what they do (i.e. Melanie) or their abilities in engage with central practices (i.e. Elana). In the next section, I describe differences in the *types* of practices students described by program.

Differences in types of practices by program. Across programs, students described similar *types* of science practices. However, an interesting difference emerged across programs for practices associated with using technology and machines, categorized as "Use Equipment" (see Figure 4). In addition, students in some programs had prior experience conducting scientific research in school (described above for two Redwood students) or through prior science program participation (one student from Westport) and this may have informed their ideas about the practices of scientists.

While students across program commonly associated using technology, equipment, and machines with doing science, Westport students made an important distinction. Westport students specifically described scientists using "big machines" and "high tech equipment". Melanie, the 10th grade Filipina student from Westport provides a representative example: "They use really high tech equipment and computers." A view that doing science requires the use of highly technical equipment may make science seem more inaccessible to Westport students. In addition, some students described prior experience with scientific research project. The science practice of "discover/explore" was unique to Redwood students with prior research experience. Similarly, the practice of "present research" was unique to the Westport student with previous experience in the science program.

In the next section, I examine the *meaning* students associated with different types of science practices discussed above.

Meaning of science practices. In order to better understand how students think about the science research process, students descriptions of science practices were analyzed for the *meaning* they associate these practices. The goal is to determine the range of meaning students' associate with science practices from prescribed/procedural to more authentic and aligning with the work of real scientists and how this shapes they ways they see themselves in relation to science. In this section, I examine the *meaning* students associated with different types of science practices described above and their views of the scientific research process.

Restrictive vs. expansive views of science practices. During interviews, students described a range of *meanings* that they associated with the different types of science practices described above. The meaning students associated with science practices fell into two broad categories: *Restrictive* and *Expansive*. As discussed above (see Methods), *restrictive views* of science practices describe the scientific research process as prescribed, known, static, rigid, and linear. Restrictive practices involve finding facts and known answers. This involves a view that there is one correct way of doing things in order to arrive at the correct answer. In addition, stereotypical images of science (e.g. mixing chemicals in a lab) and power differentials between what scientists do and what students have access to were categorized as restrictive because these views limit students' ideas about their abilities to engage with science. Restrictive science practices limited opportunities for participation in science (e.g. one way to do things) and/or students' ideas about their ability to engage with the science process in a meaningful way (i.e. based on how they see themselves in relation to the practice). Note that restrictive views of methods align with how students experienced labs/experiments in school. *Expansive views* of science practices capture the explorative, non-linear, iterative, flexible, constantly changing/evolving, and problem solving aspects of the scientific research process. Expansive practices involve the generation of new knowledge and following flexible/non-linear paths where tangents are often explored. In addition, multiple ways of approaching research are utilized. Expansive science practices align with and map onto the work of real scientists and what they actually do to conduct scientific research. This view of science practices broadens opportunities for participation in science by expanding students' ideas about their abilities to engage with the science process (e.g. multiple ways to engage with science are accepted). From students' descriptions, several expansive and restrictive subcategories emerged (see Table 2 for categories, definitions, examples). In addition, a small number of students also cited practices as both restrictive and expansive simultaneously (i.e. for an individual practice, some aspects of their description were categorized as expansive while other aspects were categorized as restrictive). These views were labeled *Combination* (see Table 2).

Table 2. Restrictive &Expansive Categories/Subcategories of Meaning for Science Practices, Definition, Student Examples

Category of Meaning	Subcategory of Meaning	Definition	Student Quote
Expansive	Iterative/ Analytic	a) Science practices as connected, iterative, how practice function together; *and/or* b) Sense making around practices, analytic understanding	"You collect enough data for you to be able to generalize things…it's like you were looking through a telescope…you thought you found it but then it turns out you didn't look far enough." (Naomi, Bay)
	Methods (create, multiple ways)	Something scientists create and adapt to their research needs. Multiple approaches utilized.	"Being able to question something and then finding like hella other answers to it… or find different ways to come at the subject." (Melanie, West)
	Unknown	Science is the pursuit of the unknown; opportunity to find out something new.	"People are always discovering new things with new technology and new research… there's a lot of things we still don't know." (Antonio, Red)
	Collaborate	The science process involves collaboration, multiple perspectives are beneficial.	"I'm guessing some scientists come together and talk about what they're researching…they might give other people tips." (Vincent, West)
	Messy *(Post only)*	a) Science as messy, unexpected things happen, problem solving is key, adapt to the unexpected b) Following tangents, unexpected observations lead to new pathways of exploration.	"Also observations because, cause I seen them like, look, like start a project but then something happens, so like, it changes their project in a way." (Carlos, Red)
Combination	N/A	Students express both restrictive and expansive views of science practices.	"They just have to redo it or find a better way to do it." (Carlos, Red)
Restrictive	Facts	Students describe science as a collection of facts.	"All of our results are just like little facts that we learn." (Jasmine, Red)
	Known	View that the right or wrong answer exists. Aspects of the scientific research process can be right/wrong.	They have to go back and correct it. And if they mess up again, they have to do it (research) all over again until they get the correct answer. (Lucas, Bay)
	Methods (prescribed, linear)	Methods used to conduct scientific research as rigid, linear and prescribed; one correct way to do things	"They first do their hypothesis, which they think 'oh this works this way', then they do a thesis and then they do it several times and then other scientists do it several times." (Alejandra, Redwood)
	Superficial	Students describe science in superficial, stereotypical ways.	"I think about Bill Nye the Science Guy, like chemical doctors with the glasses in the laboratory." (James, West)
	Power	Students express power/status differential of scientists compared to other people; power/status allows them to *do* certain practices.	"Well, first, you got to go to school. And then, get money, sponsor, and then actually do the research." (Fernando, West)

Across programs, when all subcategories were combined, focal students described science practices in slightly more restrictive ways than expansive ways (see Figure 5). Descriptions of science practices as both restrictive and expansive (i.e. combination) occurred at much lower rates (see Figure 5). This means that overall, focal students viewed science practices and the research process in slightly more rigid and prescribed ways with known answers (i.e. restrictive view) than explorative, changing and unknown (i.e. expansive view). The most common *subcategories of meaning* associated with science practices within the broader restrictive and expansive categories were: science as unknown/changing (i.e. *Expansive: Unknown*), practices as involving high tech equipment as described by Melanie above (i.e. *Restrictive: Superficial)*, and science methods as rigid, linear, prescribed (i.e. *Restrictive: Methods*). Not surprisingly, students' descriptions of methods used by scientists align with their descriptions of school science labs/experiments above (see Table 2). The common representation of both restrictive and expansive ideas suggests that students hold complex repertoires of ideas about the meaning of science practices. In the next section, I explore the multiple and often conflicting ideas that students hold within their repertoires about the *meaning* of science practices.

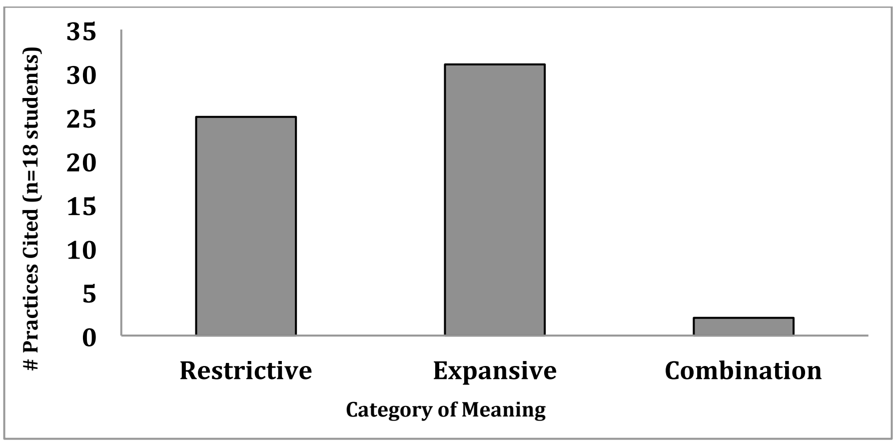

Figure 5. Incoming *meaning* of science practices described by focal students across programs.

Students have complex repertoires: Holding restrictive & expansive practices. Findings show that it was common for students to hold conflicting ideas about the meaning of science practices within their repertoires. The majority of focal students described both expansive *and* restrictive views of the scientific research process. In other words, individual students described some science practices in expansive ways while describing other practices in restrictive ways. It was rare for students to describe all science practices as either restrictive or expansive. Lucas, a 10th grade student from Bayside provides an example. When asked to describe how scientists know what is true Lucas says: "By proving it in a sort of science. Which isn't the correct word, because you can't really prove anything because at some point it is bound to change. So it can't stay like that." In this example, Lucas describes an expansive view of science where the knowledge constructed from the research process is constantly changing (categorized as *Expansive: Unknown*). However, at the same time Lucas describes a restrictive view of science methods:

> I think that's why it (research) takes so long. Because they have to go back and correct it. And if they mess up again, they have to do it all over again to try to find a correct answer.

Here, Lucas describes science as a pursuit of a "correct answer". In addition, he describes a laborious and rigid process of having to "do it all over again" if scientists "mess up" (categorized as *Restrictive: Methods*). This conflicts with his expansive views above that describe science as constantly changing. In this way, Lucas expresses both expansive and restrictive views of science. The tensions Lucas expresses were common across focal students.

In order to capture students' complex incoming repertoires and to document shifts following program participation students were grouped by the meanings they associated with science practices. Findings show there were roughly three groups of students: 1) Mostly Restrictive ideas: students who entered the program with mostly restrictive ideas about science practices, 2) Partial: students who associated restrictive and expansive meanings with science practices as approximately equal rates, and 3) Mostly Expansive: students who entered the program with mostly expansive ideas about science practices (see Figure 6). In some cases, students only described meaning associated with one science practice. In this case, students were not included in this analysis because there was not enough information available to categorize them. Most students entered the program with Partial or Mostly Restrictive views of science (see Figure 6). This reflects the slightly more restrictive views of science that students held overall.

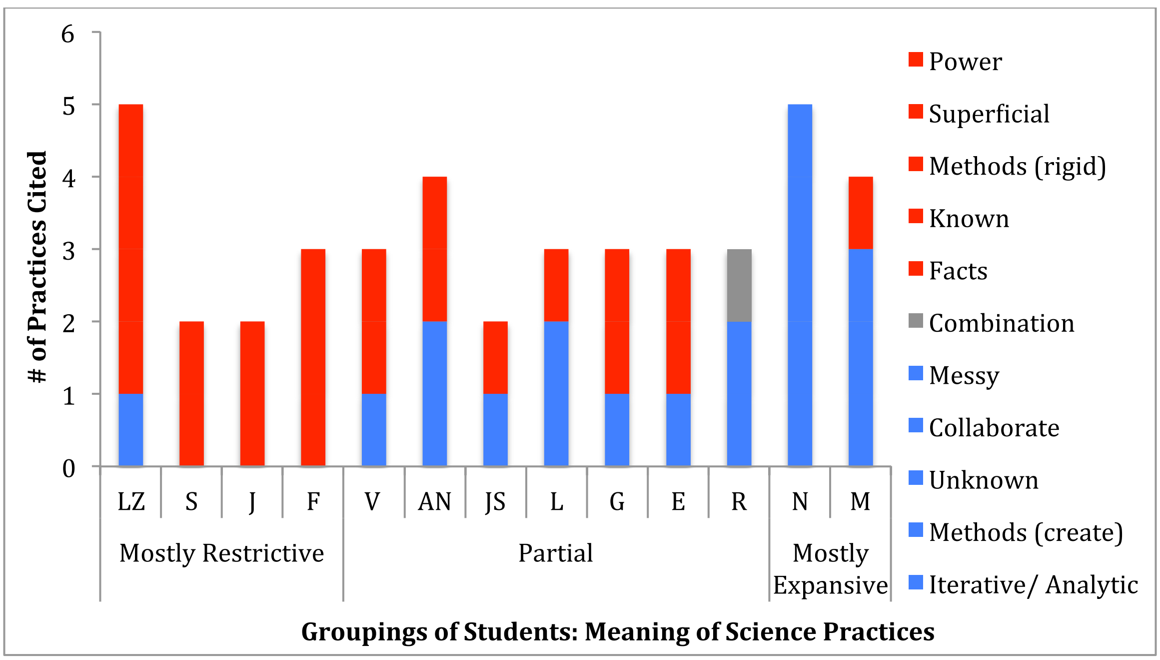

Figure 6. Students' incoming complex repertoires of meaning for scientist practices by student and group. Red=restrictive practices, Blue=expansive practices, Gray=combination.

The example of Lucas above is representative of students in the Partial grouping that described restrictive and expansive meanings of science practices at almost equal rates (see Figure 6, Partial, Student L). Examples of students that were grouped as Mostly Restrictive or Mostly Expansive are as follows:

Mostly restrictive views. Students in this group associated only or mostly restrictive meanings with science practices (see Figure 6, left side). These students most commonly described science practices in superficial ways (i.e. *Restrictive: Superficial*). In addition, students in this group described science methods in restrictive ways. Serena, a 12th grade student from

Westport provides an example (see Figure 6; Mostly Restrictive, Student “S”). She describes scientists as always in lab:

> I think of like labs, very smart people, in the labs, and tests, and stuff, and they know everything…however it’s called, the chart (periodic table).

Here, Serena says scientists are “very smart people” in labs who “know everything”. In addition, she views scientific methods as prescribed, and science as pursuit of a known answer:

> They do the lab, more than once, and record their answers, or get other scientists perspectives on it. And let them do the lab, and see what results they get. I think they should test the thing more than once, because if they did make a mistake on that one, they could see that the other ones got different answers. And be like, ‘oh I might have made a mistake on that’.

Here, Serena explains an idea that scientists record “answers” and compare their results with other scientists to make sure they didn’t make a “mistake”. Students in the Mostly Restrictive group, like Serena, describe multiple science practices as restrictive.

Mostly expansive views. Students in this group describe mostly expansive views of science (see Figure 6, right side). This was the least common group of students (2/18). Students in this group commonly described science as a pursuit of the unknown (i.e. *Expansive: Unknown*). Naomi, the case study student from Bayside provides an example:

> (Scientists) are watching things like how statistics and things are moving, how things are fluctuating and then they're also looking out for new things.

Naomi expresses an idea that scientists “look out for new things.” She views science as a pursuit of the unknown where the goal is to examine how “things are moving” in order to determine what is new and different. In addition, she describes ideas about collecting enough data in order to generalize findings:

> You collect enough data for you to be able to generalize things…if you saw 4 cats, 3 were black and 1 was white you'd think, well they're all cats. But then, you found out that all white cats have something different about them…the black ones are cats and the white ones are this special thing, you just didn't know. It was like you were looking through a telescope and you were trying to find something and you thought you found it but then it turns out you didn't look far enough.

Here, Naomi describes the analytical aspects of science (ideas categorized as *Expansive: Iterative/Analytic*). In addition, she describes science as a pursuit of the unknown. Both illustrate expansive views of science practices.

Serena, Lucas and Naomi provide examples of three different groupings of students that view science practices in ways ranging from restrictive to expansive. The groupings of Partial (i.e. Lucas) and Mostly Restrictive (i.e. Serena) were most common. The tensions that students hold suggest that students hold complex ideas about the meaning of science practices within their repertories (Linn, 2006). In addition, these tensions suggest that by building on students’ expansive conceptions of science there is an opportunity for broadening students' views of what counts as science practices.

Differences by program: Meaning of practices. Interesting differences in the meaning students associated with science practices occurred across programs. Westport students more commonly held Mostly Restrictive views of science compared to students from the other programs (see Figure 6, Mostly Restrictive, Student S, F, J). All focal students from Bayside and the majority of focal students from Redwood described aspects of science as unknown, changing (i.e. *Expansive: Unknown*). This was much less common for Westport students. In addition, the majority of focal students from Westport described science in superficial or stereotypical ways (i.e. *Restrictive: Superficial*) while half of the focal students from Bayside and no students from Redwood expressed this view of science practices. Combined with findings from above, findings suggest that Westport students experience science practices in more restrictive ways than students from other programs. This may limit focal students ideas about their abilities to engage with science practices.

What does this all mean for how students see themselves in relation to science? In many ways, the *types* and *meanings* of science practices that students describe are common; some appear to align with school science experiences (e.g. experiments) while others may emerge from students' experiences in other programs are images of science ubiquitous in the media (e.g. high tech equipment). However, what has not been explored is how students see themselves in relation to these types and meanings of science practices. How do students see themselves in relation to different "types" of science practices? What are the identity implications for associating restrictive or expansive meanings with science practices?

In the next section, I explore relationships between the meaning students associate with science practices and how they see themselves as science learners. I then build on the contrasting cases of Lorenzo/Fernando and Melanie/Naomi in order to illustrate how these relationships play out differently for high and low perceived ability students and work to further shape students' feelings of belonging or not belonging in science.

Identity implications: Meaning of science practices & perceived ability. Findings show that for focal students in this study, a relationship exists between the meaning students associate with science practices and how they see themselves as science learners. Interesting patterns emerged between focal students' incoming perceived ability in science (i.e. feeling "good" or "bad" at science) and the meaning they associated with science practices (i.e. restrictive, expansive). Low perceived ability students commonly described science practices in restrictive ways (e.g. superficial, known) (see Figure 7). In addition, all students in the Mostly Restrictive group above were low perceived ability students. In contrast, high ability students more commonly described science practices in expansive ways (e.g. unknown, changing adaptable/flexible methods) (see Figure 7). This relationship is similar to those identified in Chapter 4 between perceived ability and characteristics associated with scientists, sense making about racial/ethnic underrepresentation in science and students perceived ability in science. Though sample sizes are small (high: n=5; low: n=7), this finding is important because it suggests that a relationship exists between the meaning students associate with science practices and how they see themselves as science learners.

The relationship between perceived ability and meaning of science practices (restrictive vs. expansive) has implications for students' ideas about their abilities to engage with science practices in meaningful ways. Restrictive science practices limited opportunities for participation in science (e.g. one way to do things) and/or students' ideas about their ability to engage with the science process in a meaningful way (i.e. based on how they see themselves in relation to the practice). Low perceived ability students more commonly described science in superficial ways such as mixing chemicals (i.e. *Restrictive: Superficial*) compared to high perceived ability students (average # of practices: high = 0.4; low = 0.9). In addition, only low perceived ability students described science as a collection of facts (i.e. *Restrictive: Facts*) and as a pursuit of a known and correct answer (i.e. *Restrictive: Known*). Restrictive practices are often based on students' experiences with prescribed labs and experiments in school. These views can limit low perceived ability students' ideas about their abilities to engage with science practices because there is one correct way. Similar to their lack of success in school science, low perceived ability students may view practices of scientists as something they also can't engage with in a meaningful way. For example, if students view science as the pursuit of the correct answer, but perceive themselves as not good at science, this may limit their ideas about their ability to obtain the correct answer and to engage with science.

In contrast, expansive views of science broaden opportunities for participation in science and broaden students' ideas about their abilities to engage with science practices (e.g. multiple ways to engage with science are accepted). High perceived ability students more commonly described science as a pursuit of the unknown and a body of knowledge that is continually changing (i.e. *Expansive: Unknown*) at much higher rates than low perceived ability students (average # of practices: high = 1.4, low = 0.4). This view of science suggests there is much to be discovered in science and in this way provides an opportunity to make a contribution. In addition, only high perceived ability students described science methods as flexible (i.e. *Expansive: Methods*), science involving an iterative process and analytic sense making (i.e. *Expansive: Iterative/Analytic*) and science as collaborative (i.e. *Expansive: Collaborative*). Viewing science in these expansive ways may broaden opportunities for participation in science because science practices seem more accessible. For example, if a student views scientific methods as involving adaptability and multiple approaches it is plausible they may feel there is space to make mistakes and mess around and an overall greater agency to engage with science practices in this flexible way.

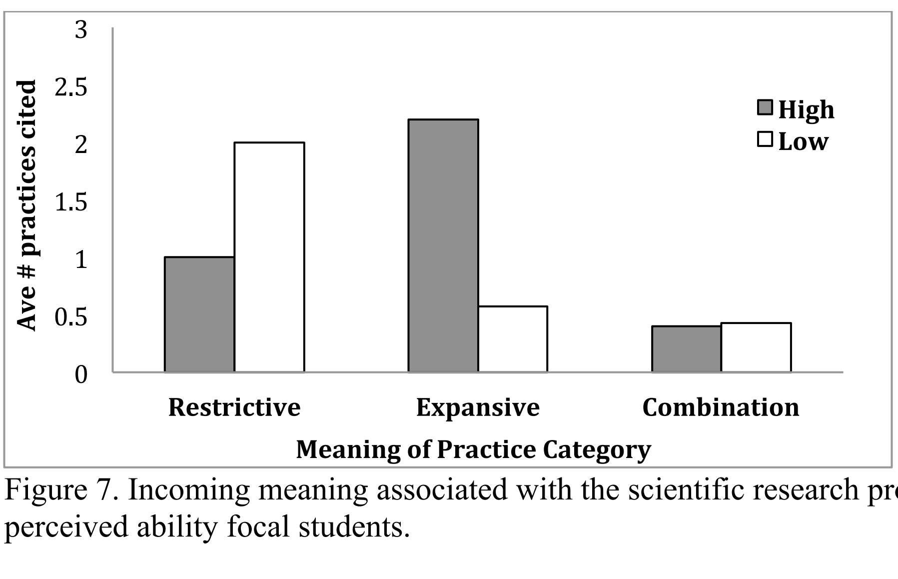

Figure 7. Incoming meaning associated with the scientific research process by high vs. low perceived ability focal students.

Views of scientific research process: All student surveys. The relationship between perceived ability and views of science practices is supported by findings from all student survey.

On pre program surveys, students answered open-ended questions regarding their views of the scientific research process. For example, students were asked to agree or disagree with the following statement and then asked to explain their choice: “In order to do good science, scientists need to closely follow the steps of the scientific method”. Responses were scored on a scale that ranged from expansive to restrictive (see Appendix 2). Aligning with findings from above, low perceived ability students described more restrictive views of science (e.g. one must closely follow steps of scientific method) while high perceived ability students described more expansive views of science (e.g. science methods as adaptable) (see Figure 8).

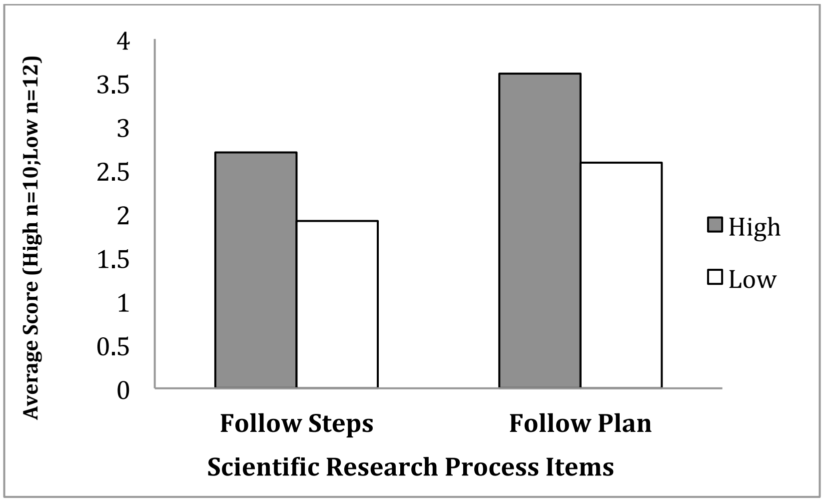

Figure 8. Incoming views of the scientific research process by high vs. low perceived ability students across programs.

In the contrasting cases below, I illustrate how the relationship between perceived ability and the meaning students associate with science practices plays out differently for high and low perceived ability students.

Case Studies: Practices of Scientists & Identity Implications. Next, I build on the contrasting cases above to explore how students’ see themselves in relation to the science practices they view as central to the work of scientists and how this contributes to their feelings of belonging or not belonging in science (see Table 1). In addition, findings from Chapter 4 are built into these cases (e.g. characteristics of scientists, race) in order to provide a holistic view of how students see themselves in relation to science.

Additional ways he doesn’t belong. As described above, Lorenzo enters the program with a low perceived ability in science. He struggles in science class and continually questions if he belongs in science. He views science practices in restrictive ways and is grouped with the Mostly Restrictive students above. He describes science as a rigid and linear process and the pursuit of a correct answer. He explains his view of the science research process: “They like experiment and go I guess through the whole methods that they're supposed to go through.” In addition, he views science as a collection of facts. In this way, Lorenzo connects prescribed steps with obtaining facts. As described in the school science section above, he struggles to learn fact-based things like vocabulary and concepts in school. This may limit his ideas about his abilities to engage with science practices.

Combining these findings with those from Chapter 4, Lorenzo does not see overlap between himself and scientists; in what they do or in *who* he sees doing science. Lorenzo struggles with science practices in school and views practices of scientists in restrictive ways. He views scientists as “good at science” and having a “serious attitude”. Lorenzo identifies as Mexican and views scientists as white and Asian. Taken together, Lorenzo struggles with some aspects of science in school, questions whether he belongs in science and describes only restrictive meanings of science practices – practices he doesn’t see himself as good at. This may limit the options they view as available to them in science.

Scientists “hella smart in lab mixing chemicals”. As described above, Fernando enters the Westport program with a very low perceived ability in science. He experiences little success in science and in school in general. Like Lorenzo, he views science practices in restrictive ways and is grouped with the Mostly Restrictive students above. In the opening excerpt, he describes superficial views of science: “I (think of) scientists hella smart in a lab, mixing chemicals.” Here, Fernando describes ideas about *who* is a scientist (i.e. “hella smart” people) and what they do (i.e. “mix chemicals”) as connected. He also associates power with science practices: “Well, first, you got to go to school. And then, get money, sponsor, and then actually do the research.” He views research as requiring money and a sponsor – things he likely does not have access to. This may make science seem inaccessible. When I ask him to describe a scientist he says: “I don't really know scientists. I don't even know one scientist's name.” In this way, Fernando describes scientists as people he cannot imagine. Despite this, he expresses a desire to pursue a career in science: “I want to be a pharmacist.”

Combining these findings with Chapter 4, Fernando characterizes scientists as “hella smart”, “hard working” and “not his race”. In addition he makes sense of disparities in *who* is a scientist by internalizing a racial narrative that “people of color slack off”. As described above, he gets “distracted” in science class and experiences low academic success. In this way, he validates the racial narrative he asserts. Taken together, Fernando does not see himself engaging with the types of science practices that he views as central to science, he views scientific research as requiring money and a lot of schooling. He views scientists as “smart” and “hard working” and not Latino. He is “distracted” in science, unsuccessful in school and Latino. It is plausible that together these conceptions may limit the options Fernando views as available to him in science.

“Questioning” like scientists do. As described above, Melanie enters the Westport program with a medium/high perceived ability in science. She enjoys science class and is confident about her science abilities. She is grouped with the Mostly Expansive students above and views science as unknown, changing, where methods are adaptable and flexible. She describes her view of science: “experimenting and finding…something new all the time.” She views science practices such as: creating methods and questioning as important. She describes the multiple approaches and adaptability she associates with the methods scientists use to conduct research: “Being able to question something and then finding the answer to it, but like not just one answer, like hella other answers to it… or find different ways to come at the subject.” When as I asked if she see science as an important part of who she is she says: “Yeah! Cause I find myself questioning a lot”. In this way, Melanie sees overlap between what she does (i.e. “questioning a lot”) and what scientists do. This may make science seems accessible to Melanie because she engages in practices she feels are important in science.

However, Melanie presents a complex example because she also views scientists in superficial ways. She describes how she envisions scientists: “I think of them in white gowns and like, with like clipboards and like really high tech equipment and computers, and like people with glasses on and goggles and stuff.” Here, she describes stereotypical ideas about what scientists look like (e.g. glasses, goggles) and what they do (e.g. use high tech equipment) and like Fernando describes these ideas as connected. In addition, as described above, she compares the types of science practices she does (small experiments) to what scientists do (findings solutions).

As described in Chapter 4, Melanie views scientists as "powerful" due to their knowledge and "not her race". She feels that some races and classes of people might not feel comfortable pursuing science because it's a high status position. Taken together, Melanie sees herself doing some of the things she thinks of as central to the work of scientists (i.e. questioning), while viewing other practices as inaccessible (e.g. using high tech equipment). When I ask her if she thinks she could be a science person she says: "I think I could be if I put like the effort and like my mind to it." She expresses a confidence that she could do this. However, she explains she's unsure if she wants to be saying "I don't know, it's hard to think." Her conflicting views of science may contribute to this uncertainty. In addition, the disconnect she sees between herself (e.g. Filipina) and *who* she sees doing science may add to this uncertainty.

"Figuring things out" like a scientist. As described above, Naomi enters the Bayside program with a very high perceived ability in science. She is confident in her science abilities and exudes passion and enthusiasm for science. Naomi thinks of science in expansive ways and is grouped with the Mostly Expansive students above:

> Just kind of really seeing what makes things tick, whether it's in a human body, whether it's with chemical compounds…science is just about figuring out what makes things happen.

Here, Naomi expresses a view that science is about figuring things out. Interestingly, Naomi's experiences with prescribed labs in school, described above, contrast to her views of what scientists do. Despite these contrasts, Naomi holds an expansive view of the science process and views scientific methods as flexible and adaptable, where multiple approaches are taken. She describes scientists as curious and the process they go through as flexible: "Kind of experimenting and fooling around with things because I mean you're not going to find anything new without just kind of going for it." Naomi views herself as engaging with similar practices:

> I'll look things up like how things work, you know if I'm wondering about them. Or I'll use them to do something fun. Sometimes I'll set up, you know like the game Rat Trap? Just set up all these different reactions and make something cool and I just kind of like doing stuff like that.

Naomi see herself doing what scientists do: wondering, being curious, and trying to figure out what makes things work in a flexible and exploratory way. It is plausible that this broadens her ideas about her abilities to engage with science practices.

Recall from Chapter 4, that Naomi views a lack of racial representation in science and views scientist as East Asian. She also feels that people do not perceive her as interested in science "at first glance" specifically because she is African American. Taken together, there are many ways that Naomi can see herself as belonging in science – engaging with similar practices as scientists (e.g. figuring things out), having similar characteristics (e.g. curious). She strongly identifies as a science person and expresses a strong desire to pursue science in college: "I want to be a surgeon." However, as described in Chapter 4, racialized narrative impacted all focal students in this study. In Naomi's case she is affected by racialized societal perceptions and by broader impacts of race in our society. This suggests that all focal students, even those that are passionate about science, like Naomi, need resources that support their science and racial identities in order to navigate productive pathways in science.

Summary: Scientist Practices. The *types* of science practices that students associated with scientists in many ways mapped onto their experiences with prescribed labs in school. Interestingly, some students compared what *they* do in science class with what scientists do, and/or questioned their ability to engage in the types of science practices they viewed as central to the work of scientists. Across programs, the *meaning* that focal students associated with science practices was more restrictive than expansive. Findings show that it was common for students to hold conflicting ideas about the meaning of science practices within their complex repertoires. There were significant differences in the meanings that students associated with science practices across programs. Westport focal students more commonly described science in restrictive ways (e.g. superficial) compared to students from Bayside and Redwood. This suggests that students from Westport may view science as less accessible to them compared to students from other programs.

In addition, findings suggest that for focal students in this study, a relationship exists between students' perceived ability in science and the meaning they associate with science practices. Low perceived ability students view science in restrictive ways while high perceived ability students viewed science in more expansive ways. Students who view science in restrictive ways and see themselves as not good at science may not view engaging with science or contributing to the scientific research process as a possibility. High perceived ability students such as Melanie and Naomi were able to identify similarities between practices they engaged in and those they felt scientists used to conduct research such as asking questions (i.e. Melanie) and figuring out how things work (i.e. Naomi). In contrast, low perceived ability students like Fernando and Lorenzo are unable find overlap between they practices they do or are good at and what scientist do. This may be an extension of their school science experiences. In this way, restrictive views of science practices may limit opportunities to engage with science, while expansive views of science may broaden opportunities for participation in science.

Summary Incoming Ideas about Practices of Science

Findings show that the school science practices focal students experienced are those commonly used to teach science in school (e.g. labs/experiments, learn vocabulary). In addition, across programs, the meaning students associated with the most common school science practice of doing labs/experiments was prescribed, procedural and where results are judged as right or wrong. However, the contrasting cases show how high and low perceived ability students experience the same school science practices in different ways. In addition, the cases illustrate how experiencing success with school science practices (or not) impacts how students see themselves as belonging or not belonging in science. High perceived ability students may be able to more easily look beyond the bounds of restrictive school science practices because they more readily experience success. In contrast, for students who don't see themselves as good at or successful at science, certain practices (e.g. memorizing vocabulary) may create barriers to entry, limit opportunities to participate in these practices, and cause students to question if they belong in science.

Students' experiences with school science practices were reflected in their ideas about the practices scientists use to conduct research (e.g. experiments/labs). In addition, findings show that students see themselves in relation to the practices of scientists in two ways: 1) by comparing the types of science practices *they* do in school to what scientists do, and 2) through the meaning they associate with science practices that may limit (i.e. restrictive) or broaden (i.e. expansive) their ideas about their abilities to engage with science. Findings suggest that a relationship exists between the meanings students associate with science practices (i.e. restrictive or expansive) and how they view themselves as science learners. This has implications for how students see themselves as able to engage or not engage with science in meaningful ways. Low perceived ability students described more restrictive views of science practices during pre program interviews. In contrast, high perceived ability students described more expansive views of science practices. The relationship between perceived ability and meaning of science practices (restrictive vs. expansive) has implications for students' ideas about their abilities to engage with science practices in meaningful ways. The contrasting cases illustrate how the relationship between perceived ability and the meaning students associate with science practices plays out differently for high and low perceived ability students. If students associate expansive meanings with science practices, see themselves as good at science, and engaging in science practices similar to what scientists do, this may broaden the opportunities students' views as available to them in science. In contrast, if students associate restrictive meanings with science practices, see themselves as bad at science and not doing or being good at the practices that scientists engage with, this may limit the options they view as available to them in science.

Finally, findings suggest that a relationship exists between students' ideas about *who* does/can do science and what scientists "do". Findings from Chapter 4 show that relationships exist between students' perceived ability and their conceptions of scientists (e.g. race, characteristics). Finding from this chapter suggest that similar relationships exist between perceived ability and students' ideas about the meaning of science practices as expansive or restrictive. The contrasting cases of Fernando/Lorenzo, Naomi /Melanie illustrate how students' ideas about *who* can do science and what scientists "do" are inextricably linked. In addition, the contrasting cases show how high and low perceived ability students see themselves in relation to what scientists do in different ways. When combined with findings from Chapter 4, findings suggest that when students view science practices as inaccessible or not aligned with anything that they do, and conceptualize science people in ways that don't coincide with how they see themselves in relation to science (e.g. race, characteristics) it may be challenging for students to view science as a possibility.

Next, I explore shifts in focal students' ideas about science practices after conducting scientific research during the summer science programs. I examine shifts in the types and meaning of science practices. In addition, I explore how in some cases students' ideas about *who* can do science and what scientists "do" shifted together through participation in the practices of science and new possibilities were made available to students.

Post Program Shifts: Science practices & Identity Implications

Findings show that students' ideas about what counts as science and the meaning they associated with science practices shifted following program participation. Across all three programs, participation in authentic scientific research: 1) allowed students to add new *types* of science practices to their repertories (e.g. analyze data) and 2) expanded or shifted the *meanings* students' associated with science practices from restrictive (e.g. prescribed, right/wrong) to expansive (e.g. science as iterative process). In addition, findings show that students' ideas about *what* science is (i.e. science practices) and *who* can do science shift together through participation in the practices of science. However, findings also suggest that program resources are needed that attend to both the science practices that are promoted and the messages youth of color receive about *who* can do science in order to make new possibilities available for focal students. Together with results from Chap 4, findings indicate that while reform efforts that focus on promoting authentic science practices are important, a focus on shifting the ways we teach science practices (e.g. inquiry, Next Generation Science Standards) alone is insufficient for dismantling persistent issues of equity in science education.

First, I discuss shifts in the *types* of science practices that occurred following program participation. Next, I examine the shifts that occurred in the *meaning* students associate with these science practices. Finally, I examine the identity implications for these shifts and how engagement in authentic science research has the potential to create new possibilities for *who* students can become in science.

Shifts in Types of Science Practices

In this section, I examine shifts in students' ideas about what counts as science practices. Findings show that following program participation and engagement with scientific research, students learned and added new *types* of science practices to their repertoires. This expanded students' ideas about what counts as science. During post program interviews, students were asked to describe their research projects and what they "did" to conduct scientific research. The biggest pre to post program shifts occurred with the following types of science practices (grouped from largest to smallest percent change): 1) present research, 2) collect data, analyze data, 3) use math/formula, question, findings/results, 4) explain, collaborate, discover/explore, 4) design build, 5) use equipment, make observations (see Figure 9). Focal students described these types of practices much more commonly in post program interviews compared to pre program interviews. In addition, following program participation, focal students added new types of science practices to their repertories that were not mentioned during pre program interviews. Focal students described the following new types of science practices (grouped in order from most commonly cited to least): 1) graph, 2) problem solve, 3) apply findings; be careful/precise, 4) make predictions; memorize (see Figure 9). What is significant is that many of the practices students gained from doing scientific research align with goals for teaching science in school and the practices promoted by the Next Generation Science Standards (NGSS). In addition, many of these practices are central to science innovation and extend beyond those promoted by standards documents (e.g. problem solve, make predications, make observations). These findings suggest that students add new, relevant, and innovative science practices to their repertoires by engaging in scientific research.

Interestingly, for some students expanding ideas about types of science practices, helped create shifts in their ideas about *who* can do science. Fernando, the 12th grade Latino student from the opening excerpt and case study above describes how his ideas about what counts as science shifted following program participation:

> I thought science was just like scientists, heavy, hella smart in a lab, mixing chemicals...but here we just walk around…taking air samples with a machine, just writing everything down, and learning how to make graphs and how to present, and talking about what we learned.

Fernando's ideas about *what* science is and *who* can do science shifted together based on the types of practices he learned during the program (e.g. take samples, make graphs, present). In addition, he expresses a shift in agency as a result of engaging in scientific research. His ideas about *who* can do science shifted from "hella smart people in a lab" to himself and his peers as capable doers of science (e.g. "talking about what we learned"). His statement suggests that science research became more accessible to him during the program (i.e. "we walk around taking air samples with a machine"). In addition, Fernando shifts from being "distracted" in class to playing an active role in the research project. This made him aware that science was something *he* and his peers could do. In this way, learning these new practices helped shift agency to himself and his peers. In addition, adding new science practices to his repertoire increased Fernando's ability to conduct research and fostered learning. For example, he describes an increased ability to "do" science because he learned how to use the machines while taking samples. In addition, through making graphs and analyzing data he describes a sophisticated insight: "I got to find out how clean (the transportation) really is, and if it's really, well, being environmentally friendly is one thing, and being clean is another." Fernando makes an important distinction between being environmentally friendly (i.e. mass transportation, running on alternate energy) and being clean (i.e. air quality in the stations). In this way, learning new practices shifted agency for Fernando, increased his ability to conduct scientific research, and fostered analytical sense making and learning.

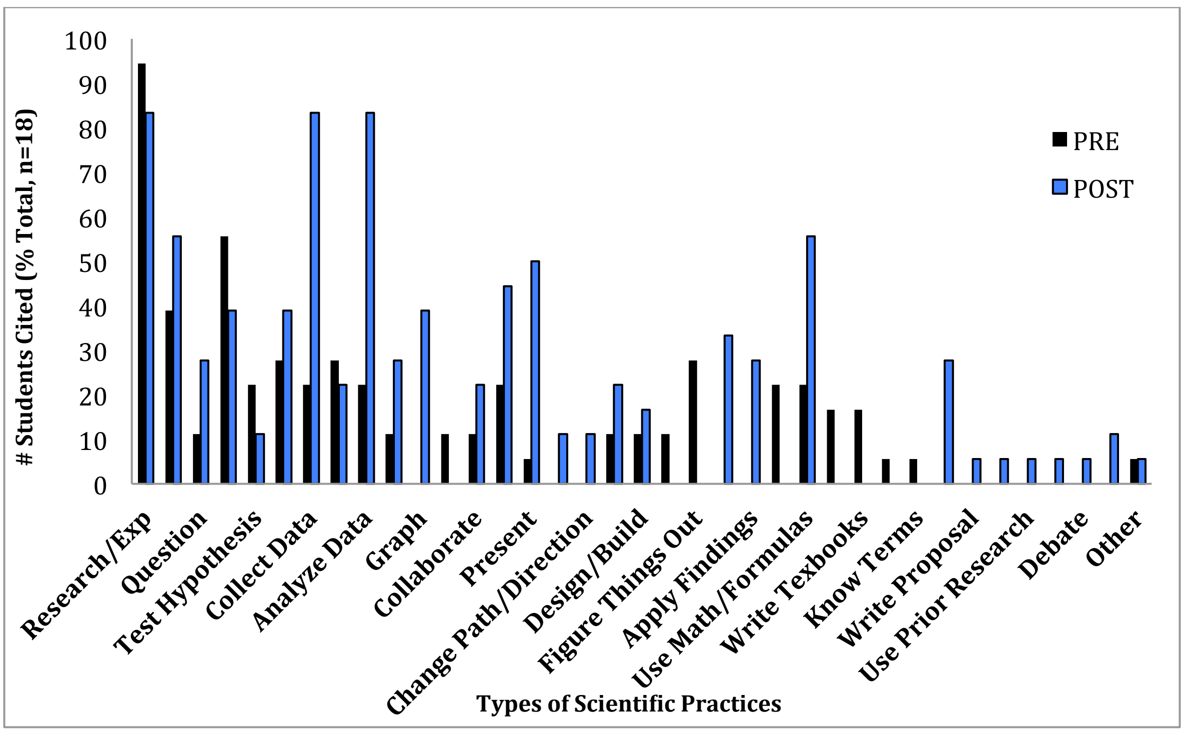

Figure 9. Pre vs. post program shifts in *types* of science practices described by focal students across programs (n=18).

Though students across programs added new science practices to their repertoires, not all students saw themselves as capable doers of science following program participation. Recall from the pre program findings above that Elana, the 10th grade student from Bayside, expressed hesitation about whether she could become a scientist based on her struggles with technology.

During pre program interviews she described using technology as central to the work of scientists. Yet she experienced a lack of success when using technology (e.g. "technology does not like her"). Elana conducted an engineering research project during the summer program and was in a research group with two boys and another girl. Students used a computer to record variables and data points while running trials during data collection. During post program interviews, I asked her what she learned from conducting research during the summer and she responded:

> The guys were doing everything, so I didn't really get to do anything. I mean they put me on the computer for like a minute. But I'm not good with computers so I didn't know what I was doing.

Elana's fear of not being good with technology is validated by her lack of success when she was put on the computer during data collection "for like a minute". When Elana says "they put me on the computer" she is referring to her group mates and the "guys" are the two boys in her group. This short time suggests she did not have adequate training and/or proper time to figure out the technology. In this way, she was not set up to experience success engaging with this practice. What is fascinating, is that even though her time on the computer passed in a moment, the take away message for Elana was that she's "not good with computers" and "didn't know what she was doing". This message reinforces her incoming concern that maybe she can't do science. She adds that in general there was "too much equipment that I did not know how to use." This suggested that Elana didn't know how to use the rest of the equipment involved in their complex study that well either. In this way, Elana does not see herself as a capable science learner like Fernando. This research highlights the importance of these moments and the powerful messages students can receive in a short amount of time about where they do and don't belong based on their experiences engaging with science practices. In addition, this example highlights the importance of providing program resources that allow students to successfully engage with science practices.

Findings show that students can learn new types of science practices that align with and extend beyond those promoted in NGSS by engaging in scientific research. For some students (e.g. Fernando), expanding ideas about what counts as types of science practices made science more accessible, fostered learning and allowed him to identify as a capable science learner. In this way, his ideas about *what* science is and *who* can do science shifted together. However, it is important to note the relational aspects of engaging in science practices and the message students may receive if they do not have the opportunity to experience success. The example of Elana underscores the importance of providing program resources that facilitate successful engagement with science practices so that students are able to see themselves as capable science learners. Program resources are explored in detail in Chapter 6.

Differences by program: Types of science practices. There were differences in the types of science practices that students added to their repertoires or emphasized as important based on the programs they attended and the focus of the research they conducted. For example, all Redwood and Westport focal students described the practices of "collect data and analyze data" as central while only half of Bayside focal students described these practices. In addition, the practices of "graphing" and "finding results" were commonly described by Redwood and Westport students but not mentioned by Bayside students. This suggests that students from Redwood and Westport experienced these aspects of the scientific research process while some

Bayside students perhaps did not. In addition, half of Bayside focal students and the majority of Westport students described the practice "present research" but much less so by Redwood students. Presenting research was a culminating experience in all three programs, but was least emphasized in the Redwood program. Finally, particular types of practices were unique to certain programs. Practices unique to Bayside were: "design/build", and "memorize", and Westport: "use prior research", "refine topic". In addition, Redwood students had the most intensive research experiences (e.g. longest program duration and time spent doing research with scientists). As a result, Redwood students described unique practices that suggest they gained insights into the nuances of the scientific research process. These practices include: "make predictions", "write proposals", and "change path/direction" of research. Variability in the science practices gained suggests that the types of science practices promoted and the program resources made available around the practices are important to pay attention to when designing program experiences.

In the next section, I build on the findings above to explore how the *meaning* students' associated with science practices shifted following program participation. In addition, I explore the identity outcomes that may be a result of these shifts.

Shifts in Meaning of Science practices: Developing Expansive Views

Across programs, students overwhelmingly developed more expansive *meanings* of science practices and views of the scientific research process following program participation. In addition, through engaging in scientific research, students' resolved conflicts within their complex repertories and integrated their ideas. Focal students' views of science practices shifted from pre to post program participation in two main ways: 1) students associated expansive meanings with the majority of practices described while almost eliminating restrictive meanings of practices from their repertoires, 2) students described a greater quantity of *types* of practices (described above) and associated an expansive *meaning* with these practices (see Figure 10). In this way, students expanded, refined and integrated ideas within their repertoires. In addition, developing expansive views of science practices through engaging in scientific research *enhanced learning*: the analytic sense making involved with engaging in practices generated the function and purpose of practices and facilitated connections between practices in ways that made science more accessible to some students.

There was a significant shift in the *meaning* focal students associated with science practices from slightly more restrictive than expansive during pre program interviews to overwhelmingly expansive following program participation (see Figure 10). Following program participation, students developed expansive meanings and showed significant shifts in the following ways: they viewed the science research process as iterative and involving analytic sense making (i.e. categorized as *Expansive: Iterative/Analytic*), gained understanding of methods as flexible, adaptable and where multiple approaches are encouraged (i.e. *Methods: Create*), and valued multiple perspectives and input during the science research process (i.e. *Collaborate*). In addition, a new expansive subcategory emerged during post program interviews; students described the science process as messy, involving problem solving, and where the path can change direction based on observations and preliminary analysis (i.e. *Expansive: Messy/Path Changes*). This new category represents a sophisticated understanding of the scientific research process and reflects the realities of conducting authentic science research. This also represents a perspective described by the scientist instructors during interviews. Alejandra, a 12th grade student from Redwood provides an example. She entered the program describing science methods as prescribed and linear based on her experiences with science in school. She describes her experiences working alongside scientists in a lab:

> I've seen some of the scientists here, they're like 'oh my god this happened' or 'wow I found this', or 'what is this'? They don't even know, they're like 'my salinity changed'….I just think that scientists learn from their imperfections to…come up with their solutions to what they're doing.

Here, Alejandra describes the messiness of science research and recalls that the scientists she worked with in the lab expressed surprise at unexpected findings or things that happened during their research. This generated an awareness that sometimes scientists "don't even know" and that science involves a lot of problem solving. Other students who generated this expansive view described how the path of their research changed based on observations that led to interesting and unexpected findings. The messiness of real science starkly contrasts to students' experiences with experiments/labs in school where they described following prescribed and rigid procedures in order to arrive at the known answer. Recall that during pre program interviews, Alejandra described science in school as a pursuit of the "correct" answer and that if you didn't achieve this known answer you "failed". Developing an understanding of the messiness and problem solving aspects that are central parts of the authentic science process, as Alejandra did, can reframe "failure" in science from something to be avoided to a natural part of the process. In addition, this broadens opportunities to participate in science by creating space for students to make and learn from mistakes and promotes innovation through problem solving.

As described above, students developed expansive views of science, integrated their ideas and resolved conflicts in their repertoires as a result of engaging in scientific research. Interestingly, many restrictive subcategories that were described during pre program interviews were not mentioned during post program interviews. The largest decrease occurred with the restrictive meaning of science methods as rigid, linear and prescribed (i.e. *Restrictive: Method*). In addition, superficial descriptions of science (e.g. mixing chemicals) were absent during post program interviews. Fernando, the 11th grade student from above provides an example. He discusses what he learned about the process of doing science while conducting his research project:

> Science is not just like...finding out facts. You actually need to know how to present what you are going to do, like to be able to get your data or whatever you researched out to people. You gotta talk to people, like look, this is what my project was, this is what I found out. So the majority of it was finding the data. But the other part was like actually knowing how to present it out.

He mentions the importance of "finding data" and "presenting research", new practices that many students added to their repertories following program participation. He describes a shift from restrictive meanings of science practices (e.g. "finding facts") to expansive (e.g. collecting data and presenting research). In addition, Fernando's statement suggests that his experience engaging in scientific research facilitated a connection between practices: presenting research as a way to get the data you collected and the research you conducted out to people. Furthermore, Fernando's statement suggests a shift in agency (e.g. "look, this was what my project was, this is what I found out"). His statement suggests that through doing his research project he learned something that he feels is important to share with people.

These findings suggest that after students gained experience with real scientific research they were able to develop new meanings of science practices that extended beyond the restrictive views of science based on doing prescribed labs and experiments in school and superficial images ubiquitous in the media. Findings above show that students extended their repertoires towards expansive views by adding new expansive meanings and reducing the restrictive meanings. This reduced the conflicting meanings within students' repertoires (Linn, 2006) (see Figure 11). Next, I examine *how* students' repertories shifted holistically towards expansive views following program participation. In addition, I illustrate how engaging in science practices fostered learning.

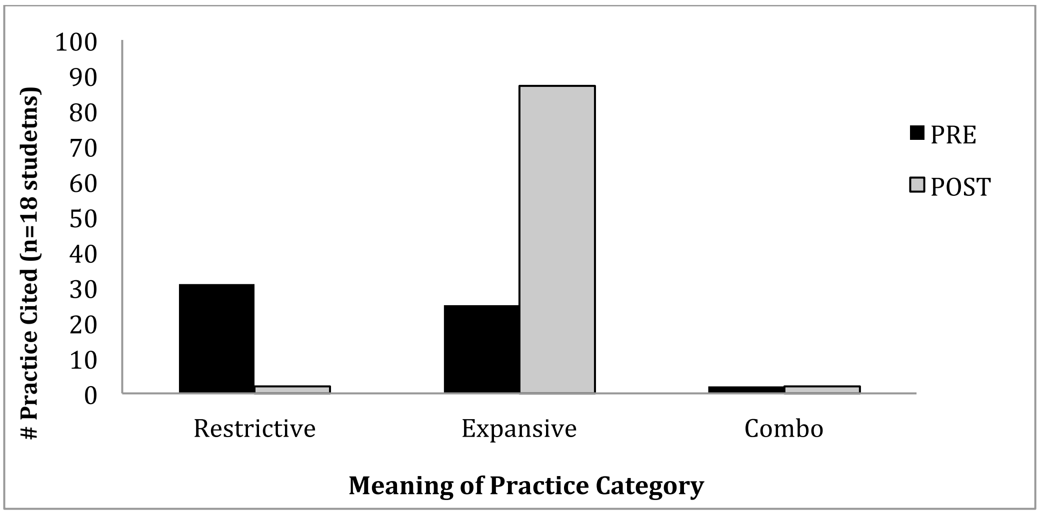

Figure 10. Pre vs. post program shifts in focal students' views of meaning of science practices across programs.

Mechanisms involved: Developing holistically expansive repertoires of meaning. Findings show that students' developed expansive repertoires of meaning for science practices following program participation. In addition, students showed more integrated and less conflicting repertoires after engaging in scientific research (see Figure 11). Participating in scientific research expanded students' views of the multiple and adaptive ways that research is done and helped students see that scientists often create, modify and change their methods throughout the process. In this way, most students shifted to the Mostly Expansive group following program participation (see Figure 11). In this section, I explore the *mechanisms* of how developing expansive views of science fostered learning and helped students resolve conflicts in their repertoires in order to construct holistically expansive views of science.

Antonio, a 12th grade student from Redwood provides an example of students that resolved conflicts within their repertoire and shifted from the Partial to Mostly Expansive group of students following program participation (see Figure 11, AN). During pre program interviews, Antonio was grouped with Partial students and described restrictive (e.g. science methods rigid; pursuit of correct answer) and expansive practices (e.g. science is unknown) at almost equal rates. During pre program interviews he describes his ideas about the research process:

Every time you do like a, science procedure, you have to, if you get, if your hypothesis is wrong you have to change the procedure every time, it takes various times…Maybe your hypothesis was wrong, and then so you have to do the whole process again, and come up with a new hypothesis and until you like get it right, your hypothesis correct some how.

He describes the science process as rigid and laborious with the goal of arriving at the "correct" hypothesis. Following program participation, Antonio expresses an evolution in his thinking about methods used to do research: "I thought it was more like 'oh you're just gonna use this method to do this and that', like they were told what to do, and then they'd do it." He describes *how* this shift in this thinking occurred:

From like seeing how like my instructor researches, and like other instructors research, the research is on them, they have to find scientific methods to try to figure something out, it's not like everything like 'oh this is how you're gonna do it'…its more like independent, they have to figure out how to do something, they have to write their own procedure.

By observing his instructors and engaging in research himself, Antonio developed an understanding of how authentic scientific research is done. His statement suggests that he gained an understanding that there are multiple ways to do science and the flexibility, independence and responsibility that scientists have to "write their own procedure". In addition, he developed an understanding of the adaptive quality to the methods scientists use so that the approach best fits their research needs. Experiences with scientific research helped Antonio, and the majority of focal students, resolve conflict within their repertories and develop a more expansive views of science.

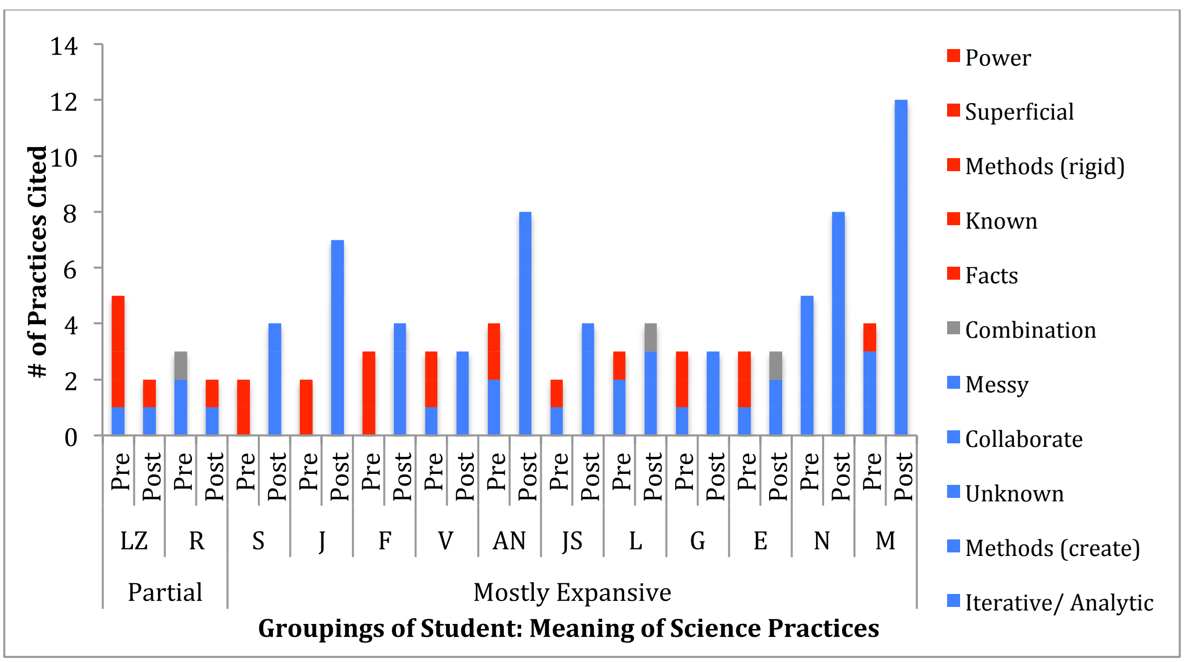

Figure 11. Pre vs. post program shifts in the *meaning* students associated with science practices by student and group. Red = restrictive, Blue = expansive.

In addition to developing more expansive views of science methods as illustrated with Antonio above, findings show that developing an understanding of the scientific process as iterative and involving analytic sense making (i.e. *Expansive: Iterative/Analytic*) helped students integrate their ideas about science practices. Findings show that developing this expansive view. In the next section, I explore how developing the expansive view, *Expansive: Iterative/Analytic*, functioned for students to help them integrate their ideas.

Creating shifts: Iterative, analytic sense making & connections between practices. During post program interviews, the majority of students made connections between different types of science practices, expressed an understanding of the function of different science practices in relation to each other and described the research process as iterative. These views were labeled *Expansive: Iterative/Analytic* and generated the biggest shift towards developing expansive views of the scientific research process following program participation. Interestingly, developing this expansive view of science coincided with the elimination of superficial views of science following program participation.

Developing an understanding of the iterative and analytic sense making involved with science practices helped students integrate their ideas and fostered learning in the following ways: 1) increased students' understanding of the purpose and function of different science practices, 2) facilitated connections between different types of practices and an understanding of the research process as iterative, and 3) made science more accessible for students. Next, I discuss these functions in relation to how they facilitated shifts for students from Mostly Restrictive or Partial groups to the Mostly Expansive group.

Shifting from restrictive to expansive: Making science accessible. Developing an understanding of the purpose, function and connection between different science practices served a significant function for students who entered the program with Mostly Restrictive views of science; *it made science more accessible to them*. Engaging in the analytic sense making involved and developing an understanding of the purpose and function of practices helped students who entered with Mostly Restrictive views resolve conflicts within their repertories (e.g. superficial ideas about science were absent following program participation). In addition, it allowed students to see themselves as capable science learners.

James, an 11th grade student from Westport who identifies as African American provides an example. He entered the program with mostly restrictive views of science and experienced little success in science class in school. When he entered the program, James described scientists as "chemical doctors" and using "heavy technology" (both superficial views of science). He developed expansive views of science while engaging in a seven-week long air quality research project along with his peers (see Figure 11, student J). To collected air quality (i.e. particulate matter) data, students used handheld devices. James describes how engaging in this research shifted his views of science practices:

> I thought it would be hard, but I see now the machines that they create…I didn't think we could use science to figure out about pm (particular matter)….without heavy technology, but I see now, these machines.

Following program participation he expressed surprise at being able to collect air quality data with simple machines. James expresses a shift in viewing science in superficial and inaccessible ways (i.e. he thought you couldn't measure particulate matter without "heavy technology") to experiencing science as accessible (i.e. "now I see the machines"). For James, learning how to use and read handheld devices broadened his ideas about *how* science data could be collected as well as his ability to collect this data. When asked to describe a time he felt good at science during the summer program he states:

> J: When we were hitting the seats on (the train) and I had the DustTrak and to see how it worked and how it went up, when the seats....
> Interview: And what do you think made you feel good at science?
> J: To actually see how the machine worked and actually just getting something out of it.

James builds on this to describe how using hand held machines to collect data and the analytic sense making involved with this practices expanded his idea about science practices. In addition, the sense making involved with reading and understanding the machines facilitated learning and shifted how he saw himself in relation to science to a capable science learner. Through engaging in these practices science became more accessible to James. In addition, he identifies himself and his peers as scientists following program participation. When I asked him what he learned while doing research over the summer he said:

> J: It shows that like other people of color could do it, it's like, you could just do it.
> Interviewer: Yeah, and what showed you that would you say?
> J: I guess, well I did it!

For James, the sense making involved with using machines to collect air quality data allowed him to see himself as a capable science learner, and to identify himself and his peers, as youth of color, as scientists. In addition, it is significant that this experience provided empirical evidence for James, that people of color can do science.

Shifting from partial to expansive: Analytical sense making. Developing an understanding of the iterative nature of the research process and analytic sense making allowed students who entered the program with Partial views of science (i.e. restrictive and expansive views) to integrate their ideas, resolve conflicts within the repertoires, and develop expansive meanings of practices. Antonio, the 12th grade student from Redwood above provides an example. As described above, he enters the program with an expansive and restrictive view of science. Antonio describes a shift in his ideas about the methods scientists use from prescribed and linear (pre) to adaptive and flexible (post). During post program interviews he describes how his ideas about developing hypotheses evolved:

> You can get more data and seeing like, you can even hypothesize well in this 10 years the nitrogen of carbon isotopes will increase or decrease depending on what you already know so you can keep on experimenting with it.

Here, Antonio describes the process of creating a hypothesis as a prediction based on "what you already know" or the data you've already collected. He shows an expanded idea about the purpose and function of this practice – hypothesizing is a form of prediction based on previous data and something to "keep experimenting with". This contrasts with his incoming idea that you do an experiment over and over until you get your "hypothesis correct" described above. Developing this understanding of the purpose and function of science practices helped students like Antonio that entered their programs with Partial views of science resolve conflicts in his repertoire and to construct expansive meanings.

Building on expansive views: *Making connections between practices:* Naomi, the case study student from Bayside, mentioned above, entered the program with an expansive view of science. Following program participation she further developed this expansive view (see Figure 11, student N). She describes how her ideas about science evolved:

> I used to think science was a little more like a 100% performing experiments and some stuff like that which is, it's fun to do, but you can also just like go around and observe things. You know, just check things out because like that's an important part of it. Because if you don't observe something then you're not going to know what to test.

Here, Naomi describes a relationship between the practices of making observations and experimentation. She describes the central role of "checking things out" in order to know what to test. Developing this understanding expanded Naomi's view of what counts as science practices; science is not just performing experiments. In addition, she developed and understanding of the importance of new science practices that she added to her repertoire (i.e. making observations). This allowed her to further develop her expansive view of science practices.

Differences in meaning by program. Overall, students from Redwood and Westport expressed more expansive views of science practices and the scientific research process following program participation compared to students from Bayside. In both programs (Redwood and Westport) students either switched from restrictive to expansive views of science practices or broadened their existing expansive views of the scientific research process. All focal students from Redwood and Westport developed an understanding of science as *Expansive: Iterative/Analytic*. This view was also expressed by Bayside students but at a lower rate. Describing the view coincided with the elimination of superficial views of science (i.e. *Restrictive: Superficial*), a view that was commonly described by Westport students during pre program interviews. As described above, developing this expansive meaning helped students integrate the ideas, resolved conflicts in their repertoires, fostered learning and made science more accessible for students.

Why does this matter for how students see themselves in relation to science? What are the identity implications for developing more expansive views of science practices? In the next section, I explore shifts in the relationship between the types and meanings students associate with science practices and how they see themselves as science learners.

Identity implications: Shifts in perceived ability & ideas about science practices. Following program participation, the relationship between the meaning students associated with science practices and how they saw themselves as science learners was disrupted. Recall that during pre program interviews low perceived ability students more commonly described restrictive meanings of science practices while high perceived ability students held more expansive views of science practices. This had implications for students' ideas about their abilities to engage with science practices.

Post program findings show that high and low perceived ability students described a greater variety of science practices and associated expansive meaning with these practices following program participation. Interestingly, low perceived ability students made gains that slightly exceeded the expansive views developed by high perceived ability students following program participation (see Figure 12). In addition, both high and low perceived ability students described restrictive meanings of practices at much lower and almost equal rates.

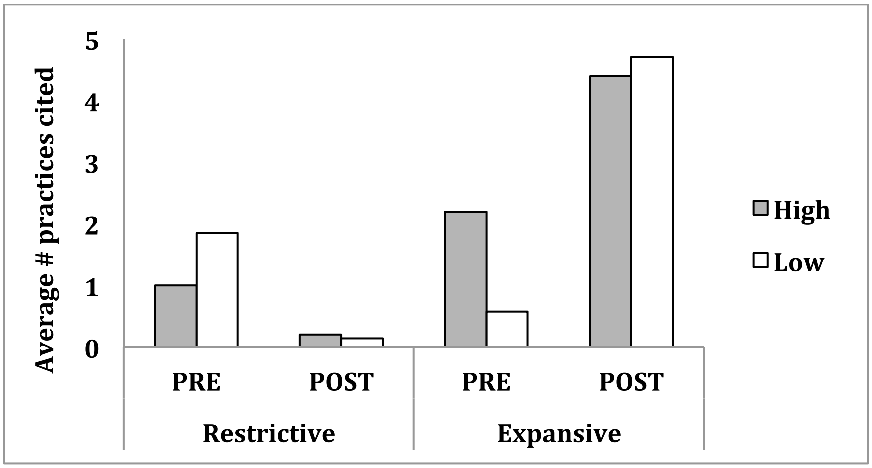

Figure 12. Post vs. post program shifts in views of science by high vs. low perceived ability focal students across programs.

The findings above align with those from all student post program surveys. Findings show that students made progress in viewing the scientific research process in more expansive ways following program participation. Across programs, both and high and low perceived ability students made gains and were more likely to "disagree" that scientists followed the prescribed steps of the scientific method and a rigid path when conducting research (see Figure 13). Even though high perceived ability students scored higher (indicating that they developed more expansive views), low perceived ability students made significant gains as well (see Figure 13). Though these findings are not as significant as those described with the focal student interviews above, they support the finding that students across programs developed more expansive views of the science process following program participation.

In the next section, I briefly revisit findings above engaging in scientific research helped students develop more expansive views of science

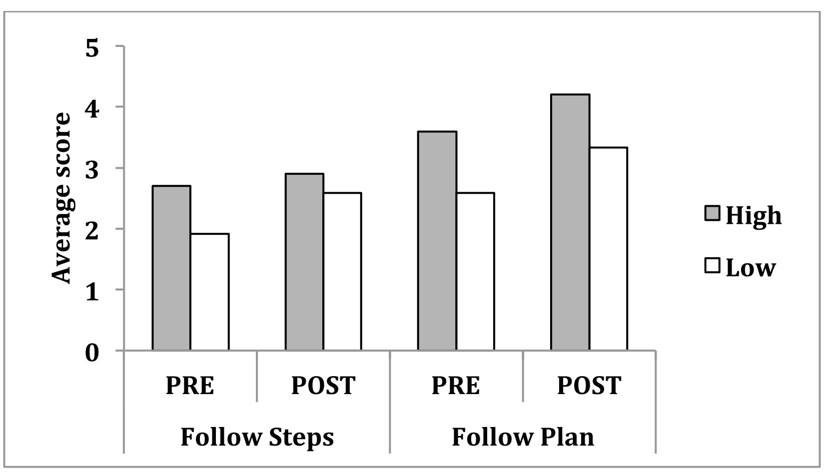

Figure 13. Pre vs. post program shifts in high vs. low perceived ability students' ideas about the scientific research process across programs.

Making science accessible & identifying as capable science learner. As described above, findings indicate that developing an understanding of science practices as connected, the research process as iterative and engaging in the analytic sense making involved (e.g. *Expansive: Iterative/Analytic*) made science more accessible to students. This is especially true for those who did not see themselves as good at science (i.e. low perceived ability students). Specifically, findings show that engaging students in the analytic sense making involved with science practices such as those involved in the data collection process (e.g. James, using/reading science equipment) helped expand students' ideas about what counts as science *and* their ability to engage with science in productive ways. The examples of Fernando and James above illustrate how engaging in analytic sense making, facilitated connections between practices, fostered learning and allowed students who entered the program feeling not good at science to identify as capable science learners.

Recall that pre program findings showed that low perceived ability students comprised the Mostly Restrictive group. Following program participation all students in this groups who developed this expansive of science (i.e. *Expansive: Iterative/Analytic*) shifted to the Mostly Expansive group of students following program participation. In addition, the view of science as *Restrictive: Superficial* that low perceived ability students commonly expressed during pre program interviews was eliminated after engaging in scientific research. This suggests that engaging in the analytic sense making involved with science research and developing an understanding of the purpose, function and connection between practices was central for helping low perceived ability students develop more expansive views of science. This made science more accessible allowed low perceived ability students to see themselves as capable science learners.

In addition, findings suggest that developing or building on expansive views was beneficial for high perceived ability students as well. The example of Naomi above shows how engaging in scientific research allowed high perceived ability students to build on their existing expansive views and find even more opportunities to engage with and participate in science. In addition, this helped high perceived ability students identify more strongly as capable science learners. During pre program interviews, Naomi described science as unknown and changing. Engaging in scientific research provided an opportunity for Naomi to experience this first hand. As a result, she learned that finding new things in science was more of a possibility than she had previously thought. She describes the affordances this experience:

> I consider like most people here somewhat scientists, not in profession but I mean we are all studying science, you know we're all making new discoveries and stuff like that, so we are technically scientists.

Because Naomi and her peers made "new discoveries" she described them all as scientists. This suggests that engaging in scientific research can further enhance how high perceived ability students see themselves (and their peers) as science learners and scientists.

However, despite the positive outcomes associated with developing more expansive views of science described above, findings suggest that the relationship between *what* science is (i.e. practices) and *who* can do science is complex for the focal students in this study. Finding show that adding new types and developing expansive meanings of science practices is important and can help students see themselves as capable science learners. However, finding show that shifting views of science practices alone does not lead to new possibilities for *who* focal students of color can become in science if their science and racial identities aren't holistically supported. I explore this complexity through the case studies below.

Post Program Cases: Shifts in Types & Meaning of Science Practices & Identity Outcomes

In this section, I revisit the cases of Lorenzo, Fernando, Melanie and Naomi a final time to demonstrate shifts in how these students see themselves in relation to science following program participation. I examine how the types and meaning of science practices developed through program participation and plays out differently for high and low perceived ability students. In addition, I examine identity outcomes for developing more expansive views of science (or not) (see Table 3). Finally, I combine students' ideas about *what* science is with their post program ideas about *who* can do science to document relationships between these shifts.

Table 3. Post Program Shifts in Ideas about Science Practices & Identity Outcomes

Student	Perceived Ability	Post Program Science Practices		Post Program Identity Outcome
		Practices	Self	
Lorenzo *(Bayside)*	Low	• Develops expansive; retains restrictive view • Memorize info	• Struggled to memorize info • Experienced "rough attitude", high expectations	• Overall shift "out" • Does not identify as scientist • Resists stereotypes, but no new possibilities made available
Fernando *(Westport)*	Low	• Develops expansive view • Collect data, present research; agency • Science accessible	• Capable science learner • Engaged in analytic sense making; fostered learning	• Overall shift "in" • Capable science learner • Identifies self/peers as scientists • Disrupts racial narrative: "slack off" • New possibilities available
Melanie *(Westport)*	Medium/ High	• Develops expansive view, resolves conflicts in repertoire • Constructs new knowledge to share	• Capable science learner • *Her* science important/useful • Shift in power to self/peers	• Overall shifts "in" • Capable science learner • Identifies self/peers as scientists • People of color as scientists • Disrupts lack of power • New possibilities available
Naomi *(Bayside)*	High	• Further develops expansive view • Practices as connected, iterative process	• Curious, wonder • Figure out how things work • Does what scientists do	• Overall shift "in" • Capable science learner • Identifies self/peers as scientists • Racialized societal perceptions not disrupted • Science identity supported; racial identity not supported • New possibilities only partially made available

"I don't see myself as a scientist". During program participation, Lorenzo develops expansive views of science but also maintains restrictive views. In addition, his perceived ability scores show no pre to post change and he leaves the program not seeing himself as a science person. His struggles to memorize concepts and vocabulary persist during the Biology class the students take as part of the Bayside program. When asked to describe a scientist he met that summer he mentions his Biology instructor, and explains what makes her a scientist: "She is really, really good at biology. I'm like how can she memorize all that? That's just, too much! She is really, really smart." This statement suggests that Lorenzo views scientists as people who are smart because they memorize a lot of information. He struggles with memorizing terms and concepts in Biology (and in general) and explains this struggle: "I learn it and I forget it. It just doesn't, it's not sticking to me. So I'm still struggling with that challenge of learning about glucose…it doesn't stick and I'm wondering when it will." In this way, his experience in his program reinforced his conception that practices that he is not good at (e.g. memorizing concepts) are important for being "smart" in science. This limits his ideas about his opportunities to engage with science.

In addition, Lorenzo describes his experience presenting his research project in a culminating event as validating his concerns that he does not belong in science. The example of Fernando above illustrates that for some students the practice of "presenting research" was an empowering experience and represented an opportunity to share knowledge. However, for Lorenzo this demonstration of knowledge was scary and made him feel like he did not belong in science. Bayside students made culminating research presentations at a formal event attended by their peers, their graduate student instructors, and other research scientists from the surrounding laboratories. Lorenzo describes his experience presenting with his research group to this audience:

> L: There was like other people that had like really high expectations of us. I noticed that they were like having that big expectation of us out there, like when we were presenting and we were like right there. I was like, 'oh my god'! And then their attitude was more like, just rougher against us.
> Interviewer: "Rougher" in what way? What do you mean by "rougher"?
> L: Expecting a lot!

The "other people" in the audience that Lorenzo refers to were research scientists from a nearby lab that attended the presentations. He expresses that he felt that the research scientists had really high expectations of him and his group. His exacerbation (e.g. "oh, my god!") suggests he felt he could not meet the high standards in a satisfactory way. It is important to note that following his groups' presentation, a research scientist with expertise in the field of their research topic asked the group a difficult question. Lorenzo attempted to answer the question, but was only able to offer an incomplete explanation. No one else in his group knew how to respond either, so the presentation ended. Interestingly, Lorenzo returned to his seat, but before he sat down he turned back towards the scientist and offered another partial idea in response to the question. This suggested that he wanted to answer the question in a satisfactory way, but was struggling to do so. During class the next day, Lorenzo expressed how intimidated he felt during the presentation and especially during the question and answer period. He felt the expectations of the scientists were really high and experienced the questioning of the scientists as doubting their knowledge and capabilities. Overall, the practice of presenting his research left Lorenzo again questioning if he belongs in science. During the post program interview, when I asked him if he could see himself being a scientist some day he responded:

> Nooo!... I don't see myself as a scientist. Like I never really thought about that fact. It sounds interesting but I never really dreamed of like doing that.

Lorenzo's statements of "never really thought about that" and "never really dreamed of doing that" suggest that Lorenzo doesn't see science as a possibility. Recall that Lorenzo identifies racially as Mexican. When asked if he learned anything about being a person of color pursuing science during the program he said:

> I mean, yeah I guess it feels good because it's one of the ways to… not be one of those stereotypical people, like one of those stereotypes that people tell you like, 'oh, see that Mexican right there, he's about to go buy…liquor, he's about to go do drugs. It feels good because you're…doing something useful for your life. And you're not fitting into the categories that other people are putting you into.

Here, Lorenzo expresses that through program participation he has the opportunity to resist a racial narrative about Mexican people and a stereotypical category that people try to fit him into. But at the same time, Lorenzo did not experience the opportunity to disrupt this racialized societal perception. Overall, it does not seem that new possibilities were made available to Lorenzo through his participation in the program, but rather that he moved farther from viewing the pursuit of science as a possibility for him. In addition, the significant differences in students' experiences engaging with the same science practices (e.g. presenting research) suggests that it is important to pay attention to the program resources made available for science practices in order to facilitate successful and empowering experiences. This is discussed in detail in Chapter 6.

Disrupting "slack off". Fernando expresses a shift in his ideas about *what* scientists do (i.e. science practices) and *who* can do science. For Fernando, shifts in his ideas about *who* can do science are directly linked to the expansive views of science he developed through program participation and the practices he engaged in to conduct research. Fernando's perceived ability score significantly increased following program participation. In addition, his overall ideas of what counts as science shifted: "I thought scientists were always in labs mixing chemicals. But probably not, probably, knowing your air quality is science too." As described above, his ideas about types of science practices and the meaning associated with science practices shifted. As a result, following program participation, Fernando, who entered the program experiencing little success in science, identified as a capable science learner. In addition, he expressed agency to share his important research findings with others.

By engaging in scientific research, his ideas about *what* science is and *who* can do science shifted together. Together his experiences provide an opportunity to disrupt a racial narrative that he asserted during pre program interviews; that people of color "slack off". Recall that Fernando identifies racially as Latino and he reasons that this "slacking off" might be why there are not more Latinos scientists. When asked what he learned about what it means to be a person of color pursuing science Fernando describes how participating in the program provided an opportunity to disrupt this narrative:

> F: Just knowing that even though you are a different race or something, you can still do what you want to do...just keep working on it.
> Interviewer: Yeah. How did this summer help you?
> F: Not doing what I usually do, just walk out of classes. And just getting mad and frustrated. Just stick to it and try my hardest.

The fact that Fernando saw himself and his peers as capable science learners and described shifts in his ideas about *who* can do science may have supported his efforts to “stick to it” and “try his hardest”. This contradicts with his previously described behavior of getting “distracted” and “walking out of class”, behaviors that directly connect to and validate the racial narrative of “people of color slacking off”. Participation in the program shifted Fernando’s ideas about what counts as science practices and allowed him to see himself as a capable science learner. This allowed Fernando to see new roles and possibilities of *who* he could become in science. It’s important to note the social context of the Westport program may have helped facilitate these shifts. The Westport program was small and students developed a close group that was passionate about the air quality research they conducted. Fernando contributed to the groups’ efforts and had the opportunity to gain expertise and display certain types of knowledge valued by the group (e.g. he taught others how to make graphs). In this way, his persona of walking out of class was not supported in the science program space. The social context of the Westport program and the program resources made available are discussed in detail in Chapter 6.

“Societally held back”. Recall that Naomi, the African American student from Bayside enters the program with a very high perceived ability and identity in science. As described above she develops an even more expansive view of science through her program participation. Naomi had the opportunity to explore and find new things as well as work through things with her group mates and problem solve together. Recall during pre program interviews she expressed frustration at not having the space or opportunity to figure things out during school science experiments. She explains how engaging in science research and learning the methods scientists use to conduct research shifted her views:

> Sometimes things got a little confusing, they get a little complicated with all the equations and stuff like that. Sometimes we'd make slip ups, but we always worked through it together and stuff and double checked each others work and helped each other redo things if we completely screwed them up.

She builds on this to describe how the opportunity to work through things as a group shaped her feelings about her abilities in science: “usually like we find, we're a lot smarter than we thought”. She describes feeling even more capable of doing science following program participation. In addition, she identifies herself and her peers as scientists and is further motivated in her pursuit of a science career. However, recall that Naomi identifies racially as African American and during pre program interviews she described a racialized societal perception that she experiences; that she’s not interested in science because she of her race. When asked what she learned about being a person of color and pursuing science over the course of the summer she says:

> Well, I’d say that it's not super common for people of my major part of my ethnicity to be involved in science, but I feel that in no way does that mean that I can't be involved in science…. I feel like maybe a little societally held back but not at all in personal motivation, definitely not.

Here, Naomi describes feeling “societally held back” due to her race. Though Naomi builds on her expansive views of science, sees herself as a more capable science learner, and continues to identify strongly with science following program participation, findings suggest that her science identity is supported while her racial identity is not. Naomi's statement above in combination with findings from Chapter 4 highlight the disproportionate identity work that focal students of color like Naomi need to do continually do in order to pursue their passions in science (Nasir & Shah, 2011). Naomi must continually assert alternative positions and options to those offered to her by society. Naomi's experience suggests that while new possibilities are made available to her in some ways, they are closed off in others. This underscores the importance of providing youth of color resources that support their science *and* racial identities in order to provide tools that allow them to navigate productive pathways in science.

"I think we're pretty powerful this summer as scientist". Like Naomi, Melanie develops more expansive views of science through program participation and describes feeling more capable to do scientific research. Recall that during pre program interviews Melanie describes mostly expansive views of science, but also envisioned scientists in stereotypical ways (e.g. lab coat, glasses), connected power to the role of scientist and linked this power to knowledge (e.g. "scientists are smarter than everyone else"), and views the work of scientists (e.g. finding solutions) as more important than her science (e.g. small experiments). Her experiences expand her ideas of what counts as science: "I never thought of science like this anyway. Science being testing air quality, science being youth." In addition, like Fernando, her ideas of *what* science is and *who* can do science shift together. She describes a greater capability to collect data following program participation: "I feel like now I'm more capable of finding data on my own and finding ways to collect data…I feel like I have more knowledge of what to use and how use it." Melanie describes engaging with the practice of "presenting research" and how this empowered her and her peers. Following completion of their seven-week long air quality research project, Melanie and her peers presented their findings to representatives from the transportation agency where they collected their data. This was a high stakes context for the students. She describes how this opportunity shifted her thinking about who is scientist and who is powerful:

> I think we're pretty powerful this summer as scientist and through out the year it paid off because we got to present in front of these representatives and I think that was powerful for us to do.

She says the power she gained came from the knowledge they constructed through their research. Her ideas about what science can be used for shifted due to what she and her peers are able to *do* with the findings from their research. Shifts in uses for scientific research and who can create change disrupted the power differential she experienced. As a result, power shifted to her and her peers. In addition, she shows a shift in her ideas about the importance of *her* science because now she and her peers are scientists. Recall, that during pre program interviews, Melanie described her science as "small" and scientists as deriving solutions to issues. These shifts make new possibilities available to her and her peers. When asked what she learned about being Filipina and pursing science she says:

> It's really important for people of color to represent scientists...to show people that scientists aren't powerful because of their race, but because of who they are and what they want to accomplish as a scientist and what they want to contribute to their community.

Melanie describes how new possibilities were made available for her and her peers, specifically as youth of color because of what they were able to *do* as scientists. In addition, her statement suggests that her science and racial identities were holistically supported through program participation. The program resources that may have led to these shifts are discussed in detail in Chapter 6.

Summary: Post Program Shifts in Science Practices

Findings show that students add new, relevant, and innovative science practices to their repertoires by engaging in scientific research. These practices align with and extend beyond those promoted by NGSS. In addition, students across programs developed expansive views of science practices and refined and integrated ideas within their repertoires. In addition, developing expansive views of science practices through engaging in scientific research *enhanced learning*: the analytic sense making involved with engaging in practices generated the function and purpose of practices and facilitated connections between practices in ways that made science more accessible to some students. Experiencing the messiness of real science and the iterative aspects of scientific research starkly contrasted to students' experiences with experiments/labs in school where they described following prescribed and rigid procedures in order to arrive at the known answer. This broadens opportunities to participate in science by creating space for students to make and learn from mistakes and promotes innovation through problem solving. These findings suggest that after students gained experience with real scientific research they were able to develop new meanings of science practices that extended beyond the restrictive views of science based on doing prescribed labs and experiments in school and superficial images ubiquitous in the media. However, finding illustrate that students don't experience science practices in the same ways and this impacts how they see themselves in relation to science. The example of Elana and Lorenzo illustrate the powerful messages students can receive in a short amount of time about where they do and don't belong based on their experiences engaging with science practices. In addition, these examples highlight the importance of examining the instruction made available for science, how engaging in science research is scaffolded, and providing program resources that facilitate successful engagement with science practices so that students are able to see themselves as capable science learners.

Findings suggest there is a relationship between meaning associated with practices, perceived ability, and identifying as a scientist. Post program findings show that high and low perceived ability students described a greater variety of science practices and associated expansive meaning with these practices following program participation. Interestingly, low perceived ability students made gains that slightly exceeded the expansive views developed by high perceived ability students following program participation. The examples of Fernando and James above illustrate how engaging in analytic sense making, facilitated connections between practices, fostered learning and allowed students who entered the program feeling not good at science to identify as capable science learners. Developing views of science as iterative and involving analytic sense making (i.e. *Expansive: Iterative/Analytic*) helped make science more accessible to low perceived ability students by shifting their views from restrictive (e.g. superficial) to expansive. The example of Naomi above shows how engaging in scientific research allowed high perceived ability students to build on their existing expansive views and find even more opportunities to engage with and participate in science.

However, findings show that developing expansive views doesn't necessarily mean focal students experienced new possibilities for *who* they can become in science. Finding show that shifting views of science practices alone does not lead to new possibilities for *who* focal students of color can become in science if their science *and* racial identities aren't holistically supported. The examples of Lorenzo and Naomi underscore the importance of providing youth of color with resources that support their science *and* racial identities in order to provide tools that allow them to navigate productive pathways in science.

Next, I briefly explore scientist instructors' perspectives of science (e.g. purpose, utility) their students (race, societal positioning) and racial disparities in the professional science community. I explore how differences in instructors' perspectives may have led to the differences in identity outcomes described above. In Chapter 6, I take an in-depth look into the program resources made available to students in the Westport program and how resources that supported students' science *and* racial identities may have led the unique identity gains described in Chapter 4.

Program Resources Supporting Holistic Identity Construction in Science

In this section, I examine how scientist instructors' perspectives of science, their students, and racial/ethnic underrepresentation in science shape the resources they make available. In addition, I examine how this impacts identity construction for the focal students of color in this study. Findings show that instructors' perspectives of science and race shape the resources they make available through their instruction. I examine contrasting cases of two instructors that hold different ideas about race in relation to science instruction. These differences impact the program resources they make available and the identity outcomes for their mentees.

Expansive views of science. Across programs, scientist instructors (n=10) described similar and expansive views of science practices and the scientific research process. They commonly described goals of teaching students that science is messy, an iterative process, and that "failure" is a natural part of the science process. These views and practices align with many of the expansive views of science that students developed through program participation as described above. Ben, a physics graduate student and scientist instructor for the Bayside program provides a representative example of the expansive views of science held by instructors. He describes science as unknown, where scientists and teachers don't have all of the answers:

> Students are conditioned that science is about, finding, like having a problem and here's the answer, you know the teacher knows the answers to *everything*. It's in the back of the book somewhere you just have to find that book.

Ben seeks to disrupt what he perceives as common perspective of science; that answers are known and exist somewhere and that the goal is to find the answers rather than to figure things out. In addition to viewing science as unknown, Ben describes some of the practices he promoted with his students:

> Being critical, meaning really questioning yourself a lot, like if you get a result that you don't just say I have the answer. Always questioning. That's what real scientists do.

This idea that scientists constantly question and explore alternatives was common across the scientist instructors. In addition, he describes an important idea about the role of "failure" in science: "Failure is not, something that's bad. I mean that's what we instill in kids. We have to break that! Failure is the first step to success!" Describing failure as a natural and important part of the science process was common across scientist instructors. Like Ben, instructors' commonly described their mentees arriving with an entrenched idea that failure is bad based on their school science experiences. The instructors strove to disrupt this idea while engaging students in scientific research.

Overall, like Ben, the scientist instructors in this study viewed science in expansive ways and promoted practices that engaged students in the messiness and iterative aspects of the science process. These practices and expansive views of science are reflected in students' experiences and the post program shifts described above. As a result of engaging in scientific research alongside scientist instructors, students developed expansive views of science and added new and important practices to their repertories. Next, I examine how instructors viewed intersections of race and science and their students, specifically as youth of color.

Perspective of students: Racial background, societal positioning. Findings show that across programs instructors' ideas about intersections of race and science, and their students' racial backgrounds fell into three main categories: 1) those that showed awareness of racial disparities in *who* is a scientist, but did not incorporate this perspective into their instruction, 2) those that incorporated a racially/politically conscious perspective into their instruction, and 3) those that held deficit-oriented views of race but didn't incorporate this into their instruction. By far, the first category was the most common across instructors. The majority of instructors identified racially as white (8/10). They described an awareness of a lack of scientists of color in the professional science community but described the racial background of their students as not something that played into their instructional goals or vision. Jill, an instructor from Redwood provides an example. She expressed an awareness of a lack of people of color in science, and thought about this in relation to her mentees, but overall felt her role was to focus on science with her students: "It's usually just getting 'em fired up about sciences." This was by far the most common view expressed by instructors. It should be noted that these instructors cared deeply about their mentees, wanted to help them succeed, and fully supported their pathways and pursuit of science. While they often discussed awareness of the barriers their mentees might face pursuing science as youth of color, they also expressed a lack of training or access to tools to empower their mentees in ways that addressed their science and racial backgrounds. While it is understandable that instructors who identify racially as white would be limited in their ability to support their mentees science and racial identities, findings from above (e.g. Naomi) underscore the importance of preparing instructors adequately for this task.

While deficit-oriented views of students' racial backgrounds were not common across instructors, Ben, the instructor above, expressed this perspective. However, his views did not play into his ideas about science instruction; in fact felt that discussions of race didn't have a place in his science lab. Ben was fluid about his racial identity, mentioning both white and Latino (his mother is Latina) but preferred not to identify as either. The three students in his group identified as Chicana/Latina or African American (i.e. Naomi). Ben discusses his ideas about racial/ethnic underrepresentation in science (and specifically in physics) and the role he viewed "culture" playing into the issue of underrepresentation specifically for Latinos in science:

> There are not very many minorities in the sciences. I mean, that's partly socioeconomic, it's partly cultural. For example, in the Hispanic culture, family is extremely important, so they want them to stay with the family you know, go to college somewhere in the area, and they don't value science very much. The culture is not one that encourages science

> development. I’ve seen that a little bit in my family too because my mother is Hispanic, and on that side of the family, you definitely see the differences.

Here, Ben describes the Hispanic culture as one that does not encourage or value participation in science. He bases this view on his perspective of his mother’s side of the family. His statement suggests that he judges the value that Hispanic families place on higher education and on science. Though his ideas about race do not play into his instruction, it is plausible that he would not offer his mentees resources that support their racial identities. It should be noted, that in many ways Ben displays exemplary science teaching. In addition to his expansive views of science described above, he positions his students as capable science learners and himself as a “member of the team”. The expansive views of science that he promoted and his positioning of students as capable science learners is reflected in the outcomes Naomi expresses above: building on her expansive view of science and identifying herself and her peers as scientist. However, as described above, a big part of *who* Naomi is not addressed when engaging in science research. In this way, though her science identity is supported, her racial identity is left unattended.

Finally, the instructor from Westport viewed science and race as highly intertwined and this racially/politically conscious perspective played into his instructional design. Matt, the Westport instructor was the only scientist instructor who held this perspective. He describes his perspective:

> Science helps reveal the relationship a lot of young people and their families have with the larger system that has alienated them so much from power or having any sort of dignity.

The racial and socioeconomic backgrounds of his students guided Matt’s instructional design. This led to the empowering experiences described by Fernando and Melanie above. In addition, as described in Chapter 4, the Westport students made the most significant identity gains of students across programs, and identified youth of color specifically as scientists following program participation; a finding unique to this program. Findings suggest that students’ science and racial identities were supported. Therefore the Westport program and the program resources made available are the focus of Chapter 6.

Discussion & Conclusion

In this chapter, I make three main arguments: First, science practices are relational; students view themselves in relation to the practices of science. In addition, a relationship exists between the meaning students associate with science practices (i.e. restrictive or expansive) and how they see themselves as science learners. Second, engaging in scientific research can expand students’ ideas about what counts as types of science practices and the meaning they associate with practices from restrictive to expansive. This can help makes science more accessible and allow students to identify as capable doers of science. Third, for focal students in this study, program resources that supported students’ science *and* racial identities created new possibilities for *who* they could become in science.

Findings show that students’ ideas about *what* science is (i.e. science practices) and *who* can do science shifted together through participation in the practices of science. Across all three programs, participation in authentic scientific research: 1) allowed students to add new types of science practices to their repertories, 2) expanded or shifted the meanings students' associated with science practices from restrictive (e.g. prescribed, right/wrong) to expansive (e.g. science as iterative process), and 3) allowed students to distinguish the multiple and conflicting ideas within their repertoires to develop holistically expansive views of science (Linn, 2006). Findings show that students added new, relevant, and innovative science practices to their repertoires by engaging in scientific research. These practices align with and extend beyond those promoted by NGSS.

These findings align with those from previous literature that show that engaging in science research and investigations expands students ideas about what counts as science (Warren et al., 2001) allows students to develop new epistemological stances (Metz, 2004; Sandoval, 2005; Lehrer et al., 2008) and identify as capable science learners (Barab & Hay, 2001; Bouillion & Gomez, 2001; Bowen & Roth, 2007, Lehrer, 2009). Findings here extend this work to show the relational aspects of how students view science practices in relation to themselves and their abilities to engage with these practices. This has important identity implications. Developing expansive meanings of science helped students integrate the ideas, resolve conflicts in their repertoires, foster learning and made science more accessible for students. In addition, engaging in scientific research broadened opportunities to participate in science by creating space for students to make and learn from mistakes and promoted innovation through problem solving. Findings show that by engaging students in the process of analytic sense making (e.g. using/understanding science equipment), students developed an understanding of the function of and connection between practices (i.e. *Expansive: Iterative/Analytic*). This helped expand students' ideas about what counts as science *and* their abilities to engage with science practices. Developing views of science as iterative and involving analytic sense making helped make science more accessible to low perceived ability students and allowed them to identity as capable science learners. In addition, developing a deeper understanding of the purpose and function of science practices allowed high perceived ability students to further develop their expansive views.

Findings suggest that a relationship exists between the meaning associated with practices, perceived ability, and identifying as a scientist. Students that develop more expansive views showed an increase in perceived ability and in some cases were able to construct new possibilities for themselves in science. However, findings from this study challenge and complicate notions of how identities are constructed in science programs and the types of experiences that create new possibilities for *who* students can become in science. Findings show that developing expansive views of science, while important, doesn't necessarily mean students experience new possibilities for *who* they can become in science. The examples of Elana and Lorenzo illustrate how students experience engaging with science practices can produce different outcomes in feeling of belonging or not belonging in science. This suggests that it is important to pay attention to types of program resources made available to ensure that students experience success when engaging in science practices. In addition, findings suggest that ideas about *who* can do science and *what* science is (i.e. practices) are inextricably linked. This requires a holistic approach to understanding relationships among different aspects of students' science and racial identities and how they develop together in science programs. While expanding students' ideas about the practices of science is important, it is often taken up as the way to increase diversity in science based on science education reforms. The idea being that if we give students the necessary tools to bolster their science learning and skills, they will succeed. While some aspects of this may be true and promoting authentic science practices is important, findings here suggest that our ideas about the necessary "tools" needed for students of color to purse productive pathways in science needs to be expanded.

Findings highlight the importance of program resources and the need to support students' science *and* racial identities in the science programs in order to make new possibilities available. Findings suggests that program resources had the potential and some cases played two central roles for focal students in this study: 1) fostered expansive meanings of science and ensured that students experience success while engaging in science practices, and 2) supported students science *and* racial identities in holistic ways and providing opportunities to take on new roles and disrupt racial narratives. Together, these mechanisms worked together to make new possibilities available for focal students in science. Findings from Chapter 4 show that students from Westport made the greatest identity gains following program participation and identified themselves and their peers as scientists more commonly than students from other programs. In addition, Westport students identified youth of color specifically as scientists, a finding unique to this program. Findings suggest these identity gains were based on what students were able to *do* as scientists but also that their science and racial identities were supported. The case studies illustrate the complexity of intersections between different aspects of students' identities and the challenge of making new possibilities available.

In addition, findings show the scientist instructors' perspectives of race and science shape the resources they make available and shape identity construction for focal students in this study in important ways. The example of Naomi complicates the idea of what it means to make new possibilities available to students. She exudes confidence and excitement for science, builds on her expansive views, but still feels "societally held back" following program participation. This highlights the magnitude of identity work that youth of color, like Naomi, need to do in order to assert alternative positions to those placed upon them and pursue their passions in science (Nasir & Shah, 2011). Findings show that the majority of scientist instructors identified racially as white and expressed a lack of training or access to tools to empower their mentees in ways that addressed their science and racial backgrounds. While it makes sense that these instructors would be limited in their ability to support their mentees science and racial identities, findings from above (e.g. Naomi) underscore the importance of preparing instructors adequately for this task. Together with results from Chapter 4, findings indicate that while reform efforts that focus on promoting authentic science practices are important, a focus on shifting *what* science is (i.e. practices) alone is insufficient for dismantling persistent issues of equity in science education.

Chapter 6: "I Never Thought We'd Go Big!" Becoming Agents of Change as Doers of Community-Based Scientific Research

Introduction

Case Example

> I've never heard of a professional Filipino scientist. Maybe it's just a lot of the other races don't feel comfortable. Here, it's a lot of low-income or working class people and they probably don't feel like they're good enough to become a scientist, cause it's like *high*.

Melanie is 10th grade Filipina student and a participant in the Westport summer science program. She describes science as her favorite subject in school, yet she expresses frustration at a lack of access to high quality science instruction. At the beginning of the program, I interviewed Melanie to gain a better understanding of her ideas about science practices, how she thinks about scientists, and how she sees herself in relation to science. As described in Chapter 4, Melanie envisioned scientists in stereotypical ways, both in what they look like (e.g. goggles, lab coats) and what they do (e.g. use high tech equipment). We also discussed her ideas about how science knowledge is constructed and the process of deciding what gets written in science textbooks. She expressed an idea that scientists play a big role in this: "I feel like sometimes maybe they can just do it because they have the power to." By "do it" she means write things in textbooks. When I asked where this "power" came from she said: "Because they are labeled scientist, and that makes them smarter than everyone else." In this way, Melanie describes the power she associates with the position of scientist and how this power is linked to knowledge. Finally, I ask her how she views herself as Filipina in relation to science and she responds with the opening excerpt above. Her statement illuminates intersections of race, class and positioning. She expresses the high status at which she holds scientists and suggests that people of certain races (e.g. Filipina) and classes (e.g. low-income) might not feel good enough to become scientists because it's "high" status. It's important to note that while Melanie feels that anyone can be good at science, her statement suggests that societal positioning complicates this.

Melanie's experience highlights the importance of examining issues of equity in new ways and from the perspective of students' science experiences. In addition, her experience suggests that race, class and positioning play important roles in how Melanie views scientists and sees herself in relation to science. Melanie's experience underscores the need to provide instructional and pedagogical resources that support students' science *and* racial identities in science learning environments in order to create new possibilities for *who* they can become in science.

Rationale

Fostering hope & possibility: The importance of an instructor's "vision". In this chapter, I explore how engaging in science practices and the accompanying program resources generates new possibilities for who youth can become in science. I document the shifts that occurred for Westport students following program participation and focus attention on the types of program resources that may have led to these shifts. In addition, I explore the role of a science instructor's vision in shaping the program resources and opportunities that they make available and that support the generation of new possibilities for students. The aspirational thinking expressed by two scholars encompasses what it means for educators to have a *vision* specifically in relation to working with youth of color from historically marginalized populations. In a interview broadcast on a local radio program, Dr. Cornel West encouraged teachers from schools serving predominantly youth of color to develop opportunities for their students to become *creators*. Empowering students as creators fosters hope and generates possibilities. In this way, students are empowered as agents who are able to create change in their lives. Along similar lines, during a presentation to undergraduates at the University of California Berkeley, Dr. Kris Gutierrez encouraged aspiring educators to approach learning with new social and *pedagogical imaginations*, to promote what is possible, and to provide tools for youth of color to become *social dreamers* and designers of their own futures (Gutierrez, 2008). Both of these scholars speak of providing tools that allow students to hope and dream, create, design and become agents of change. In this chapter, I build on this visionary thinking to illustrate what is possible in a science program when there are opportunities to generate hope and possibility and when an instructor's vision shapes program resources that position students as doers of science and agents of change in their community.

Conceptualizing program resources. This study examines how students' science and racial identities develop together through participation in the practices of science. This research explores how the types of program resources made available in science learning environments supports youth of colors' practice-linked identities in science (i.e. viewing participation in a practice as central to who one is) (Nasir & Cooks, 2009; Nasir 2012). I define *program resources* as the types of instruction, pedagogy and designed experiences that instructors make available to students in science learning environments. The development of practice-linked identities is supported by three groups of identity constructing resources: ideational, material, and relational (Nasir & Cooks, 2009; Nasir, 2012). For the purpose of this research these identity constructing resources are defined as follows: 1) ideational: instructors perspectives of race and science, ideas about their instruction; 2) material: instruction for science practices, science equipment, physical objects, artifacts; 3) relational: interpersonal connections, positioning within the science programs. I pay particular attention the types of program resources that support students' science *and* racial identities in science learning environments. I define this as *holistic support*. I examine how engaging in science practices and the accompanying program resources generates new possibilities for who students can become in science (see Figure 1).

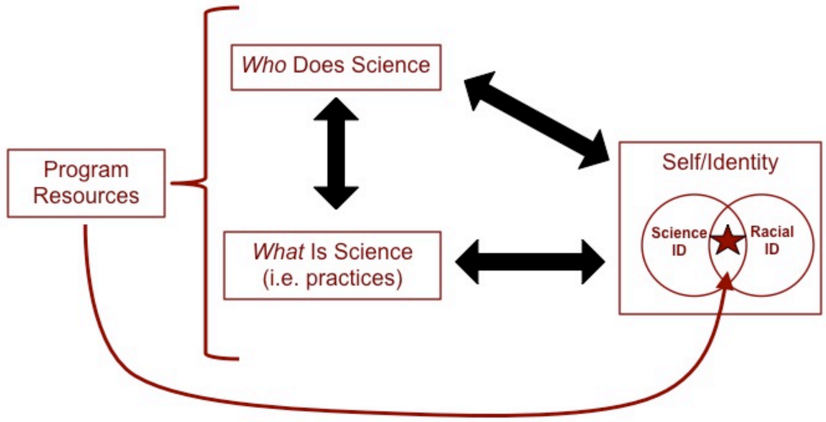

Figure 1. Relationships between program resources that support holistic identity construction and shifts in students' ideas about what science is, who can do science, and how they see themselves in relation to science.

Generating new possibilities. I examine the mechanisms involved with how new possibilities are generated: how engaging in science practices and interaction with the programs resources made available for the practices (e.g. instruction, pedagogy, designed experiences) leads to the generation of new identities/possibilities for *who* students can become in science. I define this *identity generative process* (engaging in science practice + program resources → new possibilities/identities) as a process that transforms how youth of color see themselves in relation to science. In addition, I explore how science practices "function" for students in this process in terms of the *types* of identities that are generated. The identity generative process involves the construction and implementation of program resources as described in the instructor's vision section above. It also involves the different ways that students engage with science practices and the analytical sense making and intellectual work involved. I explore how together program resources and engagement in practices allows students' agency and power to come to life. I use this ***identity generative process as my unit of analysis*** because it highlights the connection between program resources, engaging in practices and the generation of new possibilities rather than disaggregating this process into individual components. Exploring this identity generative process as a unit of analysis highlights that it's not just expansive science instruction and pedagogy or students engaging in science practices, but the combination that generates new possibilities for *who* students can become in science. I explore how the same science practice (e.g. collecting data) can serve different "functions" and therefore generate different identities for students across programs depending on the resources that are made available for the practice. As a result, I argue that the identities and possibilities generated from engaging in science practices are *program resource dependent*. Furthermore, I argue that an instructor's vision both of their students (e.g. race, social positioning) and of science (i.e. purpose, utility) guides the instruction, pedagogy and designed experiences they make available that foster the creation of new possibilities for students. I *define "pedagogical vision"* as the ways that teachers' own backgrounds and experiences inform their goals and purposes for teaching science, what they envision their students *doing* with science, and the possibilities they create for *who* their students can become in science.

Objective

In this chapter, I examine how engaging in science practices and the accompanying program resources becomes *identity generative* for students and transforms how they see themselves in relation to science. What aspects of the learning environment and students' engaging with science practices allow new possibilities to come to life? I examine how program resources that support students' science *and* racial identities in science programs serve as the mechanisms that support these shifts. The goal of this chapter is to better understand the mechanisms of *how* new possibilities are generated for youth of color. I examine one particular instructor's vision of his *students* and *science* and how this guides the instruction, pedagogy and designed experiences he makes available for selected science practices. In addition, I examine how the program resources support holistic identity construction (i.e. students' science and racial identities). I explore the shifts that occur for students through engaging in science practices, the types of new possibilities and identities that are generated, and how this transforms the ways students see themselves in relation to science. In addition, I examine how different science practices generate different possibilities for students across programs based on the types of program resources made available. I build on Chapters 4 and 5 to examine how students' incoming characterizations of *who* does/can do science (Chapter 4) and the practices they associate with "doing" science (Chapter 5) are supported or reimagined based on the resources made available in science programs.

Westport students offer a unique case for further analysis. Students from this program started with a much lower perceived ability in science than students from other programs. Yet, results from Chapter 4 show that following program participation, students from Westport made the greatest identity gains and identified themselves/peers as scientists at significantly higher rates than students from other programs. In addition, some Westport students specifically identified youth of color as scientists, a finding unique to this program. These findings suggest that unique program resources were made available that supported Westport students' science and racial identities while engaging in scientific research. Therefore, Westport is the focal program for this chapter.

In this chapter, I take an in-depth look at selected focal science practices that served significant identity "functions" for Westport students. I trace the types of program resources made available for the practices, and how engaging in the practices and accompanying resources generated new possibilities for Westport students. I examine the mechanisms involved by offering two cases of focal science practices (i.e. Case 1: Data collection process, data analysis; Case 2: Presenting research). Through the cases, I explore links between the science practices (e.g. collecting data), the program resources made available for the science practices (e.g. positioning students as doers of science) and the identities generated (e.g. capable science learner). I examine how the instructor's ideas about his students (e.g. race, social positioning) and science (e.g. purpose, utility) as ideational resources guide the instruction, pedagogy and designed experiences he makes available, the types of shifts that occur for students, and the types of new possibilities that are generated. In addition, to illustrate that it's not just engaging in science practices that is important, but equally the program resources made available for the practices, I include contrasting cases with students from Bayside and Redwood involving the selected focal science practices. I ask three main research questions:

- How does an instructor's pedagogical vision (i.e. of science, students, race) and the types of instruction, pedagogy and designed experiences made available in the science programs support the co-development of students' science *and* racial identities?

- What mechanisms support the generation of new possibilities and identities for youth of color in the science programs?

- What shifts for students in regards to how they see themselves in relation to science through engaging in scientific research?

In this chapter, *I make three main arguments*: First, for focal students in this study, identities were constructed through engaging in science practices *and* the accompanying program resources. The program resources were the mechanisms that helped facilitated shifts for students and generated new possibilities for *who* they could become in science (e.g. doers of science, agents of change). The types of program resources created or limited access to particular roles, positions and possibilities. Therefore, I argue that the *types* of identities generated through engaging in science practices were program *resource dependent*. Second, the instructor's vision of science (i.e. purpose, utility) and his students (e.g. racial background, social positioning) guided the instruction, pedagogy and the designed experiences he made available in the Westport program. In this study, the instructor's perspective of race, class, positioning and power allowed him to construct *holistic* resources that supported students' science and racial identities. Third, the youth of color in this study were able to imagine and take up new possibilities for *who* they could become in science when their science *and* racial identities were supported in the science programs. Opportunities to engage in science practices and the analytic sense making involved allowed students to construct new meanings for practices and imagine new possibilities in science.

Findings from Chapters 4 and 5 show that students ideas about *what* science is and *who* can do science are linked and that resources supporting students science and racial identities are needed to make new possibilities available for youth of color. Finding from this chapter show that in this study, the same science practices (e.g. presenting research) generated different identity outcomes and possibilities based on the *types* of resources made available for the practices. As a result, findings suggest that while it is important to broaden students' ideas about what counts as science practices (see Chapter 5), it is equally important to consider the pedagogy, instruction and designed experiences made available for science practices and the *messages* students received about *who* they can become while engaging in the practices. Through an equal focus on engaging students in science practices, the resources made available for the practices, and the messages students receive about what is possible, we can disrupt structures of power and positioning and create new possibilities for *who* youth of color can be in science.

Theoretical Framework

Conceptualizing "Pedagogical Vision": Centering Race

In this chapter, I explore how an instructor's "pedagogical vision" guides the organization and structuring of activities in a science program in ways that empower youth of color as doers of science and agents of change in their community. When conceptualizing identity construction through engagement in activities, Nasir (2004) emphasizes the importance of examining the nature of the setting including norms, institutional beliefs, distribution of roles, nature of participation and *imagined trajectories* embedded within activities. I *define "pedagogical vision"* as the ways that teachers' own backgrounds and experiences inform their goals and purposes for teaching science, what they envision their students *doing* with science, and the possibilities they create for *who* their students can become in science. This includes instructional approaches, the experience they design and the spaces they create for learning. Ultimately, the vision constructs the pathways and opportunities they make available for students. However, this "vision" needs to be further distinguished. Throughout this dissertation I explore the co-development of students science and racial identities. Therefore, the "pedagogical vision" explored here is student population specific, and in this case elevates race and social positioning as central components. The type of vision, I explore in this chapter centers race, is historically embedded, and politically and racially conscious. I examine the mechanisms by which this specific type of pedagogical vision operates: to organize the activities of a science program, the opportunities for student engagement it affords, and the possibilities that are generated for youth of color.

As one source of power in science classrooms, teachers have the ability to offer alternative possibilities and roles for their students through the organization of institutional structures, cultural practices, social interactions, and relationships (Nasir, 2004). I adopt Nasir & Hand's (2006) definition of learning as not only taking on new knowledge structures, but about "personal transformations of becoming"(Nasir & Hand, 2006, p.467). The ways students are exposed to and negotiate a variety of identities and practices during activities organized by the teacher can over time support "an array of imagined trajectories of becoming" (Nasir & Hand, 2006, p.468). In this way, a teachers' pedagogical vision and the futures they imagine for their students play a central role in guiding the program resources made available and the possibilities that can be generated.

Mechanisms of the vision: Imagining possible futures. The conceptualization of a "pedagogical vision" builds from Cole's (1996) idea of ideal artifacts and the process of "prolepsis". Cole (1996) conceptualizes ideal artifacts as ideas, experiences and cultural pasts that shape our imagining of what is possible in the future. These artifacts carry meaning across time through prolepsis (Cole, 1996). Through the process of prolepsis ideal artifacts from cultural pasts are projected into the future in ways that structure and mediate activities at present (Cole, 1996). For example, a parent's own cultural past, experiences and conceptions of the world (ideational artifacts from the past) travel through time and construct ideas about what the future holds for their child (imagined/projected futures). This proleptic process creates different materialized constraints and interactions that fundamentally constrain the child's experiences in the present (Cole, 1996).

Building on this further, Nasir & Hand (2006) conceptualize race as an ideal artifact that can carry meaning across time through the process of prolepsis described above. When employed in institutional practices, conceptions of culture and race in society often construct disparities in access to opportunities and experiences (Nasir & Hand, 2006). In addition, research shows how racialized stereotypes and narratives (i.e. race-based artifacts) carry meaning across time to impact the possible futures available to African American young men (e.g. Nasir & Shah, 2011). Findings from Chapter 4 illustrate the ways focal students' experiences are impacted and mediated by racial narratives that carry meaning across time. These narratives impact students' conceptions of science and how they see themselves in relation to science at present.

Bringing the idea of prolepsis to schooling and a teacher's vision, Nasir (2004) describes how educator's cultural pasts, experiences, and world views (i.e. ideal artifacts) shape the futures they imagine for their students and the organization of school practices at present (e.g. norms, activities). Of particular importance is that *ideal artifacts align with actions* to influence the structuring of the classroom environment and interactions between teachers and students in the present (Nasir, 2004). Findings from this research can be extended to this study to explore how scientist instructor's ideas about science, race and their students impacts the organization and structuring of activities and the construction of identities in the science programs.

Powerful role of teachers: Projecting possible futures. Building on the idea of prolepsis and projecting possible futures, research shows how a teacher's pedagogical vision and future imaginings for their students plays a powerful role. This vision organizes the activities within a learning environment in the present and creates or limits access to resources and opportunities that mediate processes of learning and identity. Research shows how educators and coaches can offer and constrain access to resources and opportunities that impacts future trajectories of students and athletes. In addition, Research shows the power of teachers to reposition students and offer alternative identities that create new possibilities of becoming (Nasir, 2004). In addition, research shows how a coach as the identifier offers differential access to particular resources that shape students' trajectories as track athletes (Nasir & Cooks, 2009). In this example, the coach's perception of an athlete's dedication and drive determined the resources he made available to certain athlete in ways that impacted the athlete's identity outcomes (Nasir & Cooks, 2009). These findings illustrate the ways the coach, as the identifier, utilizes ideal artifacts about what constitutes a successful track athlete to project different futures for certain athletes. Bringing this idea to the science programs, this study explores how an instructor's pedagogical vision guides the program resources made available, how they are taken up or resisted by students and the types of identities made available and constructed through program participation.

Re-centering race: Organizing activities in science spaces. A lot of important work is being done to support science identity construction for racially/ethnically underrepresented youth. However treatments of race in relation to science are limited (Parsons, 2014). Science identity literature offers insights into the types of identities offered to underrepresented youth (e.g. Polman & Miller, 2010; Tan & Calabrese Barton, 2010), but race is often treated simply as a means to group students rather than an aspect of *who* students are in science spaces (Parson, 2014). More work is needed that examines intersections of students' racial and disciplinary identities (Varelas, Martin, Kane, 2012). In addition, we need more insights into how students' science and racial identities develop *together* through participation in science practices.

What does re-centering race mean for the organization of activities in science programs serving youth of color? As the "identifiers" what opportunities are available for instructors to support a racially and politically conscious vision? Research shows that beginning teachers' orientations to science, students, race and diversity on personal, social and political levels informed their perspectives of science and views of science teaching (Bianchini & Solomon, 2003). This impacted teachers' views of equity in science and ideas about equitable approaches to science instruction (Bianchini & Solomon, 2003). In addition, Oakes et al., (1997) conceptualize a role for teachers as "power agents" and show how teachers' perspectives of their students based on factors including race hold incredible weight. Through their research, Oakes et al., (1997) show that when teachers confronted a racialized institutional practice (i.e. tracking) in their school as a cultural and political struggle they found it difficult to support traditional conceptions of students' abilities or the segregated tracking structure in their schools. As power agents, teachers began to realize that they had control over the creation (and re-creation) or dismantling of institutionalized structural inequity. More research is needed that explores how an instructor's vision about science, students, and race shapes the futures they imagine for their students, the opportunities they make available, and the impact on learning and identity construction in science programs.

I build on this work to re-center race in the discussion of science identity construction for racially/ethnically underrepresented youth *and* an educator's vision. I examine how an instructor's ideas about and experiences with science, their students and race impacts the possible futures they imagine for their students and organizes the structure of activities and opportunities in the science programs at present. In addition, I examine the co-development of students' science and racial identities, and what is possible when resources that support holistic identity construction are made available.

Methods

Data Sources

This study utilized four data sources: 1) Pre and post program student surveys, 2) Pre and post program focal students interviews, 3) instructor interviews, and 4) program observations.

Pre & post program student surveys. 9 of the 11 students in the Westport program completed pre and post program surveys. The goal of pre and post program surveys was to establish a baseline (pre) and determine changes (post) in students' attitudes towards, ideas about, and perceptions of ability in science as well their ideas about the scientific research process. Pre program surveys were administered on the first day of the program. Post program surveys were administered on the last day of the program. All surveys were administered and completed on paper copies during class time and turned in together.

Interviews. ***Focal students***. Seven focal students completed pre and post program interviews and two students completed follow-up interviews during the school year following program participation. Pre program interviews were designed to capture students' ideas about science practices, *who* does/can do science, how students saw themselves in relation to science and other aspects of their science and racial identities. In addition, interviews were designed to capture two types of science practices (school and scientist) defined as follows: a) School science practices: the types of activities students participate in during science class in order to "do" science in school; b) Scientists practices: the types of activities utilized by scientists to conduct scientific research and/or produce scientific knowledge through the research process. Pre program interview questions asked students to describe what it "looked like" to do science in school and their ideas about what they thought scientists did to conduct scientific research. Post program interviews asked students to describe their research projects and what *they* did to conduct scientific research during the summer science programs.

Scientist Instructors. Three instructors from Westport completed interviews (the lead instructor, assistant, and computer science graduate student that assisted). Interviews were designed to capture instructors' perspectives of science and their students as well as their sense making about racial/ethnic underrepresentation in science. Interview questions captured instructors' ideas about science that included: goals for instruction, utility of scientific research, science practices that they used themselves and found important to promote, ways that they used science in their own lives and how they hoped students would use science in their lives.

Interviews also captured instructors' ideas about their students that included: racial backgrounds, societal positioning. Finally, interviews captured instructors' sense making about racial disparities in the professional science community. Together, interview responses were used to determine an instructor's "pedagogical vision". *Pedagogical vision* is defined as the ways that teachers' own backgrounds and experiences inform their goals and purposes for teaching science, what they envision their students *doing* with science, and the possibilities they create for *who* their students can become in science. This included instructional approaches, the experiences they designed and the spaces they created for learning. Ultimately, the vision constructed the pathways and opportunities they made available for students. Instructor interviews were used in conjunction with program observations to determine how their vision played out in real-time and impacted the types of program resources made available.

Program observations. Program observations were made two to three times per week. The goal of program observations was to explore the mechanisms involved with engaging students in science practices and how the accompanying resources supported shifts in students' ideas about *what* science is and *who* can do science. Program observations were designed to capture moments of positioning between participants and instructors and the types of resources made available and exchanged between participants (e.g. students, instructors) during the programs. *Program resources* are defined as the types of instruction, pedagogy and designed experiences that instructors make available and the types of resources exchanged between participants during the summer programs.

Program observations across programs included: students conducting scientific research, classroom discussions and interactions, culminating research project presentations and informal interactions between students and instructors. Program observations were focused on the selected focal students in each program but also captured activities holistically. In all cases, field notes were recorded using pen and paper. Program observations were used in combination with instructor interviews to determine how their pedagogical vision played out and impacted the types and availability of program resources. In addition, program observations were used in conjunction with student interviews to determine moments of positioning, uptake or resistance of program resources, and the resulting impact on students' identity construction.

Analysis

Pre and post program student surveys. Attitudinal questions appeared as Likert scale items on pre and post program surveys. Likert scale items were scored from 1-5 with 5 representing the most positive response and 1 representing the most negative response. All items for a validated scale were considered a subcategory (e.g. science identity). To determine differences between students, data was averaged by subcategory for individual students and compared within and across programs. To determine differences between programs, student data was averaged by program and compared across programs. Plots were created to determine patterns between different groupings of students that included: 1) high vs. low perceived ability, 2) high vs. low science identity, and 3) male vs. female students. Findings were reported as within and between program differences.

Interviews: ***Focal students***. Focal student interview protocols were designed to capture students' ideas about the practices of science, aspects of their science and racial identities, and their ideas about who does/can do science. To better understand students' ideas about the practices of science, during post program interviews students were asked to describe the scientific research they conducted, what they did to conduct research on their topic, and changes in their ideas about the scientific research process. Transcripts were coded through an iterative process for: 1) engagement in science practices: practices that students described as utilizing to conduct scientific research, and during the construction of scientific knowledge, 2) uses for scientific research: utility and purpose of research, as well as who might find the research useful, and 3) aspects of science/racial identity: students' ideas about how they see themselves and members of their racial group in relation to science.

Linking identity statements & science practices. Through the analysis process above, it emerged that in some cases direct links could be made between science practices (e.g. collecting data) and identity statements (e.g. I am good at science). Exploring this further, certain questions (i.e. tell me about a time you felt good at science this summer) allowed for an exploration of the relationships between science practices and aspects of students' science/racial identity construction. During analyses, when a science practice could be directly linked to an identity statement (e.g. collecting data made me feel good at science) this was coded together as an identity/practice statement. Analyses revealed that these identity/practices statements were an important aspect of an *identity generative process* that emerged during this study that linked engaging in science practices and the accompanying program resources to the generation of new possibilities for students.

Practice/identity statements were analyzed as a *unit* to determine how engaging in science practices "functioned" for students with regards to identity construction. In order to determine patterns between science practices and identity statements, science practices and identity statements were aligned and sorted into groups by science practice and by identity statement. When there was overlap between the same identity statement (e.g. change agent) and the same science practice (e.g. present research) this was considered a significant aspect of students' identity generative process. Identity statements were counted once per science practice but explored across science practices and counted each time they could be directly linked to a different science practice.

To determine if and how program resources facilitated links between identity statements and science practices, identity/practice statements were explored throughout interview transcripts. Program resources that were connected to the science practices were coded and analyzed together with the identity/practice statements. Program resources from interviews were then examined in conjunction with observational field notes to gain a more holistic understanding of the complete identity generative process.

Scientist instructors. Instructor interview transcripts were read and coded for: 1) perspectives of science (e.g. utility) and students (e.g. racial background), 2) instructional goals and general approach, 3) science practices promoted, 4) their approach to engaging students in the scientific research process, 5) ideas about racial and gender disparities in the professional science community, and 6) resources they made available. Coding categories were analyzed individually and for patterns between categories (e.g. perspective of students/science and resources made available). In addition, categories for instructor's ideas about science practices and their students were analyzed in conjunction with the types of resources they made available. This analysis was used to determine how an instructor's "pedagogical vision" shaped the program resources they made available.

Observational field notes. Field notes were recorded during program observations and were used to capture the mechanisms associated with program participation and the types, availability and uptake of resources in real-time. Field note coding was done inductively and through an iterative process to remain open to novel constructs, interactions, and resources that appeared outside of the guiding framework (Miles & Huberman, 1994). Field notes were coded for types of program resources made available (e.g. instruction) and how the resources were taken up and utilized or resisted by participants. In addition, field notes were coded to capture social interactions and moments of positioning between students and instructors in the science program spaces. This process provided empirical evidence for the types of program resources (e.g. ideational, material, relational) made available in the science programs and the *mechanism* associated with how they were made available and exchanged among participants in those spaces. Coding and analysis of material resources included: a) curriculum resources, instruction, scaffolding of scientific processes made available by the instructor, and b) student engagement in the data collection process (e.g. using/reading science equipment). Coding for relational resources included positioning of students by instructors and peers during research, groups discussions and other program components. Coding for ideational resources included: a) how an instructors' perspectives of science, race, and their students shape their instruction and the types and approach for promoting science practices, and b) students' ideas about science practices, who can do science, and their place in science. Intersections among resources and unique resources outside of the framework that were made available were also explored.

Program observations were triangulated with focal student interviews and student surveys in order to gain a holistic understanding of students' experiences in the programs and how new possibilities were generated for students. Specific episodes were selected that addressed engagement or resistance of resources while students conducted scientific research. Focal students were asked about these episodes during post program interviews. This allowed for triangulation of students interviews with observations made in real-time and allowed for an exploration of how different identity constructing resources interact. Program observations were also coded in conjunction with instructor interviews to determine how aspects of an instructor's pedagogical vision and their perspectives of science and their students shaped the resources they made available and played out in real-time in the science program contexts.

Cases of focal science practices. Two cases are presented that explore how engaging focal science practices and the accompanying program resources generated new possibilities for Westport students. Case #1 examines how engaging in the data collection and analysis process generates new possibilities as follows: By engaging in aspects of the data collection process (e.g. use/read science equipment) students saw themselves as *capable science learners* (i.e. practice: use/read machines → *capable science learners*). By engaging in the practices of collecting and analyzing data, students saw themselves and their peers as *scientists* (i.e. practice: collect/analyze data → *identify self/peers as scientist*). Case #2, examines how presenting research in a high stakes context empowers students as *change agents* in their community (i.e. practice: research presentations → *change agents*).

Findings

Westport as Focal Program: What Shifts?

The Westport program is the focal program for this chapter. As described in Chapter 4, post program findings show that students from Westport, who entered the program with the lowest average perceived ability in science scores made the greatest post program identity shifts. To highlight the main findings:

Identifying themselves/peers & youth of color as scientists. Students from Westport more commonly identified themselves and their peers as scientists compared to students from other programs following program participation. Therefore, Westport students made the biggest post program identity shifts. In addition, no students from Westport described scientists as "not my race" following program participation and some specifically identified youth of color as scientists (see Figure 2). These findings were unique to Westport. This suggests unique resources were made available to Westport students that supported their science *and* racial identities.

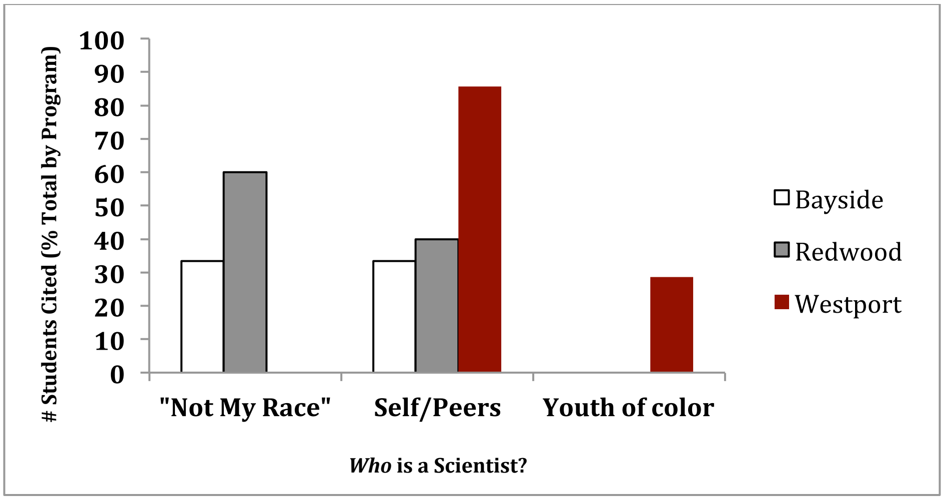

Figure 2. Post program focal student ideas about *who* is a scientist by program.

Perceived ability gains & identifying as a scientist. Findings suggest that Westport students made gains in perceived ability and identified themselves and their peers as scientists because of what they were able to *do* as scientists. Based on all student pre and post program attitudinal surveys (n=41 across programs), Westport students who entered the program with the lowest perceived ability in science made the greatest gains following program participation. In contrast, students from Bayside and Redwood showed little to no change. Findings show that increases in perceived ability and identifying as a scientist may be linked. Interestingly, all low perceived ability students from Westport moved inbound towards seeing themselves as scientists. That is, they identified themselves and their peers as scientist following program participation. This was unique to Westport students. Low perceived ability students from Bayside and Redwood either showed no pre to post program shifts in seeing themselves in science or moved outbound and found even more ways they felt that they did not belong in science following program participation.

Findings suggest that Westport students made gains in perceived ability (i.e. saw themselves as capable science learners) and identified themselves and their peers as scientists because of what they were able to *do* as scientists. Westport students' ideas about *who* does science and the characteristics they associated with scientists shifted together. In this way, engaging in scientific research allowed Westport students to construct new ideas about *who* does science that included *themselves*. This chapter seeks to identify the unique program resources that were made available to Westport students.

Expanded views of science. In addition to these findings, like students from Bayside and Redwood, Westport students expanded their ideas about what counts as science practices following program participation. Similar to students from other programs, Westport students added new types of science practices to their repertories (see Figure 3) and developed expansive meanings of science practices. Through the case studies I examine how engaging with particular science practices generated new possibilities for Westport students.

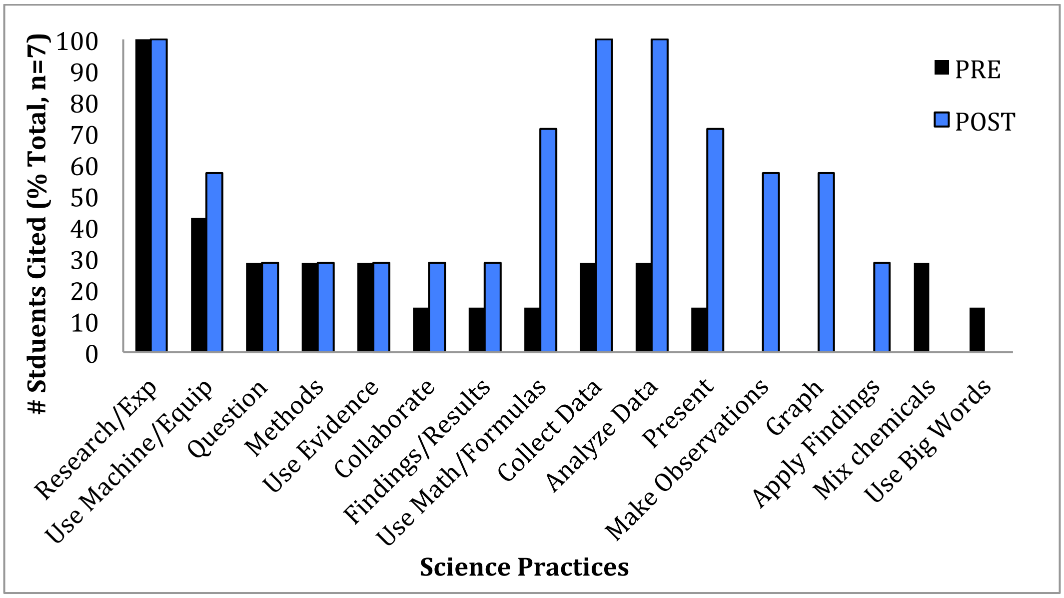

Figure 3. Pre vs. post program in shifts in types of science practices described by focal students across programs.

In this chapter, I explore the mechanisms involved with the generation of new possibilities for *who* Westport students can become in science. I explore how shifts in *what* science is can lead to shifts in *who* can do science when students' science *and* racial identities are holistically supported. First, I describe the emergence of the identity generating process and how engaging with particular science practices and the accompanying program resources created new possibilities for Westport students. Next, I examine the instructor's vision, his perspective of science and his students and how this guided the program resources and opportunities he made available. Finally, I utilize two case studies focused on particular science practices to document how students constructed identities by engaging with science practices and the accompanying program resources. For each case, I examine relationships between: 1) the program resources (instruction, pedagogy, designed experiences) made available for the science practices, 2) the nature of the shifts that occurred for students while engaging in these practices and accompanying resources, and 3) the types of identities that were constructed through this process. In the next section, I describe the emergence of the identity generative process.

Emergence of Identity Generative Process: Linking Science practices to Identities

In this section, I document how the identity generative process emerged through analyses. In the case studies that follow, I take an in-depth look at student engagement in focal science practices selected through this analytic process. As described in the methods above, during analyses, when a science practice (e.g. collecting data) could be directly linked to an identity statement (e.g. I am good at science) this was coded together as an identity/practice statement. Analyses revealed that these identity/practices statements were an important aspect of an *identity generative process* that emerged. This process links engaging in science practices and the accompanying program resources to the generation of new possibilities for students.

Practice/identity statements were analyzed as a *unit* to determine how engaging in science practices "functioned" for students with regards to identity construction.

As described in Chapter 5, students added new types of science practices to their repertoires following program participation (see Figure 3). Patterns emerged between identity statements and four types of science practices: 1) using scientific equipment, 2) collecting data, 3) analyzing data and 4) presenting research. Westport students added many of these science practices to their repertoires after conducting scientific research (see Figure 3). It is important to note that focal students across programs commonly described these same science practices following program participation. In other words, adding these types of science practices to their repertoires was not unique to Westport students. However, what is unique is the *types* of identities generated by Westport students from engaging with these science practices (see Table 1 for science practices, identities generated, student examples). Findings show that students' experiences with the same science practices and the program resources made available for the practices differed by program. Therefore, the goal of this chapter is to document the program resources made available to Westport students that supported the development of these unique identities. Next, I explore the types of identities generated by Westport students through engaging with these focal science practices.

Using science equipment & collecting/analyzing data. Findings show that engaging in the science practices of analyzing data and those associated with the data collection process (e.g. using scientific equipment, recording observational notes) generated two types of identities for Westport focal students: 1) *capable science learner*, and 2) *scientists* (see Table 1). All Westport focal students (n=7) described collecting and analyzing data as important science practices following program participation (see Figure 3). Interestingly, during post program interviews, when asked to describe a time they felt "good at science" during the summer, over half of Westport focal students (4 of 7) described experiences related to the data collection process such as learning to use/read science equipment (see Chapter 5, example of James) and recording observational notes. As a result, engaging in the data collection process was linked to the identity of *capable science learner* (see Table 1).

In addition, when asked to describe someone they met during the summer that they considered a scientist, the majority of focal students (6 of 7) named themselves and their peers. Interestingly, students from Westport commonly constructed this new possibility (i.e. identifying as a *scientist*) specifically because they had collected air quality data for their research project. Students described data collection as central to the work of scientists. Therefore, the experience of collecting data over the summer provided an opportunity for students to do what scientists do and to see themselves as scientists. In this way, engaging in the data collection process was also linked the identity of *scientist* (see Table 1).

Presenting research. Findings show that opportunities to engage with the science practice of "presenting research" generated the identity of *change agent* (see Table 1). Presenting research was a new science practice added by all focal students from Westport (see Figure 3). Westport students had the opportunity to present their research in a high stakes context. Many students described using their research to create change based on this experience. In this way, the practice of presenting research was linked to the identity of *change agent*. The identity of *change agent* was described by 5 of 7 focal students from Westport and was an identity unique to this program. Presenting research generated different types of identities across programs depending on the types of program resources made available for this practice. This is discussed in the program contrasts following each case below.

Table 1. Emergence of Identity Generative Process: Science practices, Types of Identities Generated & Student Examples

Science practice	Type of Identity Generated	Student Example (Illustrative Quotes)
• Data collection process: -- Use/read machines -- Record observational notes • Analyze data	Capable science learner	• "To actually see how the machine worked and actually just getting something out of it." (James) • "I feel like now I'm more capable of finding data on my own and finding ways to collect data. I have more knowledge of what to use, and how use it." (Melanie)
• Collect data (general)	Identify self/peers as scientist	• "I guess they (scientists) do what we do, which is go and collect data" (James) • "Well, I guess we are all scientists....doing this, cause I researched, kept going out and collecting data." (Serena)
• Present Research	Change agents	• "You actually need to know how to present… like to be able to get your data or whatever you researched out to people, you gotta talk to people, like look this is what my project was, this is what I found out." (Fernando)

In the case studies below, I examine the mechanism involved with how engaging in the focal practices described above generated new possibilities for Westport students. I document the program resources made available for the science practices, the shifts that occurred for students through engaging with the practices, and how new identities were constructed. Before I delve into the case studies, in the next section, I examine the Westport program context including the students, research, and overall programmatic vision of the instructor.

Westport Program Context & Instructor's Pedagogical Vision

In this section, I examine how the Westport instructor's perspective of both *science* (e.g. purpose, utility) and his *students* (e.g. race, social positioning) guides his overall vision and goals for teaching science. I then examine how his vision guides the instruction, pedagogy and designed experiences he makes available for the focal science practices described above.

Westport program context. ***Students***. As described throughout this dissertation, Westport students entered the program with lower average perceived ability in science scores compared to students from the other programs. All students from Westport ranged from below average to low on perceived ability scores. Students in this program commonly described experiencing little success in science class in school. This may have contributed to their low perceptions of themselves in relation to science. In addition, many of the students participated in the summer program because they had failed science class or needed to make up science credits. Serena, the 12th grade case study student from Chapter 4 is representative of the low perceived ability students from this program. She describes how she sees herself in relation to science: "I'm not really that good at science...science is not really my strong subject in school. Like, it's bad. I never really got it." However, the program also contained students who described science as their favorite subject in school and who voluntarily participated in the program (e.g. see Melanie from the opening excerpt). These students had a medium perceived ability in science but were still below average compared to students across programs. Westport students self-identified racially as Latino/a, Chicana, Mexican, African American, and Filipina. There were four girls and seven boys in the program. The group of focal students contained three girls and four boys.

Instructors. The instructor for the Westport program is Matt. Matt graduated with an environmental science degree and had a strong disciplinary and science research background. He served as the lead instructor for the Westport summer science research program. Matt identified racially as white. He had been working as an instructor for the summer program and it's afterschool component for several years when he taught the program in this study. Therefore, he was a veteran at guiding students from underserved communities in the design and implementation of community-based research. He received assistance with program instruction: he had a program assistant (an African American male) and a computer science graduate student (a white, female) that helped with data representation and analysis. In addition, he partnered with a local community-based organization that provided access to science equipment and resources. Matt played the lead role in the design and implementation of all program activities and therefore is the focus of this analysis.

Air quality research project. Matt guided his students through designing and conducting a seven-week long air quality research project involving a local transportation agency in their community. Students participated in and contributed to all aspects of the research process including: the generation of overarching research questions, experimental design (e.g. where to collect air quality samples), data analysis and deciding what aspects of data warranted for further inquiry.

Pedagogical vision: Imaging and designing for possible futures in science. In the next section, I explore Matt's vision in greater depth. Matt had a particular perspective of science and of his students, specifically as youth of color from an underserved community, that informed his programmatic goals, and the design of the instruction, pedagogy, and experiences he made available. As described above, findings show that an instructor's pedagogical vision and the resulting program resources for engaging students in scientific research played a central role the construction of new possibilities for students (see Figure 4). In the next section, I focus on Matt's vision of science and his students (see Figure 4, top black portion).

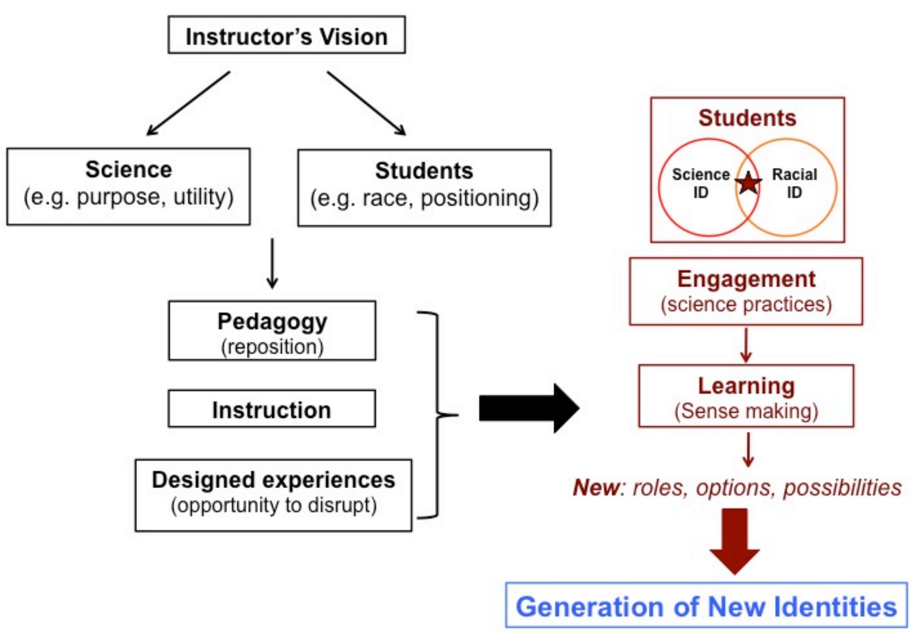

Figure 4. Relationship between an instructor's vision (science, students) the design of program resources, (pedagogy, instruction, designed experiences), engaging in science practices and the generation of new identities.

Perspective of students: Power & social positioning. Matt's years of experience working with youth of color from underserved communities shaped his perspective of his students and his ideas about his role as a science instructor. He describes a perspective that merges his ideas about his students, hierarchical power structures in society, and science:

> Science helps reveal the relationship a lot of young people and their families have with the larger system that has alienated them so much from power or having any sort of dignity.

Matt describes an awareness of the *lack of power* his students and their families experience in our society. From his perspective "power" is linked to "dignity". Matt builds on this idea, and describes other ways that he feels that his students lack power:

> They've been in so many situations like their education, which is so dominant in their lives, they have no power over anything, and so, a lot of the experiences they have just reinforces the fact that they don't have power, which isn't necessarily true, it's just, they internalize that.

Matt feels that his students internalize a lack of power because they experience this in many aspects of their lives. His statement suggests that he feels that this can be disrupted. In the case studies, I illustrate how the opportunities he provides are designed to disrupt this lack of power. He builds on this to make connections between this lack of power, societal positioning of his students, and their social-emotional well-being:

> So many of the students that we work with have extremely low self-efficacy, self-esteem and a lot of that stems just from their social and class position in society.

Matt attributes his students' low self-efficacy to their "social and class positioning". As described above, many of the Westport students were in the summer program because they had failed their science class in school. What is significant about Matt's perspective is that where others may have seen students that were unmotivated and disengaged, Matt saw students that lacked power in a hierarchical system and were impacted emotionally (and psychologically) by their positioning. Because of their low self-efficacy, he emphasizes a need for students to experience success during the summer program and views science research as a way to create opportunities for this to happen. In the case studies that follow, I illustrate how this perspective informs the ways he positions students as capable science learners during instruction. Finally, Matt describes how his ideas about race play into his vision:

> As white male, I have a lot more access to things and I've been able to maneuver the system in a way that young women and men of color cannot….It's important to me to try and address that with the work that I'm doing. It's….a responsibility of sorts to try and, utilize the power that I have, or take advantage of the power that I have in society for people that are oppressed and have less power, or to support them in whatever they want to do.

Here Matt describes an awareness of privilege and access to power that he has as a white male in society that distinguishes his experience from that of his students (i.e. "young women and men of color"). In this way, he makes links between power, race and social/class positioning (described above). His ideas about his role as a science instructor are shaped by this awareness. He describes a "responsibility" as a white male to leverage the power he has to "maneuver the system" and help those that he perceives as having less power. Next, I examine how Matt's perspective of his students is highly intertwined with his perspective of the purpose of and uses for science. This shapes his overall programmatic goals.

Perspective of science: A tool to create change. Matt describes his overall goals for science instruction:

> My larger goal is to have them be able to be scientist in all aspects of their lives, whatever they end of up doing. So that they can have a critical lens on the world and so they're not just, assuming everything is just the ways it is, but they can use science to create change in their lives and communities.

Here, Matt expresses a desire for his students to use science in all aspects of their lives regardless of what they pursue in the future. He adds: "I don't really care necessarily whether they go into a career in science." This suggests that he views science knowledge as a powerful and widely applicable tool that can be leveraged to push back on one's societal positioning. In addition to the uses for science described above, Matt emphasizes that he hopes his students use science to "support" and "develop answers and solutions to problems in their community".

There are two aspects of Matt's vision that are central: First, he views his *students* through a politically and racially conscious lens. This lens builds from a particular understanding of his positioning as white male in our society and his students' positioning as youth of color of lower socioeconomic status. He makes a link between race, class, social positioning and power and expresses awareness of the lack of power his students experience in many aspects of their lives (e.g. school, societally). Second, he views *science* as a tool that can be used to empower his students and that they can use to create change in their lives. He seeks to use science as a tool to disrupt the lack of power that his students experience. In the cases that follow, I illustrate how this disruption of power creates space for social dreaming (Gutierrez, 2008) and the generation of new possibilities and identities for students as *capable science learners*, *scientists*, and *agents of change*.

In the following case studies, I illustrate how Matt's overall perspectives of science and his students guides the pedagogy, instruction, and designed experiences that he makes available for the focal science practices described above: using scientific equipment, collecting and analyzing data, and presenting research (see Figure 4, black). I argue that these program resources are context specific and serve as the mechanisms that foster the generation of new possibilities and identities in science. I show how Matt's vision is specific to the student population he works with (i.e. youth of color, low socioeconomic status) and this guides the program resources he makes available to his students as they design and conduct their air quality research project. Furthermore, I illustrate that the program resources made available have *intended outcomes* for students that facilitate engaging in science practices (see Figure 4, red) the uptake of new possibilities and identities (see Figure 4, blue). Finally, I show how engaging in the focal science practices and the accompanying program resources fosters the generation of new possibilities and identities for Westport students as *capable science learners*, *scientists,* and *change agents*.

Cases Studies: Science Practices, Program Resources & New Possibilities

Next, I present two cases of focal science practices: Case 1 (data collection and analysis), Case 2 (present research) (see Table 2). In each case, I examine how the instructor's overall vision for specific science practices guides the program resources made available (see Figure 4, black); and how engaging in these practices fosters learning (see Figure 4, red) and the generation of new possibilities in science (see Figure 4, blue). In each case I trace links between the science practices (e.g. present research), the program resources made available for the science practices (e.g. present in high stakes context) what shifts for students, and how this facilitates identity construction (e.g. change agent) (see Table 2). In addition, I use contrasting examples to show how these same science practices serve different identity "functions" for students across programs based on the program resources made available.

Table 2. Case Studies: Science practices, Program Resources & Identities Generated

Case Study	Science practice	Program Resources	Type of Identities Generated
#1	• Use/read science equipment • Data collection process (e.g. observational notes) • Analyze data	• Introduce equipment: parts, operation - Practice: use/read equipment • Data collection process - Opportunities to practice, evaluate - Make, learn from mistakes • Software: visualization, represent data, graphing tools	• Capable science learner • Identify self/peers as scientist
#2	• Present Research	• Designed experience - Disrupt lack of power - Present high stakes context • Prepare: discuss findings • Scaffold: Incremental stakes (peers, family, board members, representatives)	• Change Agents

Case Study #1. Becoming Learners & Doers of Science

As described above, engaging in science practices associated with the data collection and analysis process generated the identity of *capable science learner* and *scientist* for Westport students (see Table 2). I examine these practices together because they form an iterative cycle: students used science equipment during the data collection process to take air quality readings. In addition, students recorded observational notes; a practice central to making sense of their data during analysis. Engaging with data analysis allowed students to identify gaps in their understanding and generated the purpose and need for certain practices. In this way, findings illustrate the learning and sense making that are afforded by keeping the synergy between these practices intact when engaging students in scientific research. I illustrate how together these practices provided an opportunity for students to construct new knowledge about air quality. This generated new possibilities for *who* they could be in science.

Program resources: Collect & analyze data. I begin with a description of Matt's vision and the instructional and pedagogical resources he made available for data collection and analysis in order to provide a context for students' experiences and opportunities to engage with these practices. In addition, I make connections between Matt's vision for these specific science practices and his broader programmatic goals as described above (see Figure 4, black portion).

Vision: Everyday data collection & generating evidence. Matt expressed a commitment to finding ways for his students to experience success in science. He viewed scientific research as a context where students that may not often experience success in science could excel because there are multiple ways to participate, contribute and display understanding. He emphasized the importance of scaffolding the process so that students would experience success. In addition, Matt described his perspective that students could (and should) learn science content through inquiry:

> You can teach content…through inquiry… students should learn that information through practice, not through reading a book or a lecture…Hopefully through the collection of data and the analysis process, they start to wonder themselves like, what does this mean? And so research itself can actually generate questions that will lead to more content knowledge and that would be developed by the students themselves.

Here, Matt describes a generative process: collecting and analyzing data, leads to questions that require more content knowledge. In addition, he sees this process of generating a need for content knowledge as student directed. Matt's goal was to provide opportunities for his students to experience success. To do this, he introduced these science practices in a social learning context that created space for making mistakes. He explains:

> I wanted them to see what data collection was like, how to design and experiment. And a lot of that is learning through mistakes, you know, so, I would say a lot of what they did this summer was seeing through their mistakes.

In this way, Matt describes the importance of providing opportunities to learn from mistakes. This suggests that Matt saw a role for making mistakes in the scientific research process and viewed mistakes as an opportunity to learn and grow as a science learner.

In addition, Matt viewed his students as natural data collectors in their daily lives. He sought to show students how science can help enhance their natural skills and to empower youth as capable doers of science in the process. He explains how this perspective ties into his goals for the specific student population that he works with:

> I think the students that we work with already have a firm lived experience and understanding and they've gathered scientific data, it's not necessarily in a graph or a data table, but I think relating that to other environmental indicators, variables, can be really powerful because it can show them that certain technologies can be relevant to addressing their lived problems.

Matt describes science as a tool that his students are already using to evaluate and make sense of their lived experiences. This perspective is specific to his students' social positioning in society. He sought to leverage students' natural data collection skills as an instructional resource and viewed technology as a tool that can build on and enhance these skills. Finally, Matt discussed the importance of gathering evidence:

> I want students to generate questions initially, but then also to be able to answer them in a genuine way, where they can develop evidence to answer those questions.

Here, he places importance on developing evidence to answer questions. To support this, he taught his students the practice of collecting and analyzing data in order to generate evidence. Later, I show how evidence becomes a powerful tool that empowers students to make claims about their research.

Instruction for science practices: Collecting & analyzing data. To empower students as capable doers of science and to ensure they experienced success while engaging with these science practices, Matt scaffolded the data collection and analysis process. He was committed to providing opportunities that allowed his students to experience success and described his simple approach: "Positive reinforcement as well as scaffolding things, so that they are successful." He scaffolded three main science practices: 1) using handheld devices to collect air quality data and making sense of the readings (i.e. use/read science equipment), 2) recording observations during the data collection process, and 3) using visualization and graphing software to analyze data. First, Matt guided his students through the use of scientific equipment to collect air quality data. Students learned to use two types of handheld, portable devices equipped with GPS units that collected particulate matter measurements. Data was stored as real-time networked data that could be geospatially located when downloaded (note: this becomes important for data analysis).

Matt provided opportunities for students to learn how to use the scientific equipment, make mistakes, and practice in a comfortable setting. He provided an overview of the equipment, the different parts, and the purposes of each component. He demonstrated how to carry the equipment when sampling. At the same time he introduced the observation data sheets that students carried with them during data collection excursions. The observation sheet contained columns for the date, time, location, and observational notes. He reviewed the purpose of this with the students. Students worked in groups and operated as a team during the data collection excursions. Students learned how to operate the equipment and had an opportunity to ask questions in a casual and information setting. Afterwards, the students went outside and practiced learning to use the machines by taking samples in the neighborhood. This provided an opportunity for students to practice, make mistakes, and feel comfortable using and reading the scientific equipment.

Matt then introduced students to the data analysis process. This involved a web-based platform that created a geospatial representation of their data. Matt described the importance of guiding students through the analysis process and helping them understand the data they have collected:

> Then there's the analysis of data, which I tried to really emphasize, and trying to make sense of what data was collected. That's why we try and use so many software tools that make it easier to visualize the data….That's really critical in order to engage young people who aren't so engaged necessarily in the sciences. I mean it makes it easier for them to understand what they did.

Here, Matt expresses an awareness of the challenges associated with data analysis, the importance of data representation and visualization as a means to reduce the complexity and the need to use tools that can help students become engaged in this process and feel successful. Matt partnered with a computer science graduate student that created the data visualization platform. She attended the majority of the program sessions in order to facilitate the use of the platform and helped guide the analysis process. In addition, he partnered with a local air quality monitoring organization that was a few blocks away from the program site.

Through practice, students learned the importance of recording good observational notes when they collected data. Students practiced using the handheld devices on the way to the air quality organization office and used the computers there to download the data they had just collected. As the group reviewed their geo-spatially represented data that overlaid onto Google maps, Cindy, an African American woman who led the organization asked the students what was happening at a specific street where the particulate matter readings were especially high. Students thought back to that location and brainstormed ideas – there was smoke from a barbeque, something that would impact the amount of particulate matter in the air. This moment was significant because it introduced students to the importance of recording observations while using the equipment. Cindy's question helped students understand that the machines provided counts and measurements of particulate matter levels but do not provide information about what was happening at a location to cause the levels to increase or decrease. Therefore, taking careful and well organized observational notes with times and locations during the data collection process would be critical to making sense of the data once they returned from excursions. In addition, to learning the importance of a science practices, this experience also exposed students to other scientists of color.

Matt also made connections between data collection and deriving evidence to support a claim. After a week of data collection students were guided through the analysis process. Students worked in teams to examine representations of data uploaded into the software platform and were tasked with finding locations with high levels of particulate matter. The students' generated research questions about what transportation stations (indoor vs. outdoor) would have worse air quality. When students offered explanations, Matt provided counterexamples that pushed their thinking in new directions. Students debated over indoor vs. outdoor transportation stations based on the data that they had collected. Near the end of class, Matt asked students if they had enough evidence to support a claim. He asked the students if they needed to collect more data and they agreed that they did. In this way, Matt helped students understand the relationship between data collection, evidence and making claims.

In summary, Matt's overall vision for his students and science guided the instructional and pedagogy he made available for the science practices associated with the data collection and analysis process. The program resources were intended to provide opportunities for students to experience success, make and learn from mistakes, and create understanding of how different aspects of the scientific research process fit together. In addition, he sought to tap into the resources and lived experiences that students brought to the classroom (e.g. natural data collectors). Overall, these resources were intended to empower students with the tools to use data and evidence to make change in their lives.

In the next section, I examine the shifts that occurred for students through engaging with the practices of "using scientific equipment", and "collecting and analyzing data". In addition, I explore how engaging in these practices and the accompanying program resources outlined above generated the identities of *capable science learner* and *scientist*.

What shifts for students? Generating new possibilities in science. Focal students described important shifts in the ways they saw themselves in relation to science as a result of engaging in the data collection and analysis process. Engaging in these practices generated two types of identities: 1) *capable science learner*, and 2) *scientist* (see Table 2). Referring back to the model, in this section, I explore how engaging with these science practices, fostered learning and analytical sense making and generated new possibilities for students (see Figure 4, red, blue portion).

Becoming a capable science learner. Students commonly expressed an increased sense of ability in science because they learned how to collect data. Melanie, the 10th grade Filipina student from the opening excerpt provides an example. During a post program interview she described feeling more confident in her science abilities after engaging in scientific research:

> I feel like now I'm more capable of finding data on my own and finding ways to collect data. I have more knowledge of what to use, and how use it.

For Melanie, learning how to collect data and knowing what equipment to use and how to use it made her more confident in her science abilities. Interestingly, findings show that for some students, engaging in particular science practices associated with the data collection and analysis process provided unique opportunities for students to see themselves as capable science learners. In this section, I focus on three science practices that created significant shifts for students: 1) using/reading science equipment, 2) recording observations, and 3) making graphs.

Sense making & understanding: Using scientific equipment. During post program interviews, when asked to describe a time they felt "good" at science, students from Westport commonly described experiences that involved using science equipment to collect data.

In Chapter 5, James, the 11th grade student who identifies racially as African American provides an example of students that felt "good" at science from using created an important shift for James. He used to think that doing science required the use of "heavy technology", but then he learned how to use the handheld machines. Following program participation he expressed surprise at being able to collect air quality data with the simple machines that they used. For James, learning how to use and read handheld devices broadened his ideas about how science is done. In addition, this shifted his idea about his ability to collect data.

Vincent, a 10th grade student who identifies racially as Latino provides another example. When I asked him to describe a time that he felt "good" at science during the summer he immediately responded: "When we were going around to like different train stations and we were taking different, um, samples from each car." I asked him why this made him feel good at science and he replied: "Cause, like I learned how to read the machine, and I got to test it out." Similar to James, Vincent entered the program envisioning scientists using "big machines" to do research. Learning how to use the handheld devices and engaging in the analytic sense involved fostered learning and allowed Vincent to see himself as a capable science learner. In addition, Vincent expresses a sense of agency because he got to test things out. It is plausible that because students contributed to the design of the research and decided on data collection locations, the independence of going out together as data collection teams helped foster this sense of agency that Vincent expresses. In addition he describes an aspect of the social context that was important to him and how this was enhanced by doing research and going out on data collection excursions together: "The environment and that everybody's like already knew each other, and we bonded even more. Like it's a smaller." For Vincent, the small size of the class (n=11) was significant because it fostered positive social interactions. He contrasted this to his experience with science in school where there were sometimes forty students in a class! In this way, students develop a strong community of scientists that supported each other through the research process.

Matt's instruction and scaffolding the use of scientific equipment set his students up for success to learn and make sense of the machines during data collection. By learning to use handheld devices, students like James and Vincent learned they could collect data without "heavy technology". In addition, learning to make sense of the machines and the analytic sense making involved allowed students to feel "good" at science and to see themselves as capable science learners.

Understanding the purpose of a practice: Taking good notes. For some students another important aspect of the data collection process, recording notes and observations, created an opportunity to feel "good" at science. Natasha, an 11th grade student who identified racially as Chicana entered the program with a very low perceived ability in science (i.e. the lowest score across programs). During a pre program interview, I asked her to describe a time that she felt good at science:

> Interviewer: Can you think of time that you felt good at science?
> N: (pause) Mmm no, not really.
> Interviewer: Like an example of a time that you were like oh yeah, I feel good at this?
> N: (shakes head no)

Natasha's lack of ability to recall a time that she felt good at science suggests that she had few opportunities to experience success as a science learner. Natasha expressed a desire to learn and understand science, but struggled to be successful in school science. She aspired to be a nurse but was worried that it might get "too complicated" for her because she viewed herself as not good at science. Following program participation, when asked to described a time she felt good at science, Natasha stated:

> I think when we were going around with the DustTrak and taking notes…I got the hang of taking good notes, just like jotting down everything that happened and what was going on around.

Here, Natasha describes feeling "good" at science because she took good notes. During the program, I accompanied Natasha's group on a data collection excursion. Natasha was in a group with two other students and she was in charge of recording observations at the data collection locations. She carried a clipboard and data sheet. Her two group mates carried the equipment in a backpack style bag and were in charge of making the sure equipment was working properly. While riding on the train with the group, I noticed that Natasha's two group mates would take air quality measurements with the machines and then rush ahead to the next data collection location. Natasha would stay back, and record observations on her clipboard to document the surrounding scene. She often lagged behind her group mates by several minutes before completing her task and rushing to catch up with them. I recounted this observation during her post program interview and asked about her process:

> Interviewer: When I think about being on (the train) with you guys, your group mates were cruising ahead but you made sure that you stopped and took notes. Why do you think you felt the need to do that?

> N: Because it was gonna determine like why, basically it was gonna…If you take good notes…you can tell why, why did it (the reading) go high or why did it go down, stuff like that.

Here, Natasha describes an important understanding about the purpose of recording good notes and making careful observations during data collection. Her statement of: "if you take good notes, you can understand why" is critical. As described above, the machines record location and measurements but provide no information about what was happening at the location – the "why" that Natasha identifies. Consistent with Matt's goal above of allowing students to learn through their mistakes, when students first collected data they took measurements and recorded few or vague observational notes. This made analysis incredibly difficult. Without observational notes, it was impossible to determine "why" the readings "go high" or "go down" as Natasha explains. Over time, like Natasha, the students developed an understanding of the importance of these observational notes. Here, Natasha expresses an understanding that these notes play a vital role in making sense of the numbers from the air quality machines. Interestingly, though the equipment used for recording observational notes was low tech (i.e. clipboard, data sheet, pencil) the information from this process was critical to making sense of the data. Natasha did important intellectual work to understand the purpose, value and centrality of her observational notes and how they made a critical connection to other aspects of the research process.

Aligned with Matt's goal for students to generate the need for knowledge and information on their own through the research process, the purpose of taking good observational notes became clear through practice and the experience of trying to analyze data with vague observational notes. In this authentic context the meaning/purpose of observational notes became clear –they were critical for the analysis process. In this way the students generated a need for this form of data. This process elevated the importance of this practice and the empowerment associated with the meaning made from engaging in this practice. It is possible that the value of the observational information she was responsible for gathering and recording may have contributed to her feelings of being "good" at science (i.e. she became good at something that was critical to their research process). This allowed her to experience success in science and see herself as a capable science learner.

Opportunity to be an expert: Teaching others to make graphs. Finally, for some students, aspects of the data analysis process allowed them to see themselves in a new way and as a capable science learner. Because the air quality machines recorded data every couple seconds, the students returned from data collection excursions with a lot of data points. A challenging task was to make sense of the data they collected and then to determine both what data to graph and how to graph it. As described above, Matt's goal was to provide opportunities for his students to feel successful during this process by utilizing software that created unique data representations to support students' sense making processes.

Students and the instructors (i.e. Matt, his assistant, and a computer science graduate student) struggled together while learning to use the graphing software associated with the analysis program. Early on in the process, Fernando, a 12th grade student who identified as Latino began to make sense of the graphing program. As described in Chapter 4, Fernando entered the program with a low perceived ability in science. He had experienced little success in science class and in school and in many ways he saw himself in opposition to how he viewed scientists. He describes himself as often "distracted" in science class and then becoming frustrated when he doesn't know what's going on. In addition, as described in Chapter 4, he internalization a racial narrative that people of color “slack off” and describes this as a reason for why he might not notice many Latino people as scientists.

During the data analysis process, Fernando develops and understanding of the graphing software and teaches other students, and eventually the instructors, how to do use the program in ways that no one else is able to figure out. I recount this episode with Fernando during his post program interview. When I asked him how he learned the program so well he replied:

> It kinda stuck cause we were following along...while she (computer science graduate student) was doing it on the computer we were doing it on the computer too…I don't know how I remember things, but just like, visual...like I can remember how things look.

Here, Fernando expresses that he was able to help others because he could remember how things “look”. He plays off the role of teaching others to use the graphing program that day in class. But the opportunity to use his visual learning skills and make sense of the software provides a way for him to experience success. In addition, it provides an opportunity for Fernando to become an expert on something and to share this knowledge with his peers.

During post program interviews, I ask Fernando if participation the program taught him anything about what it means to be Latino and pursuing science. He described what he learned:

> F: Just knowing that even though you are a different race or something, you can still do what you want to do...just keep working on it.
> Interviewer: And how did this summer helped you with that?
> F: Not doing what I usually do, just walk out of classes. And just getting mad and frustrated. Just stick to it and try my hardest.

Fernando makes an interesting statement: “even though you are a different race or something” suggesting the summer program that was all students of color provided empirical evidence that even though he entered the program thinking of scientists as “not his race” he learned this summer he and his peers could be capable science learners. He also describes an important opportunity to disrupt the racial narrative he asserts during pre program interviews that people of color “slack off”. He describes how participation in the program created a shift for him – he stuck with it and tried his hardest. This provides an opportunity to disrupted this racial narrative. It is plausible that experiencing success as a science learner through learning how to use the software, becoming and expert and teaching others helped facilitate this disruption for Fernando.

Becoming a scientists*: *“Scientists do what we do”. In addition, to providing an opportunity for students to see themselves as *capable science learners*, collecting data allowed students to identify as scientists. As mentioned above, students from Westport identified themselves and their peers as scientists following program participation more commonly than students from other programs (see Figure 4). In many cases, the generation of identities as *scientist* was directly linked to engaging with data collection. However, findings suggest that data collection in isolation would not produce similar outcomes. Students’ experiences illustrate how the type of data they collected, the importance of the knowledge they constructed about their community and what they were able to *do* with this data all contributed to the transformation they experienced.

Findings show that students viewed data collection as central to what scientists do. Therefore, in addition to broadening students’ ideas about what counts as science the practice of collecting data allowed Westport students to identify themselves and their peers as scientists. James, the African American student from above describes this connection. When asked about the work of scientists he stated: "I guess they (scientists) do what we do, which is go and collect data". In addition to seeing himself as a capable science learner by using/reading science equipment (see Chapter 5), James saw the science practices that he and his peers engaged with as central to the work of scientists (i.e. collect data). This allowed him to identify as a scientist. But what's more is that he specifically identified youth of color as scientists. Following program participation, I asked James if he learned anything about being a person of color and pursuing science. James describes an expansion in his ideas about who can do science:

> J: Yeah, it shows that like other people of color could do it, it's like, you could just like, just do it.
> Interviewer: Yeah and what showed you that would you say?
> J: I guess, well I did it!

Here, James describes a shift in his ideas about who can do science. Doing science together as a group of students' of color seems to be significant for students like Fernando and James because it provides empirical evidence that people of color can do science. In James' case, the empirical evidence that he and his peers did it shows him that he and other students of color can do science.

In addition, James describes how the social context of the program created a space where he felt engaged and wanted to try his hardest. Students divided up sampling locations and collected data in teams of three to four students. They had the opportunity to ask research questions from the pool of data and this cultivated a community of scientists. He described that his sense of responsibility to the group and the fact that they all needed each other's data shifted his engagement:

> I guess cause we were all like on the same topic and we all had data like, everybody's data fit in with ours. We needed their data to be with ours so like I think that changed.

By working together as a group of scientists, James was able to identify as a scientist and become an engaged and important member of a science community.

Like James, several other students identified themselves and their peers as scientists specifically because they had collected data. Natasha from above provides an additional example: "I think just doing the research makes everybody a scientist. Because I mean we took data and did all the research." And Serena (see Chapter 4) expresses a similar idea: "Well, I guess we are all scientists....doing this, cause I researched, kept going out and collecting data, and yeah.. we found out results from the air." Serena identifies herself and her peers as scientists because they collected data and found results. It is important to notes that James, Natasha, and Serena did not see themselves as good at science when the entered the Westport program. Recall from above that Natasha couldn't think of a time she felt good at science and Serena describes herself as "not bright" and a "slow processor" (see Chapter 4). The fact that these students saw themselves as capable doers of scientists, and identified as scientists following program participation represents a significant shift in how they see themselves in relation to science. I build on this in the next section to provide additional examples of how students' ideas of *what* science is and *who* can do science shift together through engaging with the practices of data collection.

The examples of James, Melanie, Natasha Fernando and Serena illustrate how engaging with the data collection process (e.g. taking observational notes) and analyzing data (e.g. making graphs) generated new possibilities for students as capable science learners and allowed students to identify themselves and their peers as scientists. In some cases, the sense making involved and the purpose and value of the information gained (e.g. Natasha's observational notes were central during data analysis) during the process may have contributed to these shifts. In addition, students developed an expanded idea of what counts as science practices following program participation and in this way students' ideas of what science is and who can do science shifted together.

It's important to note that the Westport program offered a social learning context where students were able to make and learn from mistakes, mess up and gain understanding through practicing. Students and instructors engaged in the learning process together and made decisions about research directions as a group. The small size of the group was significant for students (see Vincent above); they were able to ask and receive help from instructors and each other more readily. This made new roles available, provided an opportunity for students to take on these new roles and allowed students to become experts in certain areas (e.g. Fernando teaching others to make graphs). In addition, the instructor selected the topic of study, but students participated in the research design and had agency to ask their own research questions within this topic and from the vast amount of data collected. The opportunity to ask different research questions from the pool of data collected cultivated a need to collaborate and share data as a community.

Summary case study #1: Collecting & analyzing data. Findings illustrate the learning and sense making that are afforded and the identities that are generated by keeping the synergy between the practices of data collection and analysis intact when engaging students in scientific research. Students' experiences illustrate how the type of data they collected, the importance of the knowledge they constructed about their community and what they were able to *do* with this data all contributed to the transformation they experienced. Matt's goal was to empower students to use science as tool to create change, to address the low self-efficacy of his students through pedagogy and instruction, and to build off of their resources as natural data collectors. This shaped the resources he made available to students. Matt positioned students as capable doers of science through practices associated with data collection and analysis. He scaffolded important aspects of the data collection and analysis processes: using equipment, taking observational notes, making graphs in order to ensure success In addition, he positioned students as capable science learners by providing opportunities to practice, make and learn from mistakes (e.g. learning to take careful notes in order to make sense of air quality measurements). The space he created provided an opportunity for students to practice and learn from mistakes together. Through this process the group developed a close community of scientists. Engaging in the data collection and analysis process provided students with an opportunity to generate the purpose of practices, how they are connected, and the value of certain practices to different aspects of the data collection process (e.g. observational notes were critical to making sense of the data). By trying things out, making mistakes (e.g. taking vague observational notes) a need for refinement of skills was generated (e.g. recording good observational notes). The intellectual and analytical sense making that students did while engaging in the practices, afforded new ways to engage with science, made science accessible, and generated new possibilities for who students could become in science: *capable science learners*, and *scientists*.

Contrasting Example: Using & Reading Machines

As described in the introduction, I make the argument that the identities generated through participation in the practices of science are program resource dependent. To support this argument, I provide brief contrasting example of a student from the Bayside program who engaged with a similar science practice of using science equipment but whose engagement with the practice resulted in different identity outcomes.

As described in Chapter 5, Elana, a 10th grade student from Bayside enters the program with an average perceived ability in science, but lacks confidence in her science abilities because she views using technological science equipment as central to the work of scientists but something she is not good at doing. During our discussion of what scientists "do" she explains the connection between what scientists do and how she see herself in relation to that practice:

> E: They also have like machines, right? There's a bunch of, technology and everything cause that's like what scientists do.
> Interviewer: Could you ever see yourself doing anything like that?
> E: I don't know, cause like, I'm not really, (pause), technology doesn't like me so, I don't think I...
> Interviewer: (interrupts) Technology doesn't like you?
> E: Yeah if I, cause, I don't know, things always go wrong when I get a computer…like I always break it or something.

She expresses reservations about doing science because she perceives herself as bad with using technology. She continually describes herself as bad with technology throughout the pre program interview.

During the program, Elana and her group mates (two boys and another girl) conduct an engineering research project that explores the role of drag in vehicle design. The project involves using several different types of scientific equipment, computers, and calculating drag etc. During post program interviews I asked her what she learned from conducting research and she responded:

> The guys were doing everything, so I didn't really get to do anything. I mean they put me on the computer for like a minute. But I'm not good with computers so I didn't know what I was doing.

The "guys" Elana refers to are her group mates. During data collection students used a computer to record variables and data points while running trials. Her fear of not being good with technology is validated by her lack of success when she was put on the computer during data collection "for like a minute". This short time suggests she did not have adequate training and/or proper time to figure out the technology. In this way, she was not set up to experience success engaging with this practice. She adds that in general there was "Too much equipment that I did not know how to use." Even though this passed in a moment, the message Elana received was that she does not belong in science because she again struggled with technology. This research highlights the importance of these moments and the powerful messages students can receive in a short amount of time about where they do and don't belong based on their experiences engaging with science practices. In addition, this example highlights the importance of providing program resources that allow students to successfully engage with science practices. In addition, findings here contrast to the social context observed in the Westport program (and described above). Findings suggest because the "guys were doing everything", Elana did not have the opportunity to take on new roles and she did not have an opportunity to develop expertise (like Fernando above) at certain practices. In addition, this suggests that students did not support each other in taking on new roles. In combination with a lack of program resources for this practice, this may have enhanced Elana's feelings of not belonging in science.

This contrasting example, underscore two main points: 1) the importance of examining how students see themselves in relation to the practices they view as central to the work of scientists, 2) the value of program resources that support students in experiencing success while engaged in science practices, and 3) the importance of the social learning context for supporting the opportunity to take on and try out new roles.

In Case Study 1, students constructed new knowledge during the data collection and analysis process. Next, I show how presenting research provided a platform for students to share this newly constructed knowledge in an empowering context and how this experience led to the generation of a new possibility for Westport students – that of a change agent.

Case Study 2: Becoming Agents of Change

The experience of presenting research in a high stakes context generated a new possibility for Westport students; becoming *change agents* in their community (see Table 2). Constructing this type of identity was unique to Westport students. Though students across programs gave culminating research presentations, Westport students had a unique experience and as a result were empowered by their research presentations in a way that transformed how they saw themselves in relation to science. The experience of constructing new knowledge relevant to their community through data collection and analysis and presenting findings to people in a position of power shifted students' ideas about the importance and utility of scientific research, *where* research can be done, and *who* it can impact.

Program resources: **Present research**. In order to provide a context for students' experiences with presenting research, first I examine Matt's vision for this practice and how this organized and structured the instruction, pedagogy and designed experienced he made available (see Figure 4, black portion). I examine how he created an opportunity for his students to present in a high stakes context with the goal of empowering them as agents of change. Then, I examine the shifts that occurred for students and how the identity of *change agent* was generated.

Vision & positioning as change agents. Matt's goal was to provide an opportunity to disrupt the lack of power that he felt his students experienced in their daily lives. To do this, Matt designed an experience that specifically placed his students in a position of power. As a white male he described an awareness that he had access to power that his students (i.e. "young women and men of color") did not. He sought to leverage his positioning and in doing this he designed an experience for his students to present their research to representatives from the transportation agency where students had collected their data. Matt described his vision for the research presentations. This guided the resources he made available for this practice:

> They (the students) have to see that all the data collection and analysis that they've done, actually leads to something. It takes more than summer of course, but I think over time if they see that their research from this summer leads to some sort of changes, then hopefully that will encourage them to continue to use science in that way.

Here, Matt placed an emphasis on showing his students that their data collection and analysis can lead to change. He makes connections between the practices of collecting and analyzing data as a way for students to generate new knowledge (see Case Study 1) and creating change. He hoped that if he could show his students that science can be used as a tool in this way, they would continue to use in science in their lives. Throughout this process, Matt positioned his students as agents of change and provided opportunities that created the potential for this to become a reality.

Designed experience: Scaffolding for empowerment & success. Matt arranged the opportunity for his students to present their research to representatives from the local transportation agency where they had collected their data. In this way, he created an opportunity for students to be in a position of power. It is important to note that the students found high levels of particulate matter at certain transportation stations and therefore the air quality was deemed unhealthy by environmental protection agency standards in certain locations. This is not information the representatives would be eager to hear and created an additional element to this already high stakes context. The students' findings could be challenged by the officials or reviewed with a higher degree of scrutiny than more favorable information. In addition, the majority of students did not have previous experience making or delivering presentations. For these reasons, Matt carefully scaffolded the presentation process so that students were confident with presenting to an audience and explaining their results.

Matt scaffolded the research presentations in two main ways: 1) he prepared students to understand and talk about their data, and 2) he created an incremental structure of increasing stakes and formality for the presentations. He prepared his students by teaching them how to create PowerPoint presentations and discussed the important components of these presentations. In addition, Matt scaffolded the research presentations so they incrementally became higher stakes. First, students practiced presenting to the class in the middle of the program on small experiments that they conducted. These presentations provided an opportunity for students to get comfortable using power point and presenting in front of others in a familiar context. During post program interviews, Serena, the 12^{th} grade case study student from Chapter 4 who entered the program with a very low perceived ability in science, describes this experience as a time that she felt "good" at science during the summer because she felt like she did well and got positive feedback from the group. Next, students presented their final research project to their parents in a formal, yet comfortable setting. Then, students present to board members from a local organization that had expertise in air quality research. Finally, students presented to the representative from the transportation agency. Through continual practice and increasing formality, students became more comfortable explaining their research and findings to an audience.

In addition, Matt helped students learn how to make sense of their data and what it represented. The controversial findings required an additional level of preparation for the students so that they could discuss their data and findings in a knowledgeable way in a high stakes environment. To do this, Matt helped students make sense of and understand their findings and prepared students to answer questions they might receive about their data and results. Natasha, the 12^{th} grade student from above provides an example. For example, as students prepared to present to the board members, Matt spent time teaching his students how to convert the air quality measurements from one type of unit to another. During class, I asked Natasha, the 12^{th} grade student from above why they were doing this and she explained:

> I think he (Matt) wants us to understand how to do it, so whenever they ask us questions like we could explain how to do it and not look like we don't know what's happening, and stuff.

Here, Natasha explains how Matt prepared students' to answer questions and explain their data. The "they" she refers to is members of their audience. Instruction leading up to this set students up for success in a high stakes environment.

In summary, Matt had two main goals for the research presentations: 1) to disrupt the lack of power he felt that his students experienced by placing them in a position of power, and 2) to show his students that the data they collected and their research findings could create change.

In the next section, I examine the shifts that occurred for students through "presenting research". In addition, I explore how engaging in this practice and the accompanying program resources outlined above generated the identities of *change agent*.

What shifts for students? Generating identities as change agents. The experience of presenting research functioned in two main ways that allowed students to see themselves as agents of change in their community. First, the experience of communicating their findings through research presentations gave new meaning to this practice for Westport students. Presenting to people in positions of power generated an understanding of the importance and influence of data when conveying a message to an audience. Similar to taking good observations notes (i.e. Natasha, Case #1), the purpose of presenting research was generated through experience. Second, students' ideas about the importance and utility of scientific research shifted. In addition, the experience broadened students' ideas about *where* scientific research can be done and *who* is can impact. The experience empowered youth by providing an opportunity to share their novel and newly constructed knowledge about their community with people that were in positions of power. Together these opportunities shifted power from scientists (i.e. characteristic associated with scientists, see Chapter 4) to Westport students and youth of color as scientists. Referring back to the model, next, I examine these mechanisms described above in detail to illustrate how engaging in research presentations created a new possibility for Westport students as *change agents* in their community (see Figure 4, red and blue portion).

Broadening ideas about uses for scientific research. Students' ideas about uses for and the importance of scientific research shifted because of their experiences presenting their research. Findings show pre to post program shifts in students' ideas about the utility of scientific research (see Figure 6). Students moved from general to specific in uses for scientific research (i.e. pre: help environment, post: make air better). In addition, after conducting research students gained more specific ideas about *who* their research might help (i.e. pre: people, post: transportation riders) (see Figure 6). Furthermore, students described a shift in their ideas about *where* science research can be done from general contexts to their community. Natasha, the 12th grade student from above provides an example. She described the importance of their air quality research they conducted:

> Nobody's…doing stuff out here, like in low-income communities to make the air better. I guess that's why we're doing the research, to see how it (the air) is and where it like impacts more.

Natasha places a particular importance on *where* she and her peers are collecting air quality data because no one is doing this type of research in her community. In this way, the use for scientific research shifted from broad and general to local and personal. Furthermore, her statement suggests that there is a political relevance to their research and the importance of doing research in underserved areas like her community.

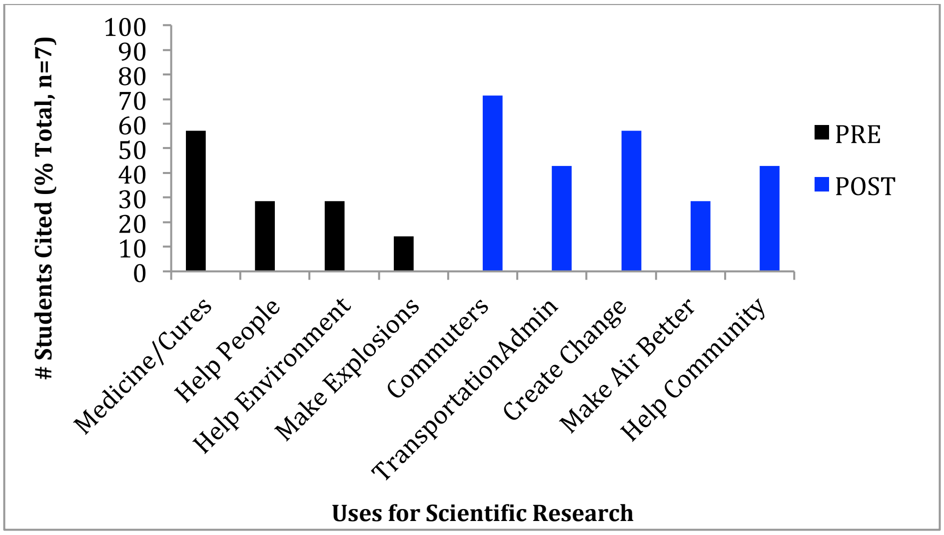

Figure 6. Westport focal students pre vs. post program ideas about uses for scientific research.

Purpose, meaning, and uses for research generated together. In addition to expanding their ideas about uses for scientific research, presenting their findings broadened students' ideas about the meaning and purpose of science practices. As described in Chapter 5, during his post program interview, when asked what he learned about the scientific research process over the summer, Fernando, the 12th grade student from above discusses an expansion in his ideas about types and meanings of science practices and how they are connected. He states:

> Science is not just like...finding out facts. You actually need to know how to present what you are going to do, like to be able to get your data or whatever you researched out to people, you gotta talk to people, like look this is what my project was, this is what I found out, so the majority of it was finding the data. But the other part was like actually knowing how to present it out.

Fernando describes a shift in the meaning he associates with science practices from restrictive and static (i.e. finding facts) to expansive and active (e.g. collect data, present research). He also made a connection between the practices of collecting data and presenting. In this way, the purpose of collecting data was generated through the context of presenting research (i.e. "get data out to people"). In addition, Fernando's statement indicates a shift in agency. When he says, "look this is what my project was, this is what I found out", he asserts that he has something to tell people. His statement suggests that he feels that his findings are an important contribution to be shared with others. In addition, he describes a connection between the practices of collecting data and sharing findings. The practice of collecting data is a means to construct new knowledge and presenting provides a platform from which to share this new knowledge.

For some students, the act of presenting and interacting with the audience generated a use for their research. In addition, by presenting their research, some students made connections between data and making claims. Natasha, from above, describes relationships between data, proof and presenting research:

> I mean cause every time you try and like show something of course you have to have something like to prove what's going. So, I mean that's basically what we're doing. Like we're trying to take data, the stuff that's going around in the air and then present it to people. Let 'em know what's going on and how it's affecting us and stuff.

Here, Natasha describes the importance of having "proof" in science when you show people your research. She describes collecting data about the "stuff that's going around in the air" as a way to "prove" how it is affecting her community. She then makes a connection between having this proof from the data to make a case for "what's going on" when presenting this information to people. Presenting their findings provides an opportunity to create awareness of how the air quality is affecting "us", or people in her community and do important work that she does not feel is happening in her community.

Cid, a 12th grade student who identifies racially as Latino makes a similar connection to Natasha about the role of data and having evidence when making a research presentation. On a post program survey he stated that his ideas about uses for science were "completely different now" after presenting their air quality research. He explained why his ideas about uses for scientific research shifted so dramatically: "Because the data can actually be used to change people's mind." Here, Cid makes an important connection between data and the impact data and research findings can have on people when shared publicly. As Fernando described above, presenting is a way to get your research out to people. Here, Cid describes the impact this information can have to "change people's minds". On post program surveys, when asked if the research they conducted was important and to whom he responded that it was very important: "to people in our community, Black and Brown." Like Natasha, Cid places importance on their research because it provides information about how bad air quality impacts their communities where little previous information exists or research is done. Cid and Natasha speak of people from a particular race (Cid: "Black and Brown") and class (Natasha: "low-income"). Natasha and Cid speak to the power of both data and the opportunity to present this data to others.

Melanie, expresses a similar idea and describes presenting their controversial findings to the transportation officials in a highs takes context. Like Natasha, she describes the importance of having data to support your claims. Melanie said that during the presentation she and her peers felt like the officials judged them as just "high schooler's collecting this data," who "don't know what they're doing". She continues: "I knew that all of us got the same impression because were all kinda scared up in front of those people." Yet despite this, Melanie and her peers described the experience as incredibly empowering. She explained that Matt stepped in and told the officials that they were high school students, and there was more data they could collect and this softened up the officials who were giving them a hard time. When I asked her how the experience made her feel she said:

> I feel like that's kinda the reality of it like just because you collect data and share it with someone they're not gonna trust you right away they're gonna want more and they want more to back up what you're telling them…I guess they are important people and

> (agency) is important to public transportation, everyone takes it and needs to get places….I think they got something out of what we presented, took it with them and hopefully shared it with their employees and co-workers.

Melanie describes the realities of presenting information that important people running a public transportation company might not want to hear. She weighs the challenges of presenting to people that may not "trust you right away" with the importance of "having more" data to back up what your have to say. She describes having more data as a way to establish "trust" in your message. In addition, the high public use of the transportation leverage the importance of the message, utility of the research, and the need to support claims with sound data. Despite her and her peers being scared she expresses a confidence in their findings and asserts that there was something for the officials to get out of their presentation. She hopes they did this and shared it with others. She expresses that it was significant that Matt stepped in to defend her and the other students. This interaction on Matt's part may have helped students feel supported, respected and that their message was valuable.

The examples of the Westport students above illustrate how the opportunity to construct new knowledge relevant to their community and share this information with people in positions of power broadened students' ideas about the utility of scientific research, *where* research can be done, and *who* it can impact.

"Going big": Becoming change agents. Students described themselves as agents of change because they presented their research to transportation officials in a high stakes context. As described above, Melanie expresses a sense of confidence and empowerment in the face of challenge and scrutiny. She builds on this to describe her overall take away from this experience:

> I think presenting to these people were good experiences…and how big it was for us youth to be presenting to these people who are so superior and are representatives of really big companies...its was great!

Here, Melanie's statement suggests that the opportunity that Matt arranged for his students had the desired impact of empowerment. In addition, it suggests that while presenting could have been a scary experience for the students, ample resources were provided that prepared Melanie and her peers for this high stakes situation. Building on this, during an interview several months after the program had ended, Melanie described the importance of the social context and how working as a close group to conduct important research was significant for her: "The community, the staff, the students who were with me too...I felt like had a passion for what we were doing that summer." Her statement suggests that working together to present in a high stakes context may have contributed to the sense of community that was created. In addition, the goal of presenting to the representatives may have helped foster the "passion" she and her peers had for their research.

Interestingly, students' research presentation didn't stop with the transportation officials. Transportation workers who were in the midst of a union strike found out about the students' research and contacted the students for their findings. The air quality results from the transportation stations were relevant to their working conditions and they felt that this information could support their case. Melanie explains this interaction:

> M: We're gonna be presenting more this summer because the media wants coverage… some of their employee…from (agency) would appreciate our findings because it would help them with wages or….getting better health benefits.
> Interviewer: Oh interesting! Because of the air quality?
> M: Yeah, they're more exposed to like high pm (particulate matter) levels….then the people who are just on and then off.

Here, Melanie explains that the employees from the transportation agency wanted their findings in order to support their argument for better health benefit. She explains that because the workers are in the same location for long periods of time they are more "exposed to high pm levels" (i.e. bad air quality) than "people who are just on and then off" or the riders of the transportation. In this way, the students' research was actually be used to create change. What's more is that a prominent newspaper picked up the story and published an article about the students' research and the union strike. I ask about all of the media and hype surrounding their research and she expressed both surprise and enthusiasm:

> I didn't think we'd end up where we're at now. I didn't think we'd keep presenting. I thought it was a one time thing…we'd collect all this data and then just leave it as it is and then continue another year doing some other project. But no, we're following up on all these different people and it's pretty cool! I never thought we'd go big!

Throughout the entire experience that Matt designed: gathering evidence to support their claims, being prepared to discuss their findings, and having the opportunity to present to transportation officials, students were positioned as change agents. In addition to becoming change agents, the continued interest in their findings from the union employees and the newspaper, helped create another significant shift for the students. Next, I discuss this shift in detail.

Shifting power to youth of color. Melanie expressed a significant transformation and shift in power that occurred over the course of the summer. Recall from the opening excerpt that Melanie entered the program not knowing of any Filipina scientists and reasoning people from certain raises and classes might not be "comfortable" or feel that they can achieve the high status of a scientist because of their societal positioning. In addition, she describes scientists as powerful and links the power to knowledge. After participation in the summer program, Melanie still views scientists as powerful: "I feel like the title of a scientist comes with like hella knowledge that people expect", but describes an important shift in who is a scientist. She explains:

> I think scientist are pretty powerful. I think we were pretty powerful this summer as scientist and through out the year it paid off because we got to present, like I said, in front of these representatives and I think that was powerful for us to do.

Here, Melanie describes a shift in power: who is a scientist has shifted from people that are "not her race" to herself and her peers as powerful scientists. In addition, she expresses a shift in power to herself and her peers because of what they were able to *do* as scientists (i.e. present to the representatives). I asked her to describe why she felt that presenting their research was powerful for them. She replied:

> I think its just having knowledge and sharing knowledge that people don't already makes...I feel like makes me feel like I'm powerful because....I have stuff to tell you that you don't know yet and then now you know it and now we both know it and you share that with more people and that creates more knowledge...that quote 'knowledge is power' really fits to what I feel like with scientists being powerful.

Melanie consistently links knowledge with power. In this case, she and her peers constructed new knowledge relevant to their community through their data collection and analysis. Collecting data provided an opportunity to generate new knowledge and presenting provided an empowering platform from which to share this knew knowledge. Melanie expresses that the knowledge they generated through collecting air quality data and conducting research uniquely placed students in a powerful position to shared information that no one else new. This unique knowledge helped create a shift in power from scientists at large to Melanie and her peers. She describes how this shift is historically embedded and why this is particularly significant based on racial positioning and hierarchy in our society:

> I mean coming from like a history of like colored people being the bottom of the food chain and white people being at the top I think that still is incorporated with like everything there is today...I mean its not as harsh but your still kinda see it. Positions as high as a scientist like a lawyer, doctors, titles like that are still high, I don't know.

The high status and power that Melanie associates with scientists is still present, yet she was able to construct a new image of *who* can occupy this position that included herself and her peers. She describes the importance of working together as a community of youth of color to do this research and how together they disrupted historically embedded power structures:

> I think its really important to represent and show people that scientists aren't powerful because of their race, but because of who they are and what they want to accomplish as a scientist and what they want to contribute to their community so I feel like its really important for people of color to represent scientist.

Melanie's statement describes a significant transformation. Above, she describes scientists, power and knowledge as linked. Here she extends this to include race. Presenting their research in a high stakes context provided an opportunity for Melanie and her peers to disrupt these links and show people that *they* are powerful scientists because of the important research they conducted in their community. Together the students experience generated a new possibility; that of becoming *scientists* and *change agents* in their community. This new possibility disrupted the links between race, power and knowledge.

It's important to note that the community-based aspect of the research provided students with a sense of importance for the work they conducted. This generated a passion both for the research and a desire to engage fully in it. Furthermore, presenting in a high stakes context and the continued interest in the students' research (e.g. media, workers union) elevated the importance of their research and how students saw themselves in relation to science.

Summary case #2: Present research. Findings illustrate how the opportunity to construct new knowledge about their community and to share this information with people in positions of power broadened Westport students' ideas about the utility of scientific research, *where* research can be done, and *who* it can impact. Matt's goals were to create an opportunity for students to see that the data they collected could lead to change and to disrupt the lack of power he felt that they experienced in their daily lives. To do this, he designed experiences that provided students with an opportunity to present their research in a high stakes context and to make these goals a reality. Collecting and analyzing data provided an opportunity for students to construct new knowledge relevant to their community and presenting their findings provided a platform to share this new knowledge in an empowering way. Engaging in practices shifted the purposes and uses for scientific research, generated new possibilities for *who* students could becomes in science, and shifted power to youth of color.

It is important to note that the students' experiences described above support the need for diversifying the science community. The importance that students like Cid and Natasha placed on doing research that is relevant to people of color and important to underserved communities reminds us of the ways that *who* is doing research guides the questions being asked and *where* research is being conducted (Harding, 2008). Diversifying the science community would profoundly impact the types of scientific research conducted. We can only imagine the *types* of research questions so many other students like those from Westport will ask, *where* they will conduct research, and *who* it will impact when given access and opportunity.

Contrasting Example: "Rough Attitude" of Scientists

As described in Chapter 5, Lorenzo, a 10th grade student from Bayside who identifies racially as Mexican struggles in science and describes questioning often whether he belongs in science. He struggles with language and this overlaps into his science experiences. While presenting research in a powerful context was empowering for Westport students, for Lorenzo it validated his concerns that he doesn't belong in science.

Students from Bayside gave culminating research presentations. This was a formal process and students dressed up and presented in a auditorium in front of their peers, research instructors, and scientists from various labs on campus. Lorenzo was in a group with three other students. They had spend two weeks on a physics project involving radiation waves and learning about, constructing and doing experiments with a cloud chamber. The presentations were formal and students dressed up. They presented to their peers, graduate student instructors, and other research scientists from the surrounding laboratories. Students prepared by learning how to make PowerPoint presentations with their research instructors, but the students mainly practiced in their groups on their own in order to prepare. Lorenzo describes his experience presenting with his research group in front of a large group of his peers, scientist instructors, and research scientists:

> L: There was like other people that had like really high expectations of us. I noticed that they were like having that big expectation of us out there, like when we were presenting and we were like right there.
> L: I was like, 'oh my god'! And then their attitude was more like, just rougher against us.
> Interviewer: "Rougher" in what way? What do you mean by "rougher"?
> L: Expecting a lot!

Here, Lorenzo experienced the "attitude" of research scientists who had attended the presentation at "rough against them". He describes the high expectations in a way that suggests he felt he could not meet these high standards in a satisfactory way. Following his groups' presentation, a research scientist asked the group a difficult question. Lorenzo attempted to answer the question, but was only able to offer an incomplete response. No one else in his group new how to respond either, so the presentation ended. Lorenzo returned to his seat, but before he sat down he turned back towards the scientist and offered another partial idea in response to the question. This suggested that he wanted to answer the question in a satisfactory way, but was struggling to do so. During class the next day, Lorenzo expressed to me how intimidated he felt during the presentation and especially during the question and answer period. He felt the expectations of the scientists were really high and experienced the questioning as the scientists having a "rough attitude against them". Overall, the practice of presenting left him again questioning if he belongs in science. During the post program interview, when I asked him if he could see himself being a scientist some day he responded:

> Nooo!... I don't see myself as a scientist. Like I never really thought about that fact. It sounds interesting but I never really dreamed of like doing that.

Lorenzo's statements of "never really thought about that" and "never really dreamed of doing that" suggest that Lorenzo doesn't see science as a possibility. The use of the word "dreamed" here is significant. Findings above illustrate how engaging in the practice of presenting research empowered Westport students as agents of change in their communities. Matt's perspective of race, class, power and positioning projected possible future for his students that guided his design of program resources in the present (Cole, 1996). In addition, engagement in the practice and the program resources facilitated the process of "social dreaming" and of imagining new possibilities (Gutierrez, 2008) for Westport students.

Discussion & Conclusions

In this chapter, *I make three main arguments*: First, for focal students in this study, identities were constructed through engaging in science practices *and* the accompanying program resources. The program resources were the mechanisms that helped facilitated shifts for students and generated new possibilities for *who* they could become in science (e.g. doers of science, agents of change). The types of program resources created or limited access to particular roles, positions and possibilities. Therefore, I argue that the *types* of identities generated through engaging in science practices were program *resource dependent*. Second, the instructor's vision of science (i.e. purpose, utility) and his students (e.g. racial background, social positioning) guided the instruction, pedagogy and the designed experiences he made available in the Westport program. In this study, the instructor's perspective of race, class, positioning and power allowed him to construct *holistic* resources that supported students' science and racial identities. Third, the youth of color in this study were able to imagine and take up new possibilities for *who* they could become in science when their science *and* racial identities were supported in the science programs. Opportunities to engage in science practices and the analytic sense making involved allowed students to construct new meanings for practices and imagine new possibilities in science.

Generating New Possibilities

Analyses revealed the emergence of an *identity generative process*: engaging in science practices and the accompanying program resources led to the generation of new possibilities for

Westport students. Findings show that the instructional and pedagogical resources made available for science practices determined *how* the practices "functioned" for students. In this way, the generation of new possibilities for focal students was program resource dependent. Findings from the Westport program highlight aspects of the learning environment and program resource design that fostered processes of learning and identity construction in science. Findings show that engaging in specific science practices (e.g. collecting data) and the accompanying program resources could be *linked* to the generation of new possibilities for Westport students (e.g. capable science learner) (see Table 2). I highlight the main design implications for the learning environment and program resources that supported students' engagement in the practices and cultivated the generation of new possibilities.

Implications for learning environment design. Findings highlight several aspects of the learning environment design that were central to making new possibilities available for students.

Importance of an instructor's vision. The resources that Matt made available were based on how he viewed science as a tool, but perhaps even more so on the way he viewed his students: as lacking power, as having low self-efficacy due to their race/class positioning in society, as natural data collectors. Matt's vision was guided by his ideas about race, class, social positioning and power. This mattered for the futures he projected for his students and it guided his actions in the present (Cole, 1996) to empower youth as change agents. Findings illustrate the importance of the Westport instructor's vision of science (e.g. purpose, utility of research) and his students (e.g. racial background, social positioning). This pedagogical vision guided the design of the programs resources he made available and the new possibilities that were generated for students. Referring back to the model (see Figure 4), the case studies of focal science practices demonstrate Matt's views of science and his students contributed equally to the program resources that he made available.

How Matt *saw* these students was critical to the outcomes that were generated. The majority of the students in the Westport program had failed their science class in school or needed to make up credits. Where others may have seen students who failed, were unmotivated, and were unengaged, Matt saw students who were not being met by the system, whose societal positioning created low self-efficacy, and whose actions (i.e. Fernando, "distracted") may have been ways to cope with the lack of power they experienced. Matt's perspective of his students was central to the possible futures he imagined for them and the organization and structuring of program resources he designed to help them make these possibilities a reality. Because he viewed his students as lacking power and having low self-efficacy due to their race/class positioning in society and he viewed science as a tool to create change, he made unique resources available for particular science practices (e.g. collecting data) that empowered students as agents of change in their community. Matt's goal was to show his students that they could use science as a tool to create change. To do this, he designed an experience that showed his students that their research was important and could lead to changes. The designed experience was a way to make this vision a reality. The opportunity to present in a high stakes context, described above, placed students in a position of power and new ways to engage with science. This generated hope and new possibilities for students.

Engaging in science practices & social learning context. Findings show that youth of color can imagine and take up new possibilities for *who* they can be in science if their science *and* racial identities are supported in science programs. Different aspects of the data collection process (e.g. read/use science equipment) created new ways to engage with science, made science accessible and cultivated the identity of a capable science doer and learner. In addition, engaging in multiple aspects of the research process generated new meanings for science practices and uses for scientific research that elevated the power and agency associated with the identities generated. In addition, the Westport program offered a social learning context where students were able to make and learn from mistakes, mess up and gain understanding through practicing. Students and instructors engaged in the learning process together and made decisions about research directions as a group. The small size of the group was significant for students – they were able to ask and receive help from instructors and each other more readily. This made new roles available, provided an opportunity for students to take on these new roles and allowed students to become experts in certain areas (e.g. Fernando teaching others to make graphs). In addition, students had ownership of their research project. The instructor selected the topic of study, but students participated in the research design and had agency to ask their own research questions within this topic and from the vast amount of data collected. Students divided up sampling locations and collected data in teams of three to four students. The opportunities to ask different research questions from the pool of data collected cultivated a need to collaborate and share data as a community. Finally, the community-based aspect of the research provided students with a sense of importance for the work they conducted. This generated a passion both for the research and a desire to engage fully in it. Furthermore, presenting in a high stakes context and the continued interest in the students' research (e.g. media, workers union) elevated the importance of their research and how students saw themselves in relation to science.

Designed experience: Opportunity to disrupt power. Matt's goal was to show his students that they could use science as a tool to create change. To do this, he designed an experience that showed his students that their research was important and could lead to changes. The designed experience was a way to make this vision a reality. The opportunity to present in a high stakes context, described above, placed students in a position of power and presented new ways to engage with science. This generated hope and new possibilities for students.

Implications for design of instruction and pedagogy for science practices. In addition, findings show how engaging in specific science practices and the accompanying program resources could be linked to the generation of identities for Westport students (see Table 2). In the next section, I discuss the program resources made available for the science practices that had the most significant impacts on learning and identity construction for Westport students.

Positioning of students. Throughout the research process, students were positioned as capable science learners, doers of science and change agents. This directly connected to Matt's vision of how he *saw* his students and how he felt his instruction could best meet their needs. In addition to how Matt positioned his students, he cultivated a learning community where students supported each other. Students had the opportunity to take on new roles, become experts, and learn from mistakes together. This helped foster a close and passionate community expressed by students such as Vincent, James, and Melanie above. It is likely that how Matt positioned the students and how they positioned each other, provided resources and opportunities to reposition themselves and become engaged as contributing members of a scientific learning community.

Scaffolding for success. Students were guided through all steps of the research process. Embedded in the social context described above, learning through practicing made science accessible for students. This provided an opportunity to disrupt racial narratives for some students (e.g. Fernando, Serena). The science practices that generated the most significant identity shifts for students and the accompanying program resources are shown in Table 2. Specific aspects of the program resources by science practices are as follows:

- Data collection process
    - Practices: Students were introduced to the equipment, had repeated opportunities to practice using equipment so that they were successful when collecting samples, and learned through their mistakes.
    - Evaluate: Students had opportunities early on to evaluate the data they collected. Though recording good observational notes was emphasized, students learned the importance through practice – they took vague notes and realized they could not properly analyze their data without good notes. In addition, Matt engaged students in discussions of their data and how to determine if they had collected enough data to support a claim.
- Data analysis
    - Visualizations/representations: The software platform that allowed students to geospatially represent their data aided in data interpretation and analysis. Students were able to color code data points to correspond to different levels of air quality based on Environmental Protection Agency standards (e.g. green = good). As a result, the geospatial representations allowed students to visually (and quickly) assess where they had collected data and what the air quality was like in different locations.
    - Graphing tools: students and instructors learned how to use the software together. The flexibility of the learning context allowed students to learn and develop expertise as a community.
- Research presentations
    - Preparation: Matt carefully scaffolded the experience of presenting research to an audience so that when students eventually presented in a high stakes context they would be empowered by the experience. To do this, he prepared students to discuss their research and findings. He made sure students knew how to convert their data to proper units and understand what their data represented. In addition, he discussed how to present and talk about their findings.
    - Incrementally higher stakes: students first presented their findings in a more comfortable settings: to each other and then to their parents. Next, students presented to board members from a local organization that had air quality expertise. Finally, students presented to representatives from the transportation agency. The continued experiences presenting and the questions that students received from different audiences prepared them for the high stakes context.

Together these aspects of the learning environment design and the design of program resources (e.g. instruction, pedagogy) fostered a community of engaged scientists. The experience of constructing new knowledge relevant to their community through data collection and analysis and presenting findings to people in a position of power shifted students' ideas about the importance and utility of scientific research, *where* research can be done, and *who* it can impact. Students' experiences illustrate how together the type of data they collected, the importance of the knowledge they constructed about their community, and what they were able to *do* with their findings contributed to the transformations they experienced.

Implications for Implementation of the Next Generation Science Standards

The Next Generation Science Standards are at the forefront of contemporary science education discussion, research, curriculum design and professional development opportunities (NGSS, 2013). The focus on science practices seeks to reframe the ways the scientific method has been taken up and taught in schools for decades. Findings from this chapter show how engaging in science practices created new possibilities for students and therefore this new focus on practices for science teaching is encouraging. However, with these opportunities, there are also challenges and concerns. In the next section I discuss affordances of engaging students in scientific research and points for consideration when designing instruction that promotes the implementation of NGSS.

Promoting data collection & analysis. Findings show how for Westport students, engaging in specific science practices (i.e. data collection and analysis, presenting research) created significant identity shifts and generated new possibilities for students as *capable science learners*, *scientists*, and *change agents*. The question this raises is how do these practices map onto the practices promoted by NGSS? NGSS highlights eight main practices (NGSS, 2013). Two of these practices: “communicating science” and “analyze/interpret data” present opportunities to create curriculum and experiences that can leverage findings from this study. Presenting research was a significant practice for Westport students that fostered the identity of *change agent*. Aspects of the program resources design for this practice, discussed below, could be taken up to implement the NGSS “communicating science” practice. In addition, making graphs and using data visualization software helped some students identify as *capable science learners* and *scientists*. Aspects of the program resource design for analyzing data could be applied to the implementation of NGSS “analyze/interpret data”. However, a group of practices that contributed to some of the most significant identity shifts for Westport students: the data collection process (e.g. use/read machines, record observational notes) is under-emphasized in NGSS.

For focal students in this study, engaging in the data collection process leveraged students’ agency as *capable science learners* and *scientists*. These practices are under-emphasized in NGSS. This could be because data collection in isolation may not be beneficial and findings here suggest this is true. However, findings show how different aspects of the data collection process (e.g. read/use science equipment) created new ways to engage with science, made science accessible and cultivated the identity of a *capable science doer and learner*. Findings here illustrate how the type of data they collected, the importance of the knowledge they constructed about their community and what they were able to *do* with this data all contributed to the transformation they experienced. This supports the perspective that data collection alone is not sufficient but needs to be incorporated into a broader constellation of practices to take on greater meaning and importance. Findings show, that we can’t underestimate the analytic work and sense making involved with science practices such as using/reading machines. For many students, the machines as a material object afforded new ways to engage with science that led to new roles and possibilities for *who* they could become in science. In addition, engaging in the data collection process along with a multitude of other practices generated new meanings, purpose/utility, and importance for science practices that created a *need* for certain practices. For example, recording observation in an authentic context promoted sense making, generated the purpose for the practice and provided a need to take careful notes (i.e. good observational notes were critical for making sense of the data during analysis). This elevated the importance of practices, the meaning made from engaging in the practice and therefore the types, power and agency associated with the identities generated. This latter point, leads to the second concern.

Promoting synergy between science practices. Findings illustrate the learning and sense making that are afforded and the identities that are generated by keeping the synergy between different science practices such as data collection, analysis, and presenting research intact when engaging students in scientific research. Findings here show that engaging students in different aspects of the scientific research process facilitated connections between practices, generated new meanings for practices and fostered a deep understanding of the purpose of practices. See the examples of data collection, analysis and presenting research described above. As promoted by NGSS, findings from this study support the need to and illustrate the importance of maintaining synergy between the science practices (NGSS, 2013). Because NGSS breaks the research process into eight focal practices, the tendency could be to teach them as separate entities rather than a collective process. The concern is that if the practices are disaggregated, we lose the iterative aspect of research and how the practices work together in ways that empower students to construct meaning, understanding and agency. NGSS emphasizes the connections between practices and this will be essential to promote through curriculum and standards implementation.

Re-Centering Race in Science Identity Research

Findings illustrate the need to re-center race in research involving science identity construction for youth of color. Westport students made the greatest identity shifts following program participation. They identified themselves and their peers as scientists more commonly than students from other programs and specifically identifying youth of color as scientists. Findings from Chapter 5 show how developing expansive views of science and bolstering students' science identities is important but not enough if students don't see a space for themselves in science. Together these findings suggest that to truly create space and new possibilities for *who* youth of color can become in science we need to directly address race (e.g. racial positioning, hierarchies of power) when considering identity construction for youth of color. This re-centering of race also requires a reframing: not bolstering the science identities of youth of color, but supporting the *co-development* of students' science and racial identities in science spaces.

The science identity literature focused on racially/ethnically underrepresented youth, still tends to focus on the science identity construction for youth of color rather than the *co-development* of students' science and racial identities. A lot of important work has been done on equitable approaches to science instruction and how this shapes science identities: expanding views of what counts, helping bridge students' world and world of science, creating hybrid spaces (e.g. Calabrese Barton & Tan, 2009; Tan & Calabrese Barton, 2010). This work is critical for creating space in science, pushing boundaries of what counts, re-conceptualizing *what* science is and for *whom*, and continuing to broaden opportunities for participation in science for youth of color. Findings from this study align with this research but speak to a need to push beyond the important work that is currently being done in this arena and to widen our scope to more holistically capture youth of colors' experiences in science. Even though there is a lot of work being done to support students of color as "doers" of science, treatments of race in relation to science are limited (Parson, 2014). Race is often treated simply as a means to group students rather than an aspect of *who* students are in science spaces (Parson, 2014). More work is needed that examines intersections of students' racial and disciplinary identities (Varelas et al., 2012) and equally considers *who* (i.e. racial identity) in relation to *what* (i.e. science). If we are talking about science identities of youth of color, we really are (or should be) talking about the *co-development* of students' science *and* racial identities.

It is important to note that in the case of Westport, the program resources Matt made available were implicit race/diversity resources – Matt didn't address race and diversity directly through instruction. However, his ideas about race, class, positioning and power were explicit when shaping the design of program resources. In the program in this study (i.e. Bayside) that was race/diversity explicit (e.g. discussion of race, diversity were part of program content) the scientific research component of the program was not race/diversity explicit. The program had several components and the race/diversity explicit aspects of the program included workshops and guest speakers of color. In this way, the "doing" of science was not connected to explicit resources. More research is needed on programs that provide race, diversity explicit resources in the context of the "doing" of science. We can only imagine what is possible and the identities that could be constructed if youth of color were supported in science spaces in ways that explicitly centered race and empowered them as youth of color. This has important implications for the design of curriculum that engages students in science practices as well as the resources made available that foster identity construction. The more closely we can document the mechanisms involved and the links between engaging in science practices, program resources and identity construction the better we can design curriculum that expands opportunities for participation in science.

Likewise, it is important to note that the students' experiences described above support the need to diversify the science community. Westport students highlighted the importance of conducting research in communities of color. Students were empowered to do research in underserved areas where no one else was doing what they did. Their experiences remind us of the ways that *who* is doing research guides the questions being asked and *where* research is being conducted (Harding, 2008). Diversifying the science community would profoundly impact the types of scientific research conducted. We can only imagine the *types* of research questions so many other students will ask, *where* they will conduct research, and *who* it will impact when given access and opportunity.

Chapter 7. Conclusions & Implications

This research explores trajectories of developing the practices of and identification with science for high school students of color as they participate in summer science research programs designed for racially/ethnically underrepresented youth. Students conducted research alongside scientist instructors as part of the programs. The goal of this research is to take a holistic approach to understanding processes of learning and identity construction for youth of color in the programs and the *mechanisms* that support the generation of new possibilities for *who* they can become in science. I explore students' incoming ideas about science practices and *who* does/can do science and how these ideas shift following program participation. In addition, I examine the types of program resources made available through engagement in science practices that may support these shifts.

First, I discuss the main findings from this dissertation. Next, I examine the main theoretical contributions of this research and how these findings build on and extend our understanding from previous literature. Finally, I discuss implications of this work for science teaching/practice and the preparation of science teachers.

Conclusions

Main Findings of Dissertation Research

The main findings from this dissertation research are grouped into four main themes:

- Focal students' incoming ideas about *who* does science and science practices are relational (i.e. they see themselves in relation to their conceptions). These relationships shaped the possibilities students viewed as available to them in science.

- Focal students' science and racial identities developed together in the science programs. Findings illuminate the disproportionate distribution of identity work that youth of color need to do in order to purse productive pathways in science.

- Students' ideas about *what* science is (i.e. science practices) and *who* can do science shifted together through participation in the practices of science.

- Engaging in science practices and the accompanying program resources generates new possibilities for *who* youth of color can become in science when their science *and* racial identities are supported.

Next, I elaborate on these main findings by theme:

Focal students' incoming ideas about who does science (e.g. characteristics, race) and science practices are relational (i.e. they see themselves in relation to their conceptions). These relationships shaped the possibilities students viewed as available to them in science.

Findings from Chapter 4 show that focal students' incoming conceptions of *who* does science serve a relational function, in that students viewed their conceptions of "science people" (i.e. characteristics, race) in relation to themselves (i.e. science *and* racial identities). Findings from Chapter 5 show that students' ideas about science practices served a similar relational function. Some students compared what *they* do in science class with what scientists do, and/or questioned their ability to engage in the types of science practices they viewed as central to the work of scientists. Awareness of these relational aspects is important because these relationships shaped the possibilities that students viewed as available to them in science.

In addition, for the focal students in this study, perceived ability in science (i.e. seeing oneself as "good" or "bad" at science) was a salient aspect of their identities in the science programs. Findings from Chapter 4 suggest that a relationship exists between how students characterize scientists, their sense making about racial/ethnic underrepresentation in science, and how they see themselves as science learners. For example, low perceived ability students more commonly associated characteristics such as "smart" with scientists, in ways that contrasted with their own perceived abilities in science. In addition, low perceived ability students more commonly internalized deficit-oriented reasoning about racial/ethnic underrepresentation in science compared to high perceived ability students. Findings from Chapter 5 suggest that a similar relationship exists between the meaning students associate with science practices (e.g. restrictive, expansive) and how students see themselves as science learners. Low perceived ability students described more restrictive views of science practices (e.g. prescribed, one correct way) during pre program interviews. In contrast, high perceived ability students described more expansive views of science practices (e.g. unknown, multiple approaches excepted). Restrictive views of science limit opportunities for participation in science (e.g. one way to do things) or students' ideas about their ability to engage with science. In contrast, expansive views broaden opportunities for participation in science (e.g. multiple ways to engage with science are accepted). These relationships impacted students' ideas about their abilities to engage with science.

The relational aspects described above have important identity implications and send messages both about *who* students must be and *what* they must be able to do in order to be "good" at science. This may impact the options the view as available to them and how they experience engaging with science practices in science programs.

Focal students science and racial identities developed together in the science programs. Findings illuminate the disproportionate distribution of identity work that youth of color need to do in order to purse productive pathways in science.

As described above, findings from Chapter 4 show that students' conceptions of scientists (i.e. characteristics, and race) shape how they see themselves in relation to science. Findings suggest that there may be a cumulative relationship between experiencing a lack of racial representation in science, the characteristics students associated with scientists, and how they see themselves as science learners. Across programs students overwhelmingly expressed awareness of a lack of racial representation in science but findings show that this awareness played out differently for high and low perceived ability students. For low perceived ability students that couldn't identify characteristics that they associated with scientists in themselves (e.g. smart) or didn't see themselves as good at the science practices they viewed as central to the work of scientists, the lack of representation added to the ways they didn't see themselves belonging in science. In some cases, this created a barrier to entry into science for students. In contrast, though high perceived ability students also experienced a lack of racial representation, they were able to find others ways they did see themselves belonging in science. For example, some high perceived ability students could identify similar characteristics they associated with scientists in themselves (e.g. inquisitive) and viewed themselves as doing similar practices to those of scientists. In this way, a lack of racial representation was a hindrance but not a barrier. However, findings show that students *across* the range of perceived ability in science needed resources that supported their science and racial identities in order to navigate productive pathways in science.

Building on the relationships described above, findings show that students' conceptions of *who* does science were further complicated by racial narratives that emerged during their sense making about racial/ethnic underrepresentation in science. Findings show that the racial narratives that emerged during students' sense making about racial/ethnic underrepresentation in science impacted *all* focal students regardless of incoming orientations to science. These racial narratives served two overlapping functions: indirectly linked the characteristics that students associated with scientists to race (e.g. smart), and in some cases confirmed students' ideas about racialized societal perceptions (e.g. *who* is smart). Findings from Chapter 4 show that even students who were confident in their science abilities were impacted by racial narratives and racialized societal perceptions. As a result, findings from Chapter 4 and 5 together illustrate that supporting students' science identities alone is not enough. Though students across programs developed more expansive views of science, Redwood students left with a greater awareness of being racially underrepresented in science and some students from Bayside described feeling held back by societal expectations.

Findings illustrate the disproportionate distribution of identity work that *all* focal students must do regardless of incoming perceived ability in science in order to pursue pathways in science; constantly redefining and presenting alternative subject positions from the one's that are placed upon them. Findings underscore the need to support youth of colors' science and racial identities in order to help them navigate productive pathways in science. In addition, this research illustrates the need to re-center race in research involving science identity construction for youth of color.

Students' ideas about what science is (i.e. science practices) and who can do science shifted together through participation in the practices of science.

Findings from Chapter 5 show that across all three programs, participation in authentic scientific research created shifts in students' ideas about science practices. Students added new types of science practices to their repertories, and broadened the meanings they associated with science practices from restrictive (e.g. prescribed, right/wrong) to expansive (e.g. science as iterative process). In addition, findings show that engaging in scientific research and developing expansive meanings of science practices allowed students to resolve conflicts within their repertoires and construct holistically expansive views of science. This helped foster sense making and learning, allowed students to make connections between practices, and generated purposes and functions of practices as well as a *need* to engage in particular practices. In addition, findings from Chapter 5 show that simultaneous shifts in students' ideas about *who* can do science occurred through conducting scientific research. Engaging in science practices created new ways to engage with the practices, helped make science more accessible to students, and allowed students to identify as capable science learners.

Findings from Chapter 6 illustrate how *who* and *what* shifted together through the experiences of Westport students. Findings show that one reason that Westport students identified themselves and their peers as scientists more commonly than students from other programs was because of what they were able to *do* as scientists. Engaging in scientific research allowed these students to construct new meanings for what counts as science practices and to co-construct the meaning, purpose, and importance of practices through engaging in them. Findings show that engaging with particular science practices, including different aspects of the data collection process fostered sense making, created new ways to engage with science, made science accessible and cultivated the identity of a capable science doer and learner. In addition, engaging in multiple aspects of the research process generated new meanings, purpose/utility, and importance for science practices. For example, recording observation in an authentic context promoted meaning making, generated the purpose for the practice and provided a *need* to take careful notes (i.e. good observational notes were critical for making sense of the data during analysis). This elevated the importance of certain practices, the meaning made from engaging in the practices, and therefore the types, power and agency associated with the identities generated. In this way, the importance of practices (e.g. taking good observational notes) elevated the students' role in the research process (i.e. collector of critical information). As a results Westport students constructed new ideas about *who* does science that included *themselves*.

Engaging in science practices and the accompanying program resources generates new possibilities for who youth of color can become in science when their science and racial identities are supported.

Findings from Chapter 6 show how engaging in science practices (i.e. data collection and analysis, presenting research) and the accompanying program resources generated new possibilities for Westport students as *capable science learners*, *scientists*, and *change agents*. Westport students made the greatest identity gains and identified themselves and their peers as scientists more commonly than students from other programs following program participation. In addition, no Westport students described scientists as "not my race" following program participation and some specifically identified youth of color as scientists – both findings unique to Westport. Findings show that the generation of new possibilities for *who* students can become in science was program resource dependent. Identities were constructed through engaging in the science practices *and* the accompanying program resources. In other words, the program resources were the mechanisms that supported the shifts described above. Furthermore, findings show that an instructor's perspective of both science (e.g. utility, purpose) and his students (e.g. racial background, positioning) shaped the resources he made available. This suggests that how this instructor *saw* his students was critical for the opportunities he created. The Westport instructor's vision was guided by his ideas about societal positioning, race, class and power. His perspective of his students was central to the possible futures he imagined for them and the organization and structuring of program resources he designed to help them make these possibilities a reality. This contrasts, with the example of Ben from Bayside in Chapter 5, who had expansive views of science and who viewed his students as capable science learners but also held deficit-oriented views about intersections of culture and science. In this way, Ben provided resources that supported his students' science identities, but left their racial identities unattended.

Matt viewed his students as lacking power and having low self-efficacy due to their race/class positioning in society and he viewed science as a tool to create change. As a result, he made unique resources available for particular science practices (e.g. presenting research) that empowered his students as agents of change in their community. The social context of the program created a space for students to learn by making mistakes and to take on and practice new roles. In addition, it fostered a close community of scientists, passionate about the importance of their research to their community. The resources made available for different aspects of the data collection process (e.g. read/use science equipment) cultivated the identity of a capable science doer and learner. In addition, collecting and analyzing data provided an opportunity to construct new knowledge. Furthermore, Matt designed an experience that provided an opportunity for students to share this newly constructed knowledge in a high stakes context. The experience disrupted the lack of power he felt his students experienced by placing them in a position of power. This enabled the construction of new possibilities for *who* they could become in science.

Findings show that youth of color can imagine and take up new possibilities for *who* they can be in science if their science *and* racial identities are supported in science programs. As described above, there were relationships between students' characterizations of scientists and students perceived ability in science (i.e. high vs. low). At the same time, findings illustrate the complexity of these relationships; all Westport students described stereotypical images regardless of incoming perceived ability in science. In addition, findings show that students commonly held tensions in their reasoning about racial disparities in *who* is a scientists, locating the issue in one's race/culture while also recognizing racialized societal structures as part of the problem. These complexities and tensions suggest that there is room to disrupt these patterns. Findings from Westport show how this disruption can happen. Engaging in science practices, the accompanying program resources and the social context of the program offered new roles for students and made new identities available (i.e. capable doer of science) while leaving others unavailable. This provided opportunities to disrupt racial narratives that some students had internalized (e.g. Fernando: "people of color slack off") or that validated some students' conceptions about *who* is smart in science (e.g. Serena: scientists = white = smarter). Resources that supported students' science and racial identities, fostered successful engagement in science practices and made new roles available: By taking on new roles and trying his hardest Fernando was able to reposition himself as hard working, engaging in data collection made science "easier" for Serena and allowed her to identify as a capable science learner, and by sharing knowledge that they constructed in a high stakes context Melanie experienced a shift in power to herself and her peers, as youth of color, as scientists. Findings underscore the importance of providing resources that support students' science and racial identities and create an opportunity to reposition students (or provide a means for them to reposition themselves) in order to create space and new possibilities for *who* youth of color can become in science.

Implications

Theoretical Contributions & Implications for Research

In this section, I describe the main theoretical contributions of this work and how this research builds on and extends findings from previous literature. In addition, I offer directions for future research.

Re-centering race in science identity research. Findings illustrate the need to re-center race in research involving science identity construction for youth of color. We need to re-center race because findings throughout this dissertation illuminate the ways that focal students' science and racial identities develop *together* in the science programs. Therefore we cannot consider one without the other. These findings demonstrate that science programs are not neutral spaces, but rather operate at the historically embedded intersections of race and science in ways that impact youth of colors' science experiences.

Findings show that students' conceptions of scientists (i.e. characteristics, race), their sense making about racial/ethnic underrepresentation in science, and their perceptions of their abilities as science learners are intimately linked and impact the options they view as available to them in science. In addition, findings show how racial narratives and racialized societal perceptions further complicate these relationships and impact all focal students of color, even those that are confident in their science abilities. Findings from this dissertation build on previous research and extend our understanding of processes of learning and identity construction for youth of color in science learning environments. Contributions to the existing literature in the arena of re-centering race in science identity research are grouped into the following main themes:

Perceived ability in science. As described above, findings show that perceived ability in science emerged as a salient aspect of students' identities in the science programs. Findings from Chapter 4 provide insights into the ways that focal students' ideas about *who* does science and how they see themselves as science learners are intimately linked by conceptions of both race and science. These relationships send particular messages about *who* students need to be in order to do science. Findings expand our understanding of how perceptions of ability operate at the intersections of race and science to limit the options youth of color view as available to them within the science discipline. Though sample sizes in this study are small, findings suggest important relationships exist between how students see themselves as science learners, their conceptions of science practices and how they experience and make sense of science as youth of color. In addition, findings suggest that in order to truly create space for youth of color we need to re-center race and explore intersections of race, science and perceptions of ability when conducting research on science identity construction for youth of color.

Findings from this research re-center race in our conceptions of perceived ability in science and extend beyond to suggest that factors may accumulate for students in ways that impact their ideas about belonging or not belonging in science. Perceived ability is often taken up as an individual attribute that works in concert with other individual factors (e.g. self-efficacy) to produce certain outcomes (e.g. motivation). More research is needed that examines how racialized experiences and perceptions operate to impact perceptions of ability as well as how perceived ability impacts sense making about racialized experiences and the options available for students to resist and reposition themselves. In addition, more research is needed that explores how this specifically operates in science spaces. Next, I discuss how this research extends our understanding of how racial narrative operated in science spaces.

Racial narratives. Findings from this dissertation show that students' conceptions of *who* can do science and perceived ability in science are further complicated by racial narratives that emerged during students' sense making about racial/ethnic underrepresentation in science. As illustrated in Chapter 4, racial narratives shape focal students experiences, positioning, how they are perceived by society, and the possibilities they view as available and not available to them in science. Foundational work on stereotype threat suggests that racialized experiences and stereotypes are important to consider when examining processes of learning and identity construction for youth of color (Steele, 1997; Steele & Aronson, 1995). Findings from this dissertation build on this work to show *how* racial narratives operate for the focal students in this study. Findings build on previous literature involving stereotypes and racial narratives in two ways: First, they extend this important work to the science discipline. Second, findings extend our understanding of how racial narratives operate collectively with different aspects of students' identities and their conceptions of *who* does science to shape the options they view available to them in science.

Findings from this study suggest that racial narratives operate collectively with different aspects of students' science and racial identities in a similar way to gender-math stereotypes (Cvencek, et.al, 2011). However, findings from this dissertation suggest an expansion of how racial narratives function in two ways. First, findings suggest that racial narratives don't have to be discipline-specific (i.e. about science) in order to operate in conjunction with student's conceptions of scientists. Interestingly, though the racial narratives that emerged were not often directly linked to science, in some cases they became linked *relationally* through the content of the narratives and the characteristics students associated with scientists. For example, the racial narrative "white people are smarter than Mexican people" became linked to science through the characteristics and race that Serena associated with scientists: "white" and "smart". In this way, the content of the racial narratives that emerged often linked the characteristics students' associated with scientists (e.g. smart) to race. This builds on previous literature that shows that racial narratives are the mechanism through which math achievement, ability, and motivation are linked to race (Nasir & Shah, 2011). Findings here broaden our understanding of how racial narratives operate by extending this body of work to the science discipline. In addition, findings show how racial narratives operate collectively with different aspects of students' identities and their conceptions of *who* does science to impact their sense making and science experiences. Second, findings suggest that racial narratives can shape students' ideas about their place in science (i.e. self-concept), but also that students conceptions of scientists and how they see themselves in relation to scientists shapes their sense making around racial narratives. In other words, for students who don't see themselves as good at science or racially represented in science, and view scientists as smart and "not their race", racial narratives can validate their conceptions about *who* is smart in science-specific ways (i.e. scientists = white = smarter).

Findings here extend our understanding of how racial narratives operate in the science discipline and in conjunction with other aspects of students' identities (e.g. perceived ability) to impact their science experiences. Together these findings further develop our understandings of how race matters when considering science identity construction for youth of color and the complex ways that racial narratives impact students' ideas about *who* belongs in science as well as the options they view as available to them.

Moving forward: Co-development of students' science & racial identities. The re-centering of race discussed above also requires a reframing: not bolstering the science identities of youth of color, but supporting the *co-development* of students' science and racial identities in science spaces. Westport students made the greatest identity shifts following program participation. They identified themselves and their peers as scientists more commonly than students from other programs and specifically identified youth of color as scientists. Findings from Chapter 5 show how developing expansive views of science and bolstering students' science identities is important but not enough if students don't see a space for themselves in science. Together these findings suggest that to truly create space and new possibilities for *who* youth of color can become in science we need to directly address race (e.g. racial positioning, hierarchies of power) when considering identity construction for youth of color.

The science identity literature focused on racially/ethnically underrepresented youth, still tends to focus on the science identity construction for youth of color rather than the *co-development* of students' science and racial identities. A lot of important work has been done on equitable approaches to science instruction and how this shapes science identities: expanding views of what counts, helping bridge students' world and world of science, creating hybrid spaces (e.g. Calabrese Barton & Tan, 2009; Tan & Calabrese Barton, 2010). This work is critical for creating space in science, pushing boundaries of what counts, re-conceptualizing *what* science and for *whom*, and continuing to broaden opportunities for participation in science for youth of color. Findings from this study align with this research but speak to a need to push beyond the important work that is currently being done in this arena and to widen our scope to more holistically capture youth of colors' experiences in science. Even though there is a lot of work being done to support students of color as doers of science, treatments of race in relation to science are limited (Parson, 2014). Race is often treated simply as a means to group students rather than an aspect of *who* students are in science spaces (Parson, 2014). More work is needed that examines intersections of students' racial and disciplinary identities (Varelas et.al, 2012) and equally considers *who* (i.e. racial identity) in relation to *what* (i.e. science). If we are talking about science identities of youth of color, we really are (or should be) talking about the *co-development* of students' science *and* racial identities.

Directions for future research: Re-centering race. Future research is needed that broadens our scope even further when exploring intersections of race, science and identity construction for youth of color in science learning environments. More work is needed that explores how relational aspects of *what* and *who*, race and science operate in the broader ecological system (Bronfenbrenner, 1977). In addition, future research is needed within this broader ecological framework that expands our understanding of intersections of race and science and goes further to explore youth of colors' ideas about who can do science and how they see themselves in relation to science. Finally, research is needed that delves deeper in the impacts of perceived ability in science on students sense making as well as how a multitude of broad and local structures impact social-emotional well-being and resiliency in science disciplines (Lee, Spencer & Harpalani, 2003).

It should be noted that because my analytical lens foregrounded race and racial/ethnic underrepresentation in science, other aspects of students' identities were in the background. The intention of this research was to understand processes and mechanisms associated with intersections of students science and racial identities. Rogoff (1997) reminds us that as researchers the planes or lenses of our analysis impact our sense making and understanding of processes and there are tradeoffs to the lenses that we choose. Research points to the need to explore intersections of identities in order to gain a holistic understanding of how people experience the world (Garcia Bedolla, 2007). A focus on race limited my inclusion of other aspects of students' identities (e.g. gender, class) that may contribute in significant ways to how students see themselves in relation to science. In addition, the aspects of identity that were salient in the science programs (e.g. perceived ability) may have been influenced by race in combination with other aspects of students' identities (e.g. gender). Future research is needed that broadens this scope further to holistically capture and grapple with the complexity of the intersectional aspects of identity at play in science learning environments.

Generating new possibilities in science. Findings from this dissertation build on and extend our understanding of *how* new possibilities are generated for youth of color through engagement in science practices. Findings from Chapter 6 illustrate the mechanisms involved with the generation of new possibilities in science: how engagement in science practices and the accompanying programs resources (e.g. instruction, pedagogy, designed experiences) leads to the generation of new possibilities for *who* students can become in science. Findings show that engaging in science practices (e.g. collecting data) can be *linked* to the construction of certain types of identities (e.g. capable science learner). For focal students in this study, identity construction involved the different ways that students engaged with science practices and the sense making and intellectual work involved. In addition, findings show that engaging in the same science practices had different identity outcomes for students depending on the resources made available for the practice. In this way, findings show that identity construction was program resource dependent. This suggests that when engaging students in science practices we need to equally consider the types of practices that we promote and *how* they are promoted. Furthermore, as described above, findings show that in the case of Westport, the instructor's vision of both science (i.e. purpose, utility) and his students (e.g. race, social positioning) guided the instruction, pedagogy and designed experiences he made available and was central to the new possibilities that were generated. Together, findings illustrate that a relationship exists between engaging in science practices, program resources and identity construction for youth of color. This requires a holistic approach and an examination of how the parts of the process operate *together* in order to further our understanding of how to create greater opportunities for participation in science.

Engaging students in science practices. Previous research shows how engaging students in science practices and scientific research allows students to develop new epistemological stances (Metz, 2004; Sandoval, 2005; Lehrer et. al, 2008) increases interest and engagement in science (Linn & Hsi, 2000) and allows students to identify as capable science learners (Barab & Hay, 2001; Bouillion & Gomez, 2001; Bowen & Roth, 2007, Lehrer, 2009). Findings here extend this foundational work to show that students view science practices in relation to themselves and their abilities to engage with these practices. In addition, finding extend beyond this work to deepen our understanding of the mechanisms involved – *how* engaging in science practices leads to identity construction and the centrality of program resources in supporting these new possibilities.

Findings suggest that a relationship exists between developing expansive views of science, perceived ability in science, and identifying as a scientist. Findings show that by engaging students in the process of analytic sense making (e.g. using/understanding science equipment), students developed an understanding of the function of and connection between practices. This helped expand students' ideas about what counts as science *and* their abilities to engage with science practices and in this way made science more accessible to some students. However, findings challenge and complicate notions of how identities are made available and the types of experiences that create new opportunities to participate in science. Findings show that developing expansive views of science doesn't necessarily equate to the generation of new possibilities for youth of color in science because engaging in science practices produced different outcomes and feelings of belonging or not belonging in science for students across programs. Findings suggest that for focal students in this study, program resources are needed that support students science and racial identities in order to make new possibilities for *who* they can become in science available. Next, I discuss the centrality of the instructor's vision in designing program resources that create new possibilities in science for youth of color.

Pedagogical Vision: Supporting science and racial identities. Research shows that beginning teachers' orientations to science, students, race and diversity on personal, social and political levels informed their perspectives of science and views of science teaching (Bianchini & Solomon, 2003). This impacted teachers' views of equity in science and ideas about equitable approaches to science instruction (Bianchini & Solomon, 2003). Findings from this research extend our understanding of the mechanisms involved: *how* these beliefs shape an instructor's vision and guide the design of program resources that impact the student *outcomes* and the types of identities generated.

This research extends our understanding of the significance of an instructor's "pedagogical vision" for the design of instruction, pedagogy, designed experiences and the student outcomes generated. Findings from Chapter 6 show what is possible when resources are made available that support students science and racial identities and how processes of social dreaming (Gutierrez, 2008) can be facilitated in science spaces. Results echo the call above to re-center race when considering the development of instructors' "pedagogical visions". Specifically, findings show how a particular vision of both science (i.e. purpose, utility) and students (i.e. conceptions of race, societal positioning) that centers race and social positioning, is historically embedded, and politically conscious can result in the creation of opportunities and experiences in science spaces that disrupt racial narratives and power. Findings show that the Westport instructor's "pedagogical vision" of science and his students shaped the goals and purposes for teaching science, what he envisioned his students *doing* with science, and the possibilities he create for *who* his students could become in science. As a result, racial narratives were disrupted and reframed in ways that offer new possibilities for *who* students can become in science when resources are made available that support students science and racial identities. By exploring and instructor's vision through the lens of prolepsis we see how ideas about race, class, positioning and power shaped the futures he imagined for his students and in ways that directly impacted the design of program resources in the present (Cole, 1996).

Previous research shows the powerful role of teachers and when a politically conscious lens is applied, teachers as "power agents" are compelled to act and disrupt institutionalized power structures (Oakes, et.al, 1990). Findings here build on this and suggest this critical lens is necessary to facilitate the process of "social dreaming" that leverages students' histories and experiences as resources to imagine and construct new futures (Gutierrez, 2008).

Directions for future research: Generating new possibilities. Findings from this research highlight the potential of using the identity generative process that emerged here (engaging in practices, program resources, identity construction) as a unit of analysis because it highlights the connection between engagement in science practices, program resources and the generation of new possibilities rather than disaggregating this process into individual components. Exploring this identity generative process as a unit of analysis highlights that it's not just expansive science instruction and pedagogy or students engaging in science practices, but the combination of the two that generates new possibilities for *who* students can become in science. In addition, this research highlights the importance of an instructor's lens: specifically of race, social positioning and power for the design of program resources that can generate new options for youth of color in science. More research is needed that explores how together program resources and engagement in practices allows students' agency and power to come to life. In addition, more research is needed that explores the idea of prolepsis in relation to the development of an instructors' vision: how experiences with race, class and power shape perspectives, futures imagined for students and the possibilities created in the present.

It is important to note that in the case of Westport, the program resources Matt made available were implicit race/diversity resources – Matt didn't address race and diversity directly through instruction. However, his ideas about race, class, positioning and power were explicit when shaping the design of program resources. In the program in this study (i.e. Bayside) that was race/diversity explicit (e.g. discussion of race, diversity were part of program content) the scientific research component of the program was not race/diversity explicit. The program had several components and the race/diversity explicit aspects of the program included workshops and guest speakers of color. In this way, the "doing" of science was not connected to explicit resources. More research is needed on programs that provide race, diversity explicit resources in the context of the "doing" of science. We can only imagine what is possible and the identities that could be constructed if youth of color were supported in science spaces in ways that explicitly centered race and empowered them as youth of color. This has important implications for the design of curriculum that engages students in science practices as well as the resources made available that foster identity construction. The more closely we can document the mechanisms involved and the links between engaging in science practices, program resources and identity construction the better we can design curriculum that expands opportunities for participation in science.

Implications: Implementation of NGSS, Science Teaching & Teacher Education

What does this all mean for how we engage students in science practices and how we train science teachers? In this last section, I discuss implications of this research for science teaching and the preparation of science teachers.

Implications for implementation of the Next Generation Science Standards. The Next Generation Science Standards are at the forefront of contemporary science education discussion, research, curriculum design and professional development opportunities (NGSS, 2013). The focus on science practices seeks to reframe the ways the scientific method has been taken up and taught in schools for decades. Findings from this research show how engagement in science practices created new possibilities for students and therefore this new focus on practices for science teaching is encouraging. However, with these opportunities, there are also challenges and concerns. In the next section I discuss affordances of engaging students in scientific research and points for consideration when designing instruction that promotes the implementation of NGSS.

Affordances & messages of science practices. Engaging in scientific research provided an opportunity for students to experience the messiness and problem solving aspects of science, make and learn from mistakes, and understand the meaning and function of science practices. This contrasts to how students commonly described their school science experiences as prescribed, linear and where there was one correct approach for arriving at the "right" answer. Findings show that engaging students in scientific research produces numerous positive outcomes: students added new types of practices to their repertoires, developed more expansive meanings of science and resolved conflicts within the repertoires. In addition, engaging in scientific research made science more accessible for some students and allowed them to identify as capable science learners.

While findings illustrate the benefits of engaging students in the scientific research process, findings also push us to consider *what* science practices we seek to promote and *why* and the affordances of practices for learning and identity construction in science. In addition, findings point to the centrality of program resources in fostering successful engagement with science practices. Findings from this research point to two inter-related points of consideration when designing curriculum and instruction for NGSS: 1) Affordances: what are the affordances of engaging students in particular science practices? What types of analytic sense making are promoted? How does engaging in and with certain practices foster the construction of new meanings and ways to engage with science? 2) Messages: what messages do students receive about belonging or not belonging in science through engaging in science practices? My research points to the contrasting messages some students received based on their experiences engaging with practices (e.g. presenting research = change agent vs. not belonging in science). Together these considerations point to the centrality of program resources in facilitating meaningful experiences with science practices. In addition, they point to the need to consider identity implications for engaging in the practices. Next, I discuss two concerns regarding the implementation of NGSS in light of these findings.

Promoting data collection & analysis. Findings show how for Westport students, engaging in specific science practices (i.e. data collection and analysis, presenting research) created significant identity shifts and generated new possibilities for students as *capable science learners*, *scientists*, and *change agents*. The question this raises is how do these practices map onto the practices promoted by NGSS? NGSS highlights eight main practices (NGSS, 2013). Two of these practices: "communicating science" and "analyze/interpret data" present opportunities to create curriculum and experiences that can leverage findings from this study. Presenting research was a significant practice for Westport students that fostered the identity of *change agent*. Aspects of the program resources design for this practice, discussed below, could be taken up to implement the NGSS "communicating science" practice. In addition, making graphs and using data visualization software helped some students identify as *capable science learners* and *scientists*. Aspects of the program resource design for analyzing data could be applied to the implementation of NGSS "analyze/interpret data". However, a group of practices that contributed to some of the most significant identity shifts for Westport students: the data collection process (e.g. use/read machines, record observational notes) is under-emphasized in NGSS.

For focal students in this study, engaging in the data collection process leveraged students' agency as *capable science learners* and *scientists*. These practices are under-emphasized in NGSS. This could be because data collection in isolation may not be beneficial and findings here suggest this is true. However, findings show how different aspects of the data collection process (e.g. read/use science equipment) created new ways to engage with science, made science accessible and cultivated the identity of a *capable science doer and learner*. Findings here illustrate how the type of data they collected, the importance of the knowledge they constructed about their community and what they were able to *do* with this data all contributed to the transformation they experienced. This supports the perspective that data collection alone is not sufficient but needs to be incorporated into a broader constellation of practices to take on greater meaning and importance. Findings show, that we can't underestimate the analytic work and sense making involved with science practices such as using/reading machines. For many students, the machines as a material object afforded new ways to engage with science that led to new roles and possibilities for *who* they could become in science. In addition, engaging in the data collection process along with a multitude of other practices generated new meanings, purpose/utility, and importance for science practices that created a *need* for certain practices. For example, recording observation in an authentic context promoted sense making, generated the purpose for the practice and provided a need to take careful notes (i.e. good observational notes were critical for making sense of the data during analysis). This elevated the importance of practices, the meaning made from engaging in the practice and therefore the types, power and agency associated with the identities generated. This latter point, leads to the second concern.

Promoting synergy between science practices. Findings illustrate the learning and sense making that are afforded and the identities that are generated by keeping the synergy between different science practices such as data collection, analysis, and presenting research intact when engaging students in scientific research. Findings here show that engaging students in different aspects of the scientific research process facilitated connections between practices, generated new meanings for practices and fostered a deep understanding of the purpose of practices. See the examples of data collection, analysis and presenting research described above. As promoted by NGSS, findings from this study support the need to and illustrate the importance of maintaining synergy between the science practices (NGSS, 2013). Because NGSS breaks the research process into eight focal practices, the tendency could be to teach them as separate entities rather than a collective process. The concern is that if the practices are disaggregated, we lose the iterative aspect of research and how the practices work together in ways that empower students to construct meaning, understanding and agency. NGSS emphasizes the connections between practices and this will be essential to promote through curriculum and standards implementation.

Implications for science teaching. Findings from the Westport program highlight aspects of the learning environment and program resource design that fostered processes of learning and identity construction in science. Findings show that engaging in specific science practices (e.g. collecting data) and the accompanying program resources could be *linked* to the generation of new possibilities for Westport students (e.g. capable science learner) (see Table 1). In the next, section I highlight the main design implications for the learning environment and program resources that supported students' engagement in the practices and cultivated the generation of new possibilities.

Implications for learning environment design. Findings highlight several aspects of the learning environment design that were central to making new possibilities available for students.

- *Instructor's vision*. The resources that Matt made available were based on how he viewed science as a tool, but perhaps even more so on the way he viewed his students: as lacking power, as having low self-efficacy due to their race/class positioning in society, as natural data collectors. Matt's vision was guided by his ideas about race, class, social positioning and power. This mattered for the futures he projected for his students and it guided his actions in the present to empower youth as change agents. The majority of the students in the Westport program had failed their science class in school or needed to make up credits. How Matt *saw* these students was critical to the outcomes that were generated. Where others may have seen students who failed, were unmotivated, and were unengaged, Matt saw students who were not being met by the system, whose societal positioning created low self-efficacy, and whose actions (i.e. Fernando, "distracted") may have been ways to cope with the lack of power they experienced. Matt's perspective of his students was central to the possible futures he imagined for them and the organization and structuring of program resources he designed to help make these possibilities a reality.

- *Social context of learning environment*. The Westport program offered a social learning context where students were able to make and learn from mistakes, mess up and gain understanding through practicing. Students and instructors engaged in the learning process together and made decisions about research directions as a group. The small size of the group was significant for students – they were able to ask and receive help from instructors and each other more readily. This made new roles available, provided an opportunity for students to take on these new roles and allowed students to become experts in certain areas (e.g. Fernando teaching others to make graphs). In addition, students had ownership of their research project. The instructor selected the topic of study, but students participated in the research design and had agency to ask their own research questions within this topic and from the vast amount of data collected. Students divided up sampling locations and collected data in teams of three to four students. The opportunities to ask different research questions from the pool of data collected cultivated a need to collaborate and share data as a community. Finally, the community-based aspect of the research provided students with a sense of importance for the work they conducted. This generated a passion both for the research and a desire to engage fully in it. Furthermore, presenting in a high stakes context and the continued interest in the students' research (e.g. media, workers union) elevated the importance of their research and how students saw themselves in relation to science.

- *Designed experience: Opportunity to disrupt power*. Matt's goal was to show his students that they could use science as a tool to create change. To do this, he designed an experience that showed his students that their research was important and could lead to changes. The designed experience was a way to make this vision a reality. The opportunity to present in a high stakes context, described above, placed students in a position of power and new ways to engage with science. This generated hope and new possibilities for students.

It is important note that findings here illustrate how the type of data Westport students collected, the importance of the knowledge they constructed about their community and what they were able to *do* with this data all contributed to the transformation they experienced. Students were empowered to do research in communities of color and an underserved area. This supports the support the need to diversify the science community. The Westport students' experiences remind us of the ways that *who* is doing research guides the questions being asked and *where* research is being conducted (Harding, 2008). Diversifying the science community would profoundly impact the types of scientific research conducted. We can only imagine the *types* of research questions so many other students will ask, *where* they will conduct research, and *who* it will impact when given access and opportunity. In the final section, I discuss implications of this research for teacher education and the preparation of pre-service teachers.

Implications for teacher education. Findings from this research have three main implications for teacher education and the preparation of science teachers. First, as stated throughout the conclusion and implications above, findings demonstrate the need to re-center race when considering the identity construction of youth of color in science learning environments. This indicates a need to re-center race in teacher education and to prepare teachers equally for teaching science content and developing relationships with students who often come from racial/ethnic backgrounds and that have lived experiences that differ from their own. Specifically, findings suggest a need for a more holistic approach to training teachers to "see" students in more racially conscious and politically relevant ways. Second, findings indicate a need for teachers to gain authentic science experiences themselves so that they can confidentially implement the NGSS practices, understand the synergy between different science practices, and are empowered to guide students through the scientific research process. Finally, in relation to the first two points, instructors need examples of what equitable approaches to science instruction and the implementation of racially and politically conscious vision for the design of science instruction and experiences looks like in action.

Often, science is viewed as a universal, culture free enterprise (e.g. Harding, 2008). The focus of teacher preparation tends to be on science and math content rather than how students "see" their students. Findings from this research demonstrate that an instructor's perspective of science and his students mattered for the futures he imagined for them and the pedagogy, instruction and designed experiences he made available. This illustrates a need for an equal focus on science content and how science teachers "see" their students. As a pre-service teacher educator myself, I had the unique opportunity to teach a course addressing issues of equity in science and math education in an undergraduate teacher credentialing program. Each semester, I witnessed the growth of my students as they learned about, struggled with, reflected on and debated contemporary issues of equity involving intersections of race, class, and STEM educational opportunities. Like myself, many of my students were white or from racial backgrounds well-represented in math and science fields and in many ways their learning trajectories mapped onto my own. Students culminating statements of equity often were evidence of trajectories of growth and the development of at least some aspects of a racially and politically conscious vision. However, courses that address issues of equity and intersections of race, culture and learning in relation to STEM education in pre-service teaching programs at the undergraduate and Master's level are limited.

As described above, previous research shows how beginning teachers' beliefs about students and science matters for perspective of equity and diversity in science teaching (Bianchini & Solomon, 2003). Findings here show the *outcomes* of these beliefs for the teaching and learning of science and how these beliefs matter for the program resources made available and the student outcomes generated. Future research is need that builds on these findings and continues to make links between a pedagogical vision, the types of instruction and experiences created, and student outcomes. In addition, more research is needed that documents instructional approaches that engage students in science practices and offer new identities and opportunities to reposition students in science. As part of the undergraduate course students' designed lessons with an equity focus of they're choosing. There are examples of culturally relevant and other equitable approaches to science instruction, more examples and research are needed that show what teaching practices like look in action. As teacher educators we are often training teachers to approach instruction in ways they did not experience and do not observe at the field locations. More resources are needed to support equitable approaches to instruction. In addition, as described above, future research is needed on the development of resources that are race/diversity explicit and are connected to the "doing" of science. What do explicit resources look like in practice as connected to the "doing" of science? Finally, there is a need to engage teachers in the science practices so that they can experience what scientific research is like on their own. This will allow teachers to develop curriculum that empowers them to engage students in the NGSS practices in important and meaningful ways.

Summary & Scholarly Significance

Findings from this dissertation build on and extend our understanding of *how* new possibilities are generated for youth of color through engaging in science practices. This research illustrates the mechanisms that support the generation of new possibilities in science: how engaging in science practices and the accompanying programs resources leads to the generation of new possibilities for *who* students can become in science. Exploring this identity generative process as a unit of analysis highlights that it's not just expansive science instruction or engaging students in science practices, but the combination of the two that generates new possibilities. In addition, this research extends our understanding of the significance of an instructor's "pedagogical vision" in guiding this process. Findings document links between an instructor's vision, the design of program resources that engage students in science practices and student *outcomes* in the form learning and identity construction. Findings support the need for a holistic approach and an examination of how the parts of the identity generative process operate *together* in order to further our understanding of how to create greater opportunities for participation in science.

This research illustrates the need to re-center race in research involving science identity construction for youth of color. Findings illuminate the complexity of identity construction, how youth of color see *who* does science and science practices in relation to themselves, and the disproportionate distribution of identity work that they need to do in order to purse productive pathways in science. This research shows that youth of color can imagine and take up new possibilities for *who* they can be in science if their science *and* racial identities are supported in science programs. This highlights the importance of re-centering race in teacher education opportunities that prepare teachers for both engaging students in science practices and developing racially conscious and politically relevant ways of "seeing" their students. Therefore, this re-centering of race also requires a reframing: not bolstering the science identities of youth of color, but supporting the *co-development* of students' science and racial identities in science programs.

Findings from this research inform the design of learning environments that create multiple pathways for learning and identification in science. In addition, findings can be leveraged across contexts to construct pedagogical and instructional resources that support meaningful learning opportunities in schools. This research has implications for the implementation of the Next Generation Science Standards and highlights the need to consider the affordance of the science practices for learning and the messages youth receive about belonging or not belonging in science based on their experiences engaging with the practices. This research shows how together program resources and engagement in science practices allowed students' agency and power to come to life. Findings can be applied to the creation of opportunities and resources in science programs, classrooms and teacher education that reframe how students see themselves in relation to science, foster successful and meaningful engagement with science practices, disrupt racial narratives, and empower youth of color as capable learners, doers and changes agents in science. In this way we can broaden participation in science and truly create space for youth of color in science learning environments.

References

Archer, L., DeWitt, J., Osborne, J., Dillion, J., Willis, B. & B. Wong (2010). "Doing" science versus "being" a scientist: Examining 10/11-year-old schoolchildren's constructions of science through the lens of identity. *Science Education*, 94(4), 617-639.

Aschbacher, P.A., Ellen, E.L., Roth, J. (2010). Is science me? High school students' identities, participation and aspirations in science, engineering, and medicine. *Journal of Research in Science Teaching*, 47(5), 564-582.

Barab, S.A. & Hay K.E. (2001). Doing science at the elbows of experts: Issues related to the science apprenticeship camp. *Journal of Research in Science Teaching*, 38(1), 70-102.

Bianchini, J.A. & Solomon, E.M. (2003). Constructing views of science tied to issues of equity and diversity: A study of beginning science teachers. *Journal of Research in Science Teaching*, 40(1), 53-76.

Bonilla-Silva, E. (2006). Racism without racists: Color-blind racism and the persistence of racial inequality in the United States. Rowman & Littlefield Publishers.

Bouillion, L.M & Gomez, L.M. (2001). Connecting School and Community with Science Learning: Real World Problems and School-Community Partnerships as Contextual Scaffolds. *Journal of Research in Science Teaching,* 38(8), 878-898.

Bowen, G.M. & Roth, W.M. (2007). The practice of field ecology: Insights for science education. *Research in Science Education,* 37, 171-187.

Brickhouse, N.W. (2001). Embodying science: A feminist perspective on learning. *Journal of Research in Science Teaching*, 38(3), 282-295.

Bronfenbrenner, U. (1977). Toward and experimental ecology of human development. *American Psychologist* 32, 513-532.

Brown, B., Reveles, J.; & Kelly, G. (2005). Scientific literacy and discursive identity: A theoretical framework for understanding science education. *Science Education*, 89, 779-802.

Calabrese Barton, A. (1998). Teaching science with homeless children: Pedagogy, representation and identity. *Journal of Research in Science Teaching*, 35, 379–394.

Calabrese Barton, A., Tan, E., & Rivet, A. (2008). Creating hybrid spaces for engaging school science among urban middle school girls. *American Educational Research Journal*, 45, 68–103.

Calabrese Barton, A. & Tan, E. (2009). Funds of knowledge and discourses and hybrid space. *Journal of Research in Science Teaching*, 46(1), 50-73.

Cole, M. (1996). Cultural psychology: A once and future discipline. Cambridge, MA: Belknap Press of Harvard University Press.

Cvencek, D., Meltzoff, A.N. & Greenwald, A.G. (2011). Math–gender stereotypes in elementary school children. *Child Development*, 82(3): 7566-779.

Darling-Hammond, L. (2010) The flat world and education: How America's commitment to equity will determine our future. New York: Economic Policy Institute and Teachers College Press.

Edwards, R. & Mauthner, M. (2002). Ethics and feminist research: Theory and practice. In, Mauthner, Birch, Jessop, and Miller, Eds. Ethics in Qualitative Research. New York: Sage.

Garcia Bedolla, L. (2007). Intersections of inequality: Understanding marginalization and privilege in the post-civil rights era. *Politics & Gender*, 2: 232-248.

Gutierrez, K. (2008). Developing a sociocritical literacy in the third space. *Reading Research Quarterly*, 43 (2), 148-164.

Hammer, D. & Berland (2013). Confusing claims for data: A critique of common practices for presenting qualitative research on learning. Journal of the Learning Sciences, 1-10.

Harding, S. (1995). 'Strong objectivity': A response to the new objectivity question." *Synthese* 104, 331-349.

Harding, S. (2008). *Sciences from Below: Feminisms, Postcolonialities, and Modernities,* Duke University Press.

Harre, R. (2008). Positioning Theory. Self-Care and Dependent-Care Nursing, 16(1), 28-32.

Holland, D., Skinner, D., Lachicotte, W., and Cain, C. (1998). Identity and Agency in Cultural Worlds. First Harvard University Press.

Johnson, A., Brown, J., Carlone, H., and A.K. Cuevas (2011). Authoring identity amidst the treacherous terrain of science: A multiracial feminist examination of the journeys of three women of color in science. *Journal of Research in Science Teaching*, 48(4), 339-366.

Kind, P.M, Jones, K. & Barmby, P. (2007). Developing attitudes towards science measures. *International Journal of Science Education*, 29(7), 871-893

Lee, C.D., Spencer, M.B. & Harpalani, V. (2003). "Every shut eye ain't sleep.: Studying how people live culturally. *Educational Researcher*, Vol. 32, No. 5, pp. 6–13(Carol Lee course).

Lee, H.S. & Songer, N.B. (2003). Making authentic science accessible to students. *International Journal of Science Education*, 25(8), 923-948.

Leonardo, Z. & Broderick, A.A (2011). Smartness as property: A critical exploration of intersections between whiteness and disability studies. *Teachers College Record*, 113(10), 2206-2232.

Lehrer, R. (2009). Designing to develop disciplinary dispositions: Modeling natural systems. *American Psychologist*, 64(8), 759-771

Lehrer, R., Schauble, L. & Lucas, D. (2008). Supporting development of the epistemology of inquiry. *Cognitive Development*, 23, 512-529.

Linn, M.C. (2006). The knowledge integration perspective on learning and instruction. In K. Sawyer (Ed.), The Cambridge handbook of the learning sciences (pp. 243–264). New York: Cambridge University Press.

Linn, M. C., & Hsi, S. (2000). Computers, teachers, peers: Science learning partners. Mahwah, NJ: Lawrence Erlbaum Associates.

Light, Singer & Willet (1990). By Design: Planning Research on Higher Education.

Malone, K.R., & Barabino, G. (2008). Narrations of race in STEM research settings: Identity formation and its discontents. *Science Education*, 93(3), 485-510.

Maxwell, J.A. (2004). Causal explanation, qualitative research, and scientific inquiry in education. *Educational Researcher*, 33(2), 3-11.

Metz, K.E (2004) Children's understanding of scientific inquiry: Their conceptualization of uncertainty in investigations of their own design. *Cognition and Instruction*, 22: 2, 219-290.

Miles, M. B. & Huberman, A. M. (1994). Qualitative data analysis: An expanded sourcebook. Second edition. Thousand Oaks: Sage.

Nasir, N.S. (2012). Racialized Identities: Race and Achievement Among African American Youth. Stanford University Press, Stanford, CA.

Nasir, N.S. (2004). “Halal-ing” the child: Reframing identities of resistance in an urban Muslim school. *Harvard Education Review*, 74(2), 153-174.

Nasir, N.S. & Cooks, J. (2009). Becoming a hurdler: How learning settings afford identities. *Anthropology & Education Quarterly*, 40(1), 41-61.

Nasir, N.S. & Hand, V. (2006). Exploring sociocultural perspectives on race, culture, and learning. *Review of Educational Research* 76(4), 449-475.

Nasir, N.S. & Hand, V. (2008). From the court to the classroom: Opportunities for engagement, learning, and identity in basketball and classroom mathematics. *Journal of the Learning Sciences*, 17:2, 143-179.

Nasir, N.S & Shah, N. (2011). On defense: African American males making sense of racialized narratives in mathematics education. *Journal of African American Males in Education*, 2(1), 24-45.

National Research Council. (2011). Successful K-12 STEM Education: Identifying Effective Approaches in Science, Technology, Engineering, and Mathematics. Washington, DC: National Academies Press

National Science Board (2012). Science and Engineering Indicators Digest 2012. Arlington VA: National Science Foundation (NSB 12-02).

NGSS Lead States (2013). *Next Generation Science Standards: For States, By State*s. Washington, DC: The National Academies Press.

Norguera, P.A. & Akom, A. (2000). Disparities demystified. The Nation.

Oakes, J., Ormseth, Bell & Camp (1990). Multiplying inequalities: The effects of race, social class, and tracking on opportunities to learn mathematics and science. RAND Report. Pp. 1-152.

Oakes, J., Wells, A.S., Jones, M. & Datnow, A. (1997). Detracking: The social construction of ability, cultural politics, and resistance to reform. *Teachers College Record.* 98 (3), 482-510.

Omi, M. & Winant, H. (1994). Racial Formation in the United States from the 1960s to the 1990s. New York: Routledge.

Parsons, E. C. (2014). Unpacking and critically synthesizing the literature on race and ethnicity in science education. In N.G. Lederman & S.K. Abell (Eds.), *Handbook of research on science teaching, volume II* (167-186). New York: Routledge.

Polman, J.L. & Miller, D. (2010). Changing stories: Trajectories of identification Among African American youth in a science outreach apprenticeship. *American Educational Research Journal*, 47, 879-918.

Rahm, J. (2007). Youths' and scientists' authoring of and positioning within science and scientists' work. *Cultural Studies of Science Education*, 1, 517–544.

Rogoff, B. (1997). Evaluating development in the process of participation: Theory, methods and practice building on each other. In E. Amsel, K.A. Renninger, A. Renninger (Eds.), *Change and Development: Issues of Theory, Method, and Application* (265-286). New Jersey: Lawrence Erlbaum Associates.

Sandoval, W. A. (2005). Understanding students' practical epistemologies and their influence on learning through inquiry. *Science Education*, 89, 634-656.

Stanley, W. & Brickhouse, N. (1994). Multiculturalism, universalism, and science education. *Science Education*, 78(4), 387-398.

Steele, C. (1997). A threat in the air: How stereotypes shape intellectual identity and performance. *American Psychologist, 52*(6), 613-629.

Steele, C., & Aronson, J. (1995). Stereotype threat and the intellectual test performance of African Americans. *Journal of personality and social psychology, 69*, 797-797.

Siegel, M.A. & Ranney, M.A (2003). Developing the changes in attitude about the relevance of science (CARS) questionnaire and assessing two high school science classes. *Journal of Research in Science Teaching*, 40 (8), 757–775.

Schweingruber, H. A., Hilton, M. L. & S.R. Singer, Eds. (2005). America's Lab Report: Investigations in High School Science. National Academies Press.

Spradley, J. P. (1979). Chapter 4: Asking descriptive questions. In The ethnographic interview (pp. 78-91). Fort Worth: Harcourt Brace Jovanovich College Publishers.

Tan, E., & Calabrese Barton, A. (2007). From peripheral to central, the story of Melanie's metamorphosis in an urban middle school science class. *Science Education*, 92, 567–590.

Tan, E. & Calabrese Barton, A. (2010). Transforming science learning and student participation in sixth grade science: A case study of a low-income, urban, racial minority classroom. *Equity & Excellence in Education*, 43(1), 38-55.

Tucker-Raymond, E., Varelas, M. & Pappas, C.C. (2007) "They probably aren't named Rachel": Young children's scientist identities as emergent multimodal narratives. *Cultural Studies of Science Education,* 1(3), 559-592.

Varelas, M., Martin, D.B, Kane J.M. (2012). Content learning and identity construction: A framework to strengthen African American students' mathematical and science learning in urban elementary schools. *Human Development*, 55, 319-339.

Warren, B., Ballenger, C, Ogonowski, M., Rosebery, A. S., Hudicourt-Barnes, J. (2001). Rethinking diversity in learning science: The logic of everyday sense-making. *Journal of Research in Science Teaching*, 38(5) 529-552.

Wenger, E. (1998). Communities of practice: Learning, meaning, and identity. New York: Cambridge University Press.

Appendix 1: Pre Program Student Science Survey

<u>Directions</u>: Mark the box that best answers the following questions.

1. How did you find out about the Internship Program? (mark ALL that apply)

- ☐ Teacher
- ☐ Parents
- ☐ Friend
- ☐ Other (please describe)____________

2. Why did you decide to join the Internship Program this summer? (mark ALL that apply)

- ☐ Teacher encouraged me to join
- ☐ Parents wanted me to join
- ☐ I decided to join on my own
- ☐ Other (please describe) ____________

3. What is your favorite subject in school? (mark ONE)

- ☐ English/Language Arts
- ☐ Math
- ☐ Social Studies/History
- ☐ Science
- ☐ Foreign Language
- ☐ Other (please describe) __________________

4. Are you in sports or extracurricular activities? If so, which one(s)?

- ☐ Sports (list sport(s)) ____
- ☐ Extracurricular activities (e.g. clubs) (please describe)
  ____

5. Have you participated in any other science programs or activities outside of school (e.g. science
camp, science fair/club)?

- ☐ Yes (please describe) ________________________________
- ☐ No

6. What science classes did you take in middle/high school? (mark ALL that apply)

- ☐ Earth Science
- ☐ Physical Science
- ☐ Biology
- ☐ Chemistry
- ☐ Physics
- ☐ Environmental Science
- ☐ Other (please describe) _____________________________________

7. Are advanced science courses or AP (advanced placement)/IB (International Baccalaureate)
courses offered at your school?

- ☐ Yes
- ☐ No
- ☐ I don't know

7a. If YES: have you taken or do you plan to take an advanced science course?

- ☐ Yes (please describe) ____________________________
- ☐ No
- ☐ I don't know

8. How would you describe the type of student you are in school? (mark ONE)

- ☐ Excellent (all A's)
- ☐ Good (A's and B's)
- ☐ Average (mostly C's)
- ☐ Below Average (C's and D's)
- ☐ Far Below Average (D's and below)

9. What was your <u>science</u> grade this past school year?

- ☐ A
- ☐ B
- ☐ C
- ☐ Below C

10. Do you plan to take the PSAT or SAT?

- ☐ Yes
- ☐ No
- ☐ Not sure

11. What do you plan to do after high school? (mark ONE)

- ☐ Attend a four-year college
- ☐ Attend a community college
- ☐ Join the military
- ☐ Work full-time (not attend more school)
- ☐ Not sure

12. How far do you think you will go in school? (mark ONE)

- ☐ High school diploma
- ☐ Undergraduate college degree (Bachelors)
- ☐ Graduate school degree (Master's or beyond)
- ☐ Not sure

__Directions__: **Please answer the following questions to the best of your ability.**

1. **Some high school students have described science in the ways listed below.**

   Science is:
   - ☐ **Finding facts**
   - ☐ **Asking questions**
   - ☐ **Following steps of the scientific method**
   - ☐ **Doing experiments**
   - ☐ **Figuring out how things work**
   - ☐ **Memorizing information**
   - ☐ **Exploring the natural world**

Please explain your choice(s):

What else would you add to this list that isn't there? Why?

__Directions__:
How much do you agree or disagree with the followings statements about **uses for science**?

	Strongly Disagree	**Disagree**	**Not Sure**	**Agree**	**Strongly Agree**
Science can help me make better decisions in my everyday life.	☐	☐	☐	☐	☐
Science helps me understand more about world-wide problems.	☐	☐	☐	☐	☐
I can use the science I learn to help make my community better.	☐	☐	☐	☐	☐
The things I do in science class have nothing to do with my life outside of school.	☐	☐	☐	☐	☐
Science helps me to judge other people's points of view.	☐	☐	☐	☐	☐
Scientific research has nothing to do with local issues.	☐	☐	☐	☐	☐
I can use the science I learn to evaluate information in my everyday life.	☐	☐	☐	☐	☐
Findings from scientific research have nothing to do with my life.	☐	☐	☐	☐	☐
Learning science helps me understand about the environment.	☐	☐	☐	☐	☐
Much of what I learn in science is useful in my everyday life today.	☐	☐	☐	☐	☐
Scientists can make a difference in their community.	☐	☐	☐	☐	☐
I can use the science I learn to help solve environmental problems.	☐	☐	☐	☐	☐

Directions:
How much do you agree or disagree with the followings statements about **science in general**? (**mark ONE box in each row**)

	Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
Science is interesting to me.	☐	☐	☐	☐	☐
I am good at science.	☐	☐	☐	☐	☐
I only take science because it is a required course.	☐	☐	☐	☐	☐
Science is one of my best subjects.	☐	☐	☐	☐	☐
Science should be required in school.	☐	☐	☐	☐	☐
I have a hard time understanding science.	☐	☐	☐	☐	☐
I am a science-type person.	☐	☐	☐	☐	☐
I get good grades in science class.	☐	☐	☐	☐	☐
I can imagine myself as a scientist someday.	☐	☐	☐	☐	☐
People in my family encourage me to continue with science.	☐	☐	☐	☐	☐
Science just isn't for me.	☐	☐	☐	☐	☐
It is important for everyone to learn science.	☐	☐	☐	☐	☐
I could make a new discovery in science someday.	☐	☐	☐	☐	☐
I would like to study more science in the future.	☐	☐	☐	☐	☐
People in my family talk to me about science at home.	☐	☐	☐	☐	☐
I would like to have a job that involves science.	☐	☐	☐	☐	☐
Science class is easy for me.	☐	☐	☐	☐	☐
Other people think of me as a science-type person.	☐	☐	☐	☐	☐
My parents think it is important for me to learn science.	☐	☐	☐	☐	☐
Learning science is about memorizing information	☐	☐	☐	☐	☐

Directions:
How much do you agree or disagree with the followings statements about **scientists and the work of scientists**? **(mark ONE box in each row)**

	Strongly Disagree	**Disagree**	**Not Sure**	**Agree**	**Strongly Agree**
Scientists spend most of their time working by themselves.	☐	☐	☐	☐	☐
Scientists rarely make mistakes in their work.	☐	☐	☐	☐	☐
Scientists spend most of their time working indoors.	☐	☐	☐	☐	☐
I see a lot of people from my ethnic background working as scientists.	☐	☐	☐	☐	☐
I have role models in science who share my ethnic background.	☐	☐	☐	☐	☐

Directions: How much do you agree or disagree with the followings statements?

1. In order to do good work, scientists need to closely follow the steps of the scientific method.
(mark ONE box)

☐ **Strongly Disagree**
☐ **Disagree**
☐ **Agree**
☐ **Strongly Agree**

Please explain your answer (give an example if possible):

2. Everything in science textbooks is true. (mark ONE box)

☐ **Strongly Disagree**
☐ **Disagree**
☐ **Agree**
☐ **Strongly Agree**

Please explain your answer (give an example if possible):

3. Scientists rarely stray from their plan when they do experiments. (mark ONE box)

☐ **Strongly Disagree**
☐ **Disagree**
☐ **Agree**
☐ **Strongly Agree**

Appendix 2: Post Program Student Science Survey

Please complete the following survey. Please note that you can skip any question that makes you feel uncomfortable. You can submit the survey even if you do not complete all the questions.

Name ________________________
Grade (in fall 2012)_____________
School ________________________

<u>Directions</u>: Please answer the following questions to the best of your ability.

1. **Some high school students have described science in the ways listed below.** **<u>Mark the box or boxes</u> that apply most to how YOU think about science.**

   Science is:

   - ☐ **Finding facts**
   - ☐ **Asking questions**
   - ☐ **Following steps of the scientific method**
   - ☐ **Doing experiments**
   - ☐ **Figuring out how things work**
   - ☐ **Memorizing information**
   - ☐ **Exploring the natural world**

Please explain your choice(s):

What else would you add to this list that isn't there? Why?

How (if at all) are the ways you think about science different NOW compared to before you started the program?

Directions:
How much do you agree or disagree with the followings statements about **uses for science**? (**mark ONE box in each row**)

	Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
Science can help me make better decisions in my everyday life.	☐	☐	☐	☐	☐
Science helps me understand more about world-wide problems.	☐	☐	☐	☐	☐
I can use the science I learn to help make my community better.	☐	☐	☐	☐	☐
The things I do in science class have nothing to do with my life outside of school.	☐	☐	☐	☐	☐
Science helps me to judge other people's points of view.	☐	☐	☐	☐	☐
Scientific research has nothing to do with local issues.	☐	☐	☐	☐	☐
I can use the science I learn to evaluate information in my everyday life.	☐	☐	☐	☐	☐
Findings from scientific research have nothing to do with my life.	☐	☐	☐	☐	☐
Learning science helps me understand about the environment.	☐	☐	☐	☐	☐
Much of what I learn in science is useful in my everyday life today.	☐	☐	☐	☐	☐
Scientists can make a difference in their community.	☐	☐	☐	☐	☐
I can use the science I learn to help solve environmental problems.	☐	☐	☐	☐	☐

How are your ideas about uses for science different NOW compared to before you started the program?

My ideas about uses for science are:

- ☐ **Exactly the same now**
- ☐ **Mostly the same now**
- ☐ **Somewhat different now**
- ☐ **Completely different now**

Why? Please explain your answer:

<u>Directions</u>:
How much do you agree or disagree with the followings statements about **science in general**?
(**mark ONE box in each row**)

	Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
Science is interesting to me.	☐	☐	☐	☐	☐
I am good at science.	☐	☐	☐	☐	☐
I only take science because it is a required course.	☐	☐	☐	☐	☐
Science is one of my best subjects.	☐	☐	☐	☐	☐
Science should be required in school.	☐	☐	☐	☐	☐
I have a hard time understanding science.	☐	☐	☐	☐	☐
I am a science-type person.	☐	☐	☐	☐	☐
I get good grades in science class.	☐	☐	☐	☐	☐
I can imagine myself as a scientist someday.	☐	☐	☐	☐	☐
People in my family encourage me to continue with science.	☐	☐	☐	☐	☐
Science just isn't for me.	☐	☐	☐	☐	☐
It is important for everyone to learn science.	☐	☐	☐	☐	☐
I could make a new discovery in science someday.	☐	☐	☐	☐	☐
I would like to study more science in the future.	☐	☐	☐	☐	☐
People in my family talk to me about science at home.	☐	☐	☐	☐	☐
I would like to have a job that involves science.	☐	☐	☐	☐	☐
Science class is easy for me.	☐	☐	☐	☐	☐
Other people think of me as a science-type person.	☐	☐	☐	☐	☐
My parents think it is important for me to learn science.	☐	☐	☐	☐	☐
Learning science is about memorizing information	☐	☐	☐	☐	☐

How is your <u>interest in science</u> different NOW compared to before you started the program?

My <u>interest in science</u> is:

- ☐ **Exactly the same now**
- ☐ **Mostly the same now**
- ☐ **Somewhat different now**
- ☐ **Completely different now**

Why? Please explain your answer:

<u>Directions</u>:
How much do you agree or disagree with the followings statements about **scientists and the work of scientists**? **(mark ONE box in each row)**

	Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
Scientists spend most of their time working by themselves.	☐	☐	☐	☐	☐
Scientists rarely make mistakes in their work.	☐	☐	☐	☐	☐
Scientists spend most of their time working indoors.	☐	☐	☐	☐	☐
I see a lot of people from my ethnic background working as scientists.	☐	☐	☐	☐	☐
I have role models in science who share my ethnic background.	☐	☐	☐	☐	☐

How are your ideas about <u>WHO does science and the work of scientists</u> different NOW compared to before you started the program?

My ideas about <u>WHO does science and the work of scientists</u> are:

- ☐ **Exactly the same now**
- ☐ **Mostly the same now**
- ☐ **Somewhat different now**
- ☐ **Completely different now**

Please explain your answer:

<u>Directions</u>: How much do you agree or disagree with the followings statements?

1. In order to do good work, scientists need to closely follow the steps of the scientific method.
(mark ONE box)

- ☐ **Strongly Disagree**
- ☐ **Disagree**
- ☐ **Agree**
- ☐ **Strongly Agree**

Please explain your answer (give an example if possible):

2. Everything in science textbooks is true. (mark ONE box)

- ☐ **Strongly Disagree**
- ☐ **Disagree**
- ☐ **Agree**
- ☐ **Strongly Agree**

Please explain your answer (give an example if possible):

3. Scientists rarely stray from their plan when they do experiments. (mark ONE box)

- ☐ **Strongly Disagree**
- ☐ **Disagree**
- ☐ **Agree**
- ☐ **Strongly Agree**

Please explain your answer (give an example if possible):

THANK YOU VERY MUCH!!

Appendix 3: Pre Program Student Interview Protocol

Background

Why did you decide to join this program? What do you want to get out of it?

Where does science fit into your interests?
- *If interested*, how did you become interested in science?

Experience w/ Science

What science is:
Give me an example of a time that you felt good at science. Why did you feel good at it?
- Are there times when science has been hard for you? Why was it hard?

Describe the different kinds of science you do. What does it mean to do science:
- in school?
- outside of school?

- What do you think the science you do here will be like?
  - What do you hope to learn about science this summer from the program?

What did you like about "doing science"? Why?
- What did you dislike about "doing science"? Why?

[What makes science different from other subjects (e.g. Social Studies)?
- What make science, science?]

Give me an example(s) of a professional scientist(s) (someone who does science for a job)
- What types of things do you think professional scientists [*use ones they named*] do?
- Are these different from the science you described above for how YOU do science?

What types of skills/characteristics make the professional scientists [*use those mentioned above*] a "science person"?
- Do you think you are/could be a "science person"?
- How is what you envision the same of different from you?

[What types of skills do you think are important to "do" science (*refer to descriptions above*)?
- Which of these skills do you think you have already?]

Utility/Access
Do you think some kinds of scientific research are more important than others?
- If so, which ones?

Give me an example of something science can be used for?
- Do any of those uses apply to you/your life?

- Do you think everyone has the same access to science knowledge or research?

Does everybody need to know science or just certain people? Why?]

Nature of Science

-Scientists decided a few years ago that Pluto should no longer be considered a planet. Scientists and people have thought of Pluto as a planet for my whole life – it's even written in textbooks.

- How do scientists determine of something is true? (*How can they decide that Pluto should no longer be a planet?*)
- How does something become a scientific fact?
- What do scientists do to become sure about something?

- Do you think all of the information in science textbooks is true?

[- Do you think scientists ever make mistakes when doing science? Can you think of an ex?]

Identity

What are some words you'd use to describe or define who you are?

- How do you define yourself racially/ethnically?
- Is being ___(*ethnicity named*) an important part of how you define yourself?

Are there parts of you/your life that conflict with science or being interested in science?

- Do you see science as an important part of who you are? Why or why not?

Do you think being ___(*their ethnicity*) affects your experiences in science? If so, how?

Do you notice any racial differences (*use their race*) in science or w/ who is a professional scientists that you hear about?

- If so why do you think that is?
- Do you think certain groups of people are just better at science than others?
- Have you heard any other stereotypes about science?

[People are working to make the science work force more equal for everyone. Do you think it's important to have (*name their race*) people better represented in science jobs? Why?]

What types of things do you think would help get more (*name race*) involved with science?

Career/Future

Have you thought about what you want to do after high school?

Appendix 4: Post Program Student Interview Protocol

Experience w/ Science

**After participating in this program, have any of the following changed?
- your interest in science?
- your feelings about your ability to do science?

Give me an example of a time that you felt good at science this summer (during the program). Why?
- Are there times when science was hard for you this summer? Why was it hard?

Describe the ways you "do" science here (in the program)
- In class
- Doing research
- How is this different from the science you've experienced before?

What did you like about doing science here? Why?
- What did you dislike? Why?

**What do you think of science before this program? Has your idea of science changed because of your experience here?

Science Investigations

Tell me about the research project you did here. What are the main things you learned?
- How sure are you about your findings?
- How could you be more sure?

What are the most important things you learned about the **scientific research process from doing this project?
- Has it added to or changed your ideas about science?
- Do you think it's a good way to learn science?

**Do you think your research topic is important? Why?
- What can you do with the findings from your research?
- Did doing this project change your ideas about uses for science?

**Give me an example(s) of a professional scientist(s) you met this summer.
- What types of things does this person do?
- What skills/characteristics did they have that make them science people?

**Did you learn anything this summer that changed your idea of what professional scientists do?
- About who is or can be a professional scientist?

**Do you think you are/could be a "science person"? Why or why not? Do you want to be?

Nature of Science

*Describe in your own words what you think science IS.

- Where did you learn that?

Identity

Race & Science

**During pre interview you defined yourself as "X". What did you learn through this program (if anything) about:

- Being an "X" (e.g. African American) in science?
- About who does science?

Do you think being "X" impacts your experiences in science?

- Your ability to be good at science? If so, how?
- Have you learned anything in the program that helped you think about this?

**Do you think science can help you better understand what it means to be a person of color in our society – if so how?

- Have you learned anything in the program that helped you think about this?

** In Bio class, your instructor talked about relationships between health and race. She asked if you thought personal choice, race/gender, or environment impacted health the most.

- What was your take on this?

Do you notice any racial (*name race*) differences in who is a scientist? (*in pre you mentioned you noticed "x"*)

- If so why do you think that is?
- Do you think certain groups of people are just better at science than others?
- What other stereotypes have you heard about science?

**What types of things did you learn in the program (if anything) that might help get more (*name race*) involved with science?

Career/Future

Have you thought about what you want to do after high school?

Appendix 5: Scientist Instructor Interview Protocol

Experiences with Science:

Tell me about your experiences/pathway in science.
- How did you get interested in science?
- Were there certain people or experiences that helped you get involved with science?
- Do have friends/family that are involved with science or science-related careers?

**How do you think of or define science? Tell me what science means to you. Where did you learn that?

In what ways is science important to you personally? Do you use science in your everyday life outside work?

- How does science fit into who you are?

Nature of Science/Purpose of Learning Science:

What do you feel like you can do with science based on your own experiences?

*What skills do you think are most useful to be good at science?

Teaching Science
Why did you decide to become a mentor (project leader) in this program?

- What did you hope to learn through the experience?
- Did you receive any training to become a mentor (project leader)?

Tell me a little about the project that you did with the students. What were your goals?

**What do you think is most important for your mentees to learn about the process of science?

- About science in general?
- Why?

**What are the things you really emphasized during the project?

- HOW did you emphasize them?
- What did you DO?

[**Give me an example of how you taught them (*whatever mentioned above*) during their research project? - e.g. How did you teach them to analyze data etc?]

What lessons, if any, have you learned about how to talk to high schools students about science?

- What went well (things that you were most happy/excited about)?

- What were some challenges? Or what would you change next time?

What do you envision your mentees “doing” with science? (What are you goals for being a mentor?)

- What are the main things you want them to take away from this experience?
- Why?

Diversity & Science: *Questions such as this will be asked to understand how mentors view diversity and science.*

In the professional science community, do you notice disparities based on race/ethnicity? Gender?

- What meaning do you make of these disparities?
- Why do you think these disparities exist?

Do you think your own **race** has influenced your experiences in science – positively or negatively? Your **gender**?

- If so, in what ways?

How would you describe the population of students you work with in this program?

- How do you imagine their experience are similar/different from your own in high school?

Do you have experience working with students from these demographics?

- Did you receive any training about working with students who may have backgrounds very different from you own?

    - If so – what?
    - If not, do you think you should have? What would be helpful?

How (if at all) do you think the race/ethnicity of your mentees will affect their experiences in science?

- Is this something you think about?

Does race (or gender) play into your vision of how you mentor or what you emphasize?

- If so, HOW?

Thank you for your time! Do you have any questions for me

Appendix 6: Item #1 Scoring Rubric

Score	Explanation	Student Example Quotes
0	No response	
1	I don’t know	B/c you can work alone.
	Irrelevant/doesn't make sense	
2	Must follow methods in order	You can't just pop an answer to your head. You need to go in order.
	Methods are linear/done in order	No other other method has been proven to work better.
	Make mistakes if don't follow exact method	Because if you don't follow step something can go wrong…
	RIGID	
3	Follow steps, but SEMI rigid/linear; Yes & No (display struggle: no should follow AND no, don't have to)	It may not be follow exactly, step by step, but to a reasonable range
	a. Can make minor changes: tweak, slightly modify etc	Scientists need to follow it, but there can be some changes.
	b. Should follow but other options are possible	I think that it is necessary to follow the scientific method, but I believe that they can "tweak" it a little bit. The scientific method may not always solve problems and if it doesn't, they should go for a different method.
	c. can be variation, but indicate there is an order to follow	
	Don't have to follow, but WHY INACCURATE or VAGUE RESPONSE	
	SEMI RIGID; YES & NO	
4	Not always followed in order/not linear + science as iterative BUT NO WHY	I believe it depends on what kind of resaerch a scientist is doing. I believe the scientific method provides guidelines but can be rearranged or repeated at any given step of an experiment if needed.
	a. Mention science as iterative process (repeat some steps, go back, use findings to modify, use new methods)	Science is about finding new methods
	b. science as unexpected, discovery	

	c. create other methods	
	NO WHY (e.g. why you repeat, why use new methods etc) OR WHY INACCURATE	
	SCIENCE AS CHANGING/NOT STATIC	
5	Not linear/followed in order+ science=iterative/not static + WHY	Scientist need to follow important scientific procedures but there might be times when they might have to do their own procedures because there isn't a procedure to help them go around a problem they might in counter. They have to improvise sometimes to make their experiments work and have better results.
	WHY NOT LINEAR: results, data, obstacles/problem, find something new, improvise own methods	Science is all about discovery. It is important to note your methods and have a goal in sight, as a sort of validation for the purpose of your project. However, a hypothesis changes as you go along; you may have a certain expectation for your project, but it can change as you work with your samples.
	Iterative • scientists follow standards but doesn't have to be step by step sceintific methods • science not static/modify methods accordingly: things change, unexpected things happen, discoveries etc	

Appendix 7: Item #2 Scoring Rubric

Score	**Explanation**	**Student Example Quotes**
0	No response	
1	I don't know	"I am not sure"
	Irrelevant/doesn't make sense	
2	Don't have a plan, just wing it	"They might if any other topic interests them."
	It's up to them, change not systematic	
3	Never/cannot change plan	They stay to their method and plan until they finish the experiment.
	If change plan mess up/make mistakes	I don't think scientist go off there plan because they planned out on what they did and don't want to make mistakes.
	Not sure, but most likely stick to plan	I'm not sure but I guess most of them do.
	RIGID	
4	Change plans + NO WHY (vague WHY)	Scientists can change their plan as they go./I bet they change their plan all the time!
	Sometimes change plans (but not WHY)	Because they are usually on the same experiment threw out the time most of the time but they some times change.
	Have many plans - but NOT WHY	I think scientists make different plans and have back up plans also. So I disagreed because I feel that scientists have many plans. YEAH!
	Change plan - WHY INACCURATE (e.g. interest changes, feel like it) -NOT based in evidence	
	Change plans INACCURATE - WHY ACCURATE	
5	Change plans + WHY	Based on information gained, scientists may modify or expand their experiments to use this new data.
	Why = results, findings, data, new information, new methods	When they're in the process of completing their experiments, they could find something out that will make them change their plan.

	Why must be accurate (or=4)	
6	Change plans + WHY + Explicit: Nature of science is changeable/not static/unexpected	I believe that because science is not fully set in stone it is bound to change. For example, if a scientist studying shellfish discoveres a microbe on the shellfish, they may want to investigate and change their focus, or include the microbe as a central part of their investigation.
	Science Changes/Not Static = never know what you will find, discoveries made etc.	I find this to be inaccurate for the greatest discoveries are made unexpectedly and challenges had to be surpassed. Scientist need to create a different path when they confront an obstacle.
	Unexpected: can cause perspective/question to change, follow tangent, unexpected finding along way	In observing my mentor, I noticed she had to change around what she wanted to do for her experiment given different problems that arose. Her main goal remained the same, but the way she reached it changed.
	Gets as nature of science beyond WHY	
	SCIENCE IS NOT STATIC	

Appendix 8: Coding Scheme

Category of Practices	Category Description	Student Quote
RESTRICTIVE	Views of scientific practices that describe science as static, rigid, linear, ordered/prescribed, and known. Offers limited opportunity to contribute, participate. **RESTRICTIVE: SUBCATEGORIES**	
	Known Answer Exists Students express a view that the right or wrong answer exists. Aspects of the scientific research process can be right/wrong Right vs. wrong answer exists Aspects of the science process (e.g. hypothesis, results) can be right or wrong *No space to "mess up"*	(Results) "Say you mess up in the process and then in the end, like after 2 longs months of hard work your like the ***wrong results*** that you didn't want so it's like you get frustrated in a way, so idk, but yet again if you get the ***right results*** maybe it could be helpful in some way to other researchers/ if you get it in the end, if you get, if your ***hypothesis is correct***, then it's worth it in the end i guess." (PA, pre)
	Methods: Prescribed, Linear, Rigid Students describe methods used to conduct scientific research as rigid, linear and prescribed. Students express a view that there is one correct way to do things. Process as linear Prescribed, rigid, ordered Goal of scientific research process is pursuit of correct answer If mess up need to start over/do over again (rigid) so get correct answer *No space to "mess up"*	"They research, first, and its is it called a hypothesis or a thesis, so they first do their hypothesis, which they think oh this is works this way then they do a thesis and then, they do it several times and then other scientists do it several times and they gather information." (IT Pre, Redwood) "They like experiment and go I guess through the whole methods that they're supposed to go through." (LCV Pre) (Methods) Like maybe your hypothesis was wrong, and then so you have to ***do the whole process again,*** and come up with a new hypothesis and until you like get it right, your hypothesis correct some how, cause every time you do like a, science procedure, you have to, if you get, if your hypothesis is wrong you have to change the procedure every time, it takes various times (PA, pre) "I think that's why it takes so long. Because they have to go back and correct it (data). And if they mess up again, they have to ***do it all***

		over again to try to find a correct answer. (LC, Pre Bayside) If mess up need to start over/do over again (rigid) so get correct answer /"I think they should test the thing more than once, because if they did make a mistake on that one, they could see that the other ones ***got the same answers*** And be like.." oh I might have made a mistake on that." (Serena, Pre Intv, Westport)
	Science = facts Students describe science as a collection of facts. Results = facts Information = facts	"All of our results are just like little facts that we learn." (JG Pre)
	Superficial *(RELATIONAL: Self ←→ Scientist Practices;* *often = Inaccessible)* Students describe science in superficial, stereotypical ways. They express scientific research as involving equipment/technology that they don't have access to or doing things that are foreign to them (i.e. mixing chemicals). Science involves: Technology: High tech equipment, don't have access to Superficial: Chemical doctors	"White gowns and like, with like clipboards and like really high tech equipment and computers, and like people with glasses on and goggles and stuff." (MT, Pre) "Um, like chemical doctors with the glasses and lab" (JP, Pre) "I thought scientists were always in labs mixing chemicals." (FL)
	Power/Status *(RELATIONAL: Self ←→ Scientist Practices)* Students express power/status differential of scientists compared to other people – this power, high status allows them to DO certain practices (often connects to characteristics) Scientists can write formulas, write what they want in textbooks Need money and sponsors to do	"They just need to make up like formula. and not trying to being worried about it, whether, like they don't need to go up to like someone that's like above them, because they're already, the ones that are like smart./I guess that they're the smart ones (laughs), so they would need to gather a lot of information and then with the information make a conclusion" (LH, pre) "Well, first, you got to go to school. And then, get money, sponsor, and then actually do the research." (FL, pre)

	research	
COMBO (R & E)	Students express both restrictive and expansive views of scientific practices.	(Methods) "They just have to redo it or find a better way to do it" (CG, Pre) "Being able to question something and then finding the answer to it, but like not just one answer, like hella other answers to it." (MT, Pre)
EXPANSIVE	View of scientific practices that describe science as unknown, changing, messy, iterative process. **EXPANSIVE: SUBCATEGORIES**	
	Unknown/Find New Things Students' express a view of science as pursuit of the unknown; opportunity to find out something new. Results as unknown Discover new things Find something new Apply findings/k gained to figure something out	"Here more real life because it's actually outside in the field, and i guess, contr, finding something out that people ***don't really know*** about instead of like, doing a project in class, like people have done over and over and already know the answer to" (CG, Post) "I always thought of it as a possibility but i didn't know like how much of a possibility it was, that we could like discover new things". (OR Post) "At first I was just like oh it's chemistry and you just gotta know your elements and their properties but like from doing this research I've learned how to ***apply what you learn*** into like the real life and ***actually figure out like something*** (emphasis) using your knowledge of science" (PA, Post)
	Methods: Create/Multiple Ways A view of scientific methods as something scientists create and adapt to their research needs. Multiple approaches utilized and acceptable. Multiple ways Flexible Use different types/approaches Trial/error Mess around, experiment	"Experimenting and ***fooling around with things*** because I mean you're not going to find anything new without just kind of going for it." (OR, Pre?) "So instead of it being structured like this is step 1, step 2, step 3, there was like step 1, step 2, go! and so you know we all kind of, we just naturally, started thinking like oh we should do this for this or, we all just kind of got to come up with ideas. (OR, Post) "Most scientists conduct research in ***different ways*** but it's all research." (CG, Post) "I thought it was more like oh you're just gonna use this method to do this and that, like

		they ***were told what to do***, and then they'd do it/from like seeing (emphasis), how like N researches, and like other mentors research, like ***it's the research is on them, they have to find like scientific methods to try to figure something out***, it's not like everythings like oh this is how you're gonna do it like this and that, its more like independently, like they have to figure out how to do something, ***they have to write their own procedure***./Every researcher does different methods, it's not always going to be the same." (PA, Post) "R like does her own thing and over there they kinda follow the textbook, so, I mean she could always ***try new things*** here to come out with different results, but over there it's like we have to follow textbook " (JG, Post)
	Messy/Problem Solving/Path Changes a) A view of science as messy, where unexpected things happen, things don't work out, problem solving is part of the process. Scientists need to adapt/adjust to the unexpected. b) A view of science as following tangents, unexpected observations lead to new pathways of exploration. Unexpected things happen Process is messy Science involves problem solving Things don't always go as planned New directions/follow tangents **Space to" mess up" and figure things out**	"And i've seen some of the scientists here, they're like 'oh my god this happened' or 'wow. i found this', or 'what is this'? They don't even know, they're like '***oh my god this happened'*** or 'my salinity changed', …..I just think that scientists learn from their like their imperfections to make you know, hypothesis… I mean to like come up with their solutions to what they're doing/Try to like do things as perfect as you can, because i mean you're passionate about a research and really want it to go well but sometimes ***the data changes and you're like what***?"(IT, Post) "I guess, patience, because like, they've been talking about how, because they all go out and plant umm seeds outside in the field, and sometime its not, it's dry, it's a dry season so they have to redo it. so like keep working at it and patience…and I saw it actually happening not just think about it, but saw it, and like (CG Post) "Cause if something goes wrong its like you have to figure out how to solve it and go around it and continue with the research" (PA, Post) "Also observations because, cause I seen them like, look, like start a project but then something happens, so like, it changes their

		project in a way"/maybe like, their researching on something so they're following a certain path, like instructions or something, but then like, I guess maybe, like they see something else like maybe with like S's she was thinking that it was the scotch broom like killing the trees but it's actually like killing the microrhaizze affecting the trees. (CG, post) "(It's) good for you to think of other opportunities. You know you might end up going on a completely different path because of it and it could end somewhere really good." (OR, Post)
	Iterative/Analytic (sense making) a) View of scientific practices as connected, iterative, how one practice functions in relation to another (e.g. observations lead to research questions). b) Offer an analytical view/understanding of the purpose/function of different practices. Sense making around practices Practices as connected New meaning of purpose of practice Analytical aspects of practices as connected (e.g. data is something you make sense of) Research as iterative process	So then, those observations would help them come up with a result, kinda thing (CG, Post) "You can even hypothesis well in this 10 years the nitrogen of carbon ispotopes will increase or decrease depending on what you already know so you can keep on experimenting with it." (PA, Post) "This was unfiltered data (shows me plot again) that we use, and after running it, running it to a, through a 2, to 8 ah hertz, ah filter we have this and you can see like all this, like the things that spike up, that's tremor, and the levels go from 0 to 400, which is a very small margin compared to the unfiltered data, which goes from 0 to 2000"..."it filters, it takes away all the noise, and all the, or big earthquakes, and just leaves the tremor behind" (RM, Post) "Getting results from picking all those forams under the microscope, so I mean it's something you have to do to get the results" (IT, Post)
	Share Ideas: Collaborate The science process involves collaboration, multiple perspectives are beneficial Multiple perspectives	"I'm guessing some scientists come together and talk about what they're researching…they might give other people tips." (VR, Pre) "We all just kind of got to come up with ideas and collaborate and it was a lot of, it was a pretty different process than the kind of things we do in school and stuff like that." (OR Post)
Neither R or E on Own	**Specialized** *(RELATIONAL: Self ←→ Scientist Practices)*	"There was like other people that had like really high expectations of us. Like I noticed that they were like having that big expectation

	(Exclusionary or Inclusionary based on ID factors) Students express a view that there are certain scientific practices that are necessary to be good at in order to be a scientist/fully participate or to do science well. Need to memorize material/know content Language: complex, big word Use complex formulas science Demonstrate knowledge in certain contexts/ways (present, debate)	of us out there, like when we were presenting. And we were like right there!"/ I was like, 'oh my god!' And then…their attitude was more like, just rougher against us. (LV, post)