The Impacts of Informal Science Education on Students’ Science Identity and Understanding of Science Inquiry

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Abstract

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This study examines the development of science identity and understanding of science inquiry among a sample of high school and college-aged students of color, a majority of whom were female, during a yearlong informal science research internship. Formal science settings often have structures that form barriers between students and science, by removing these structures, informal science settings transform the science process into a relevant learner-centered experience. Informal science education (ISE) programs have been commonly studied for simple affective outcomes. These programs have been shown to improve interest, confidence, and motivation in science in addition to improving general attitudes toward science. However, the outcomes of ISE programs on deeper affective outcomes such as identity have yet to be thoroughly explored. Additionally, research on the impact these programs have on cognitive growth and science inquiry development is extremely limited. With the importance of ISE programs becoming increasingly recognized, the need to develop a deeper understanding of the program impacts is imperative. Lastly, the impact these programs have on students of color is of keen interest as ISE programs show potential for combatting their persistent underrepresentation in science.

Guided by Carlone and Johnson’s (2007) science identity framework, this study utilized a case-study approach, which included a mixed-methods data collection process. Observations and semi-structured interviews were used in conjunction with an open-response questionnaire and quantitative survey to analyze the interactions within the
informal science setting more deeply. Findings showed that participants experienced a positive statistical change in their understanding of science inquiry and science identity. Qualitative analysis of the data revealed two over-arching themes of the research experience: (1) Students’ Self-Development; and (2) The Learning Environment. Lastly, structural implications, such as program duration and same-race mentorship, are discussed as methods for retaining students of color in science.
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Dedication

To all the students who ever felt marginalized or unheard. Stay curious, stay brilliant; your voices and thoughts matter - this is for you.

And

To my grandfather. While I was not lucky enough for you to see this day, your wisdom, strength, and unconditional love guided me to it. Pedar Joon, not a day goes by that you are not loved, cherished, and missed; may your presence always be felt and your memory never fade.
CHAPTER I

INTRODUCTION

A fundamental goal of most societies is to foster individuals with the desire, capacities and tools necessary to fulfill their quest for knowledge and engagement, this includes the exceedingly important field of science. Science education is essential in supporting the ability of adults to apply science knowledge and skills to everyday decision-making (Crowell & Schunn, 2016). It is also necessary to meet the demand of jobs in the expanding field of Science, Technology, Engineering, and Mathematics (STEM) (Estrada, Woodcock, Hernandez, & Schultz, 2011), a field that continues to be disproportionately dominated by White males (National Science Board [NSB], 2015). To illustrate the lack of diversity in STEM, Landivar (2013) noted that while Whites make up approximately 65% of the country’s population, they account for about 71% of all conferred STEM degrees. Similar in this overrepresentation, Asians make up approximately five percent of the population but represent 15% of STEM professionals. Severe underrepresentation can be seen in Hispanic and African American populations. Hispanics represent approximately 14% of the population, yet have earned only seven percent of the awarded STEM degrees. African Americans comprise about 15% of the U.S. population but have received only 6% of all conferred STEM degrees. If the numbers are separated by gender, we see the disparities continue. In 2012, males earned significantly more baccalaureate degrees than their female counterparts in computer science (81.8% to 18.2%), mathematics (56.9% to 43.1%), physical science (59.8% to 40.2%), and engineering (80.8% to 19.2%) (NSB, 2015). The trend continues in the workforce, with women making up only 28% of the science and engineering workforce (NSB, 2015). If this underrepresentation is further distilled by gender and ethnicity, the numbers continue to decline. In 2016, only 12.6% of bachelor’s degrees in science
and engineering were awarded to female students of color\(^1\) (National Science Foundation [NSF], 2019). Less than eight percent of master’s degrees and a mere five percent of doctorate degrees in science and engineering were awarded to women of color\(^2\) (NSF, 2019).

Underrepresentation continues in the labor force. Underrepresented groups make up a significantly smaller percentage than their White counterparts, 13% to 71%, respectively (NSB, 2015). African Americans and Hispanics compose less than eight and nine percent, respectively, of the science and engineering workforce (NSB, 2015). Separated by gender and ethnicity, these women make up a small fraction of the science and engineering workforce (NSB, 2015). White women constitute approximately 20% of the science and engineering workforce, and women of color represent less than 10% (NSB, 2015). These participation gaps illustrate the increasingly significant unbalanced representation based on gender and race in STEM degrees and work.

This data becomes even more important when it is situated in the greater demographic makeup of the United States, and how that makeup is projected to change over the next thirty years. In 2018, Non-Hispanic Whites made up 60.5% of the total population, 18.3% were Hispanic, and 12.5% were Black (The Brookings Institution, 2018). New Census population projections confirm the importance of racial minorities in the nation’s future as they counter an aging, slow-growing White population. In 2060, the Non-Hispanic White population is projected to decrease to 44.3%, while the Hispanic population is projected to increase to 27.5%. The Black population is projected to only slightly increase by about one percent, to 13.6% (The Brookings Institution, 2018). It is imperative that our education system and workforce reflect these

\(^1\) Students of color is used in place of underrepresented minority or minority. Minority, as defined by the National Science Foundation, includes African-American, Hispanic, Native American/Alaskan Native, and Pacific Islander.

\(^2\) Women of color is used in place of female underrepresented minorities or minority women. Minority women, as defined by the National Science Foundation, includes African-American women, Hispanic women, Native American/Alaskan Native women, and Pacific Islander women.
demographic changes, as all segments of the U.S. population must be tapped to meet the demands of a growing STEM workforce; one million more STEM professionals are needed over the next decade for the United States to retain preeminence in science and technology (President’s Council of Advisors on Science and Technology [PCAST], 2012). Efforts must be placed on improving science education and redefining science as a field relevant and of interest to all individuals.

Rationale

The greater research problem targeted by this study is the underrepresentation of people of color in science. While there have been advances in degree completion rates and workforce involvement (American Institutes for Research [AIR], 2012), much remains to be accomplished. As a result, significant attention has been continuously devoted to the recruitment and retention of underrepresented students in science or STEM, because White and Asian students are still disproportionately represented in these fields. The challenges experienced by students of color within science classrooms have been consistently recognized, with students viewing science as irrelevant and alienating (Atwater, 2000; Carlone & Johnson, 2007; Chang, Sharkness, Hurtado, & Newman, 2014; Malone & Barabino, 2009; Zacharia & Calabrese Barton, 2004). As a result, learners who start out motivated in science, based on interest and other persistence factors, shy away from science (Maltese & Tai, 2011). To combat this deidentification with the field, identity theory offers a lens to study the problem of low engagement and persistence for students of color. Most women and students of color have foreclosed science identities, further distancing them from science and any science-related field (Brown, Henderson, Gray, Donovan, & Sullivan, 2012; Hazari, Sadler, & Sonnert, 2013; Krogh & Anderson, 2013). While traditional science classrooms are teacher-focused and standards-driven in a way that forms barriers for
students of color to get engaged and stay engaged with science, informal science experiences are designed in a way that is relevant and motivating for all learners.

Informal learning environments provide countless opportunities for social participation (Dierking, Falk, Rennie, Anderson, & Ellenbogen, 2003; Falk & Dierking, 2000; National Research Council, 2009), which can in turn lead to the construction of group and individual identity. Informal experiences within science are also one of several forms of “science capital” that fosters motivation and the ability to excel and persist in science (DeWitt & Archer, 2015). These informal settings are categorized as learner-motivated, voluntary, contextual, and guided by learner interest (National Research Council [NRC], 2009). Because of these defining characteristics, experiences in informal science education (ISE) have been shown to increase attitudes and interest of students toward science (Ferreira, 2001; Hofstein & Rosenfeld, 1996; Jarvis & Pell, 2002, 2005; NRC, 2009; Zacharia & Calabrese Barton, 2004). However, some previous research on the impacts of informal science experiences are limited to examining simple affective outcomes, and deep constructs such as identity development are scarce. The purpose of this study is to explore informal science experiences for their potential to impact learners on a deeper level, by fostering a positive science identity, which in turn will define the learner’s science orientation as part of who they are and who they wish to become. The importance of this impact is magnified for students of color (Aschbacher, Li, & Roth, 2010; Carlone & Johnson, 2007; Hazari, Sonnert, Sadler, & Shanahan, 2010; Watkins & Mensah, 2019).

Research Questions

The potential for ISE spearheaded this study’s examination of a yearlong informal science internship. Participants of the BioBus internship were high school and college-aged
students, majority of whom were women of color. This study consisted of three research questions, and their corresponding sub-questions, all of which were centered on youth’s experiences in a yearlong BioBus research internship.

1. How do participants (whole group) experience a yearlong informal science education research internship?
   - Is there a statistically significant change in students’ mean Views About Science Inquiry (VASI) score over the yearlong internship?
   - Is there a statistically significant change in students’ mean Science Identity Survey (SIS) score over the yearlong internship?

2. How does an informal science education research internship foster science identity among participants of color?

3. How do three female participants of color experience a yearlong informal science education research internship?

Organized of the Dissertation

This dissertation tackles the continuous problem of racial and gender underrepresentation in science. A shifting demographic coupled with an expanding science and technology market, highlight the urgent call for equity in science. Chapter I presented the rationale for this study and the research questions.

In Chapter II, a review of the literature is presented in addition to the theoretical framework of this study. Informal science education is introduced, in addition to how these experiences have been evaluated thus far. Science identity and science inquiry are then discussed as they relate to this study. Throughout the literature review an emphasis is placed on students of color. The way in which these learners identify with science is of keen importance for this study.
The science identity framework that guides the study is presented in detail. Along with factors of social constructivism as they are relevant to the context of this work.

In Chapter III, the research methods are presented. The context, setting, and participants are described and introduced in detail. The research design is described primarily as case study, using mixed-methods for data collection. The quantitative instruments are discussed in addition to the qualitative methods that were undertaken to provide the rich detail associated with case study methodology. Methods of analysis for both quantitative and qualitative data are presented in addition to a study timeline, which documents the points of data collection.

Then, in Chapter IV the findings are presented. The findings are presented by research question and their corresponding sub-questions, in sequential order. The first presentation of the findings looks at the whole group of participants (Research questions one and two), while the second presents the themes that emerged from three, selected female individuals (Research question three). Findings are presented in detail for the greater research question and corresponding sub-questions.

Lastly, Chapter V concludes this dissertation. Major findings are highlighted with a discussion of the implications regarding informal science education, science identity, and students of color in science education. The chapter addresses limitations of the research and culminates with proposed areas for future studies.
CHAPTER II

REVIEW OF THE LITERATURE

This chapter provides a review of the literature significant to construct the study’s foundation. The literature review begins with an overview of ISE, describing settings, curricula, and activities that define informal learning, as well as how informal learning is evaluated. The two evaluation strands significant for this study, science inquiry and science identity, are then discussed. Science identity is discussed from the perspective of students of color. A major intention of this study was to understand the impacts ISE has on the science identity of these students. In order to understand the impacts of ISE, the theoretical framework of identity theory was primarily used to ground this study and understand the impacts on students who participated in this study. Aspects of social constructivism are also discussed as they are relevant to the context of the study.

Informal Science Education

Science learning can occur in both formal and informal settings. Formal science learning is one that occurs within a school context, while informal learning, broadly defined, is learning that occurs outside a traditional school setting (Falk & Dierking, 1992). However, because the definition offered by Falk and Dierking is quite broad, other scholars have provided descriptors to further clarify informal science education. Hofstein and Rosenfeld (1996) defined informal science learning environments as various out-of-school contexts such as museums, zoos, after school programs and clubs, and different science media. Learning that occurs in informal science environments is regarded as occurring outside of the traditional classroom, not being primarily part of school use or any school curriculum, and voluntary (Crane, Chen, Bitgood, Serrel, Thompson, & Nicholson, 1994). Furthermore, the National Science Foundation (1997) described
ISE as voluntary, self-directed, and lifelong. Programs that support informal science education are described as encouraging learning that was

Motivated by intrinsic interests, curiosity, exploration, manipulation, fantasy, task completion, and social interaction. This informal learning can be linear or nonlinear and often is self-paced and visual- or object-oriented. (National Science Foundation, 1997, p. 8, NSF #97-20)

The most common forms of ISE are, everyday learning, designed environments, school-based field trips, and community-based programs. The most informal type of learning is everyday learning, which includes a range of experiences that occur over a learner’s lifetime (Fenichel & Schweingruber, 2010). It includes, but is not limited to, family discussions, reading books or magazines, browsing the Internet, watching television, etc. (Fenichel & Schweingruber, 2010). Thus, in terms of science learning, everyday learning can be a student explaining to their parents what they learned in science class. Second, designed environments, are the most studied informal learning environment. They include museums, science centers, botanical gardens, zoos, planetariums, etc. The experience of the learner is guided by exhibits, artifacts, and media; however, the nature of the interaction is ultimately driven by the learner (NRC, 2009). Free-choice learning is the common framework used to analyze this type of informal learning.

Compared to everyday learning and designed environments, school-based field trips and community-based programs are the more structured forms of informal learning. School-based field trips are related to ISE as they are trips arranged by a school where students can visit a place where content materials can be observed and studied directly (Krepel & Durall, 1981). Field trips often take place in flexible environments that provide more opportunity for student voice and student learning than the traditional classroom setting (Hofstein & Rosenfeld, 1996).

Community-based programs are often referred to as semi-formal experiences. This type of optional science learning has a number of characteristics common with formal school
learning. The common forms of semi-formal experiences are after-school discovery programs, science camps and internships, and career programs (Crane et al., 1994). Discovery programs are after-school clubs that prioritize science engagement and offer hands-on science experiences (Crane et al., 1994). Summer, weekend, and after-school camps have pre-planned, structured activities that learners are expected to complete. These informal learning experiences are referred to as semiformal because of the structure that is built into the programs. Lastly, career programs are more extensive forms of informal learning that are designed as support systems to ensure students stay in the scientific pipeline (Crane et al., 1994). These programs have frequent participation as well as activities and strategies for mentoring and preparing participants for science careers (Crane et al., 1994). Generally, activities include engaging learning in authentic science with scientists and providing enrichment programs for diverse students (Crane et al., 1994; Rahm, 2012). The informal science program in this current study mostly resembles a community-based program because learners voluntarily applied to the internship where they participated in experiential science research alongside scientists.

**Evaluation of Informal Science Education**

The United States NRC Committee report: *Learning science in informal environments: People, places and pursuits* (NRC, 2009) places great importance on informal learning practices, arguing that they are critical for students’ science skill development and holistic understanding of the natural world. Research has highlighted the various impacts informal science education has on learners, such as increasing scientific reasoning ability, increasing science interest, valuing science for society, and developing positive attitudes towards science (NRC, 2009). With the outcomes of informal science education being wide-ranging, several institutions have worked to develop, improve, and document the goals of informal science learning.
The NRC Committee on Learning Science in Informal Environments developed and published six interrelated aspects of science learning that acknowledge the holistic understanding of science that comes from ISE, i.e., knowledge beyond merely understanding the content. These six “strands of science learning” became a framework that articulates the science-specific goals and capabilities of informal science learning, they are: (1) experience excitement, interest, and motivation to learn about phenomena in the natural and physical world; (2) come to generate, understand, remember, and use concepts, explanations, arguments, models and facts related to science; (3) manipulate, test, explore, predict, question, observe, and make sense of the natural and physical world; (4) reflect on science as a way of knowing; on processes, concepts, and institutions of science; and on their own process of learning about phenomena; (5) participate in scientific activities and learning practices with others, using scientific language and tools; and (6) think about themselves as science learners and develop an identity as someone who knows about, uses, and sometimes contributes to science.

Although these six strands provide a cohesive framework of the goals of informal science education, it is difficult to evaluate success in these informal learning environments. One of the cornerstones of informal learning is the absence of standardized testing, the most common instrument used to evaluate formal learning. While it is important to restrict the use of standardized testing in informal learning, as it is at odds with the learning that characterizes informal education, it is still necessary to evaluate the impacts informal science education has on its learners. However, despite the consensus on the importance of measuring learning outcomes, the field struggles with theoretical, methodological, and practical aspects of measuring learning outcomes (NRC, 2009). This is due to a plethora of factors ranging from the diversity of informal learning environments to the leisure nature of informal learning, which make following up with
participants, arranging for pre- and post-measurements, etc., especially changing (NRC, 2009). It is essential that researchers develop methods of measuring the impacts of informal learning, especially given the recent emphasis put on its importance.

This dissertation focuses on Strand 3 and Strand 6 of the NRC Report (2009) and addresses the suggestions for assessing these strands. Strand 3 focuses on the activities and skills of “doing science” (NRC, 2009, pp. 44). The outcome involves skills necessary to practicing science inquiry and successfully navigating through life (e.g., looking through nutrition labels to make healthy food choices or understanding the impact of decisions related to the health of the environment). The science inquiry skills outlined by Strand 3 include posing and answering questions, making predictions based on data, and generating and explaining evidence (NRC, 2009). These ideas can be communicated through modes of informal learning. However, assessing this type of learning is generally challenging for most informal settings due to the inability to gather “pre” data for use in pre- and post-testing. Fortunately, because of the nature of the yearlong internship and the continuous involvement of the participants, I was able to collect not only “pre” data but “mid” and “post” data as well, which is generally used to measure learning over an extended period of time. Observations are used to assess Strand 3 (NRC, 2009), and were used in the study to assess both Strands.

Strand 6 (“think about themselves as science learners and develop an identity as someone who knows about, uses, and sometimes contributes to science”) is a challenging yet necessary goal in science education. Creating a welcoming, authentic science-learning environment has proven to be an arduous task. The pervasive white, male-dominated representation of science has ostracized many from the field, specifically women of color, who do not sense a feeling of belonging in the sciences (Mensah & Jackson, 2018; Rosa & Mensah, 2016). Because Strand 6
of the Report (2009) is looking at identity, self-reported techniques are appropriate. Ethnographic methods involving surveys, interviews, analysis of learner’s artifacts, and self-reports can paint a holistic picture of the effect informal learning has on identity (NRC, 2009). The following sections delve deeper into the constructs defined in Strands 3 and 6, (science inquiry and science identity, respectively), describing the importance of them generally, and then specifically for science students of color.

**Science Inquiry**

The term “inquiry” is one that is frequently used in the field of science education. While the importance of scientific inquiry is widely recognized, it is a term that is often used in a variety of ways (Bybee, 2000). This section begins with the varying views of inquiry as defined by existing literature and reform documents, then narrows the definition for the purpose of this study.

The National Science Education Standards (NRC, 2000) divided inquiry into three distinct areas: content, process, and a teaching method. This categorization is frequently seen in existing literature as well. Bybee (2000) published two categories: inquiry as content and teaching by inquiry. Similarly, Anderson (2002) breaks down inquiry into three components--science as inquiry, learning as inquiry, and teaching as inquiry. Science as inquiry is the study of natural phenomena through inquiry, learning as inquiry is the hands-on approach to learning, and teaching as inquiry describes the pedagogy enacted by teachers to aid students in understanding scientific ideas (Anderson, 2002). For the purposes of this study, the term ‘science inquiry’ refers to “learning as inquiry”, or the hands-on, active process of learning often at the forefront of informal learning environments.
In 2012, the NRC developed a special committee (The Framework Committee) to develop overall guidelines for a complete revision of the national K-12 science education standards. The Framework Committee articulated a new vision that intertwined scientific practices, crosscutting concepts’, and disciplinary core ideas. These form the foundation for the Next Generation Science Standards (NGSS) (Next Generation Science Standards [NGSS] Lead States, 2013). Within this framework, the first dimension refers to the scientific practices commonly used by scientists, with an added engineering practice aspect. The second dimension emphasizes concepts with applications across all science areas. Lastly, the third dimension involves the most basic and current scientific knowledge K-12 students are expected to know.

The NGSS (Achieve, Inc., 2013) and the Framework for K-12 Science Education (the Framework) (NRC, 2012), further complicate inquiry by giving preference to the term ‘science practices’ rather than ‘inquiry’, stating, “we use the term ‘practices’ instead of a term such as ‘skills’ to emphasize that engaging in scientific investigation requires not only skill but also knowledge that is specific to each practice” (p. 30). Thus, both the NGSS (Achieve, Inc., 2013) and the Framework (NRC, 2012) highlight the importance of both “skills” of inquiry and “knowledge about” inquiry. While the two go hand-in-hand, implicitly assuming that doing inquiry will automatically develop students’ understanding of the inquiry process is invalid (Abd-El Khalick & Lederman, 2000; Lederman & Lederman, 2012; Metz, 2004). Rather, explicit instruction on the knowledge that is specific to each inquiry practice is necessary to develop students’ understanding of science inquiry (Schwartz, Lederman, & Crawford, 2004). An example illustrating this tension is often encountered in science classrooms, when students conduct scientific investigations or, in general, “do” science inquiry. Frequently, this is assumed to develop students’ knowledge about science inquiry (Lederman, Lederman, Bartos, Bartels,
Meyer, & Schwartz, 2014; Sadler, Burgin, McKinney, & Ponjuane, 2010); however, the problematic nature of this presumption is assuming that asking students to control for variables (a common undertaking in “doing” science inquiry) means they understand how this process relates to the practice of doing research or scientific design (Lederman et al., 2014).

Science Inquiry and Informal Science Education

Learners in informal settings are regularly involved in inquiry-based active learning that focus on critical thinking and problem-solving tasks (Wong & Hodson, 2009). However, studies on cognitive development of learners in informal environments are geared towards science concepts and facts (Gerber, Cavallo, & Marek, 2001; Newell, Zientek, Tharp, Vogt, & Moreno, 2015; Quigley, Pongsanon, & Akerson, 2010); even so, these findings to date are limited and relegated generally to museum learning. For example, Callanan, Cervantes, and Loomis (2011) found that children increase their vocabulary and reasoning skills when learning in a ‘museum family’ with their own family.

Although informal science environments are increasingly inquiry-based, as previously noted, the assumption that students who engage in inquiry will develop an understanding about inquiry is false. To this point, an investigation of an eight-week summer science camp of high school students in a university research lab setting found that despite being involved in authentic research, learners’ naïve understanding of science inquiry persisted (Bell, Blair, Crawford, & Lederman, 2003). Even though the students were involved in diverse methodologies including experimental and non-experimental designs, 70% of participants expressed views of a single scientific method, both before and after the science camp. Studies focused on science inquiry skill development (such as, there is no single set of steps followed in all investigations) in informal settings are extremely limited. The dearth in the literature in addition to knowing it’s
false to assume that students engaging in science inquiry will develop knowledge about science inquiry (Lederman et al., 2014; Sadler et al., 2010), highlight the importance of studying students’ science inquiry development in ISE settings. It is time to go beyond some of the established approaches of assessing learners’ knowledge of isolated facts and explore the deeper cognitive outcomes of understanding science inquiry.

Eight interrelated components of scientific inquiry have been suggested by Lederman et al. (2014) as both reflective of authentic science work and developmentally appropriate for K-12 students. These components were informed by and based on current education reform documents (NGSS Lead States, 2013; NRC, 2000, 2012). The accumulated information published on the “practices” of science inquiry and their description served as a conceptual framework of science inquiry that guided this study. They are:

1. Scientific investigations all begin with a question and do not necessarily test a hypothesis.
2. There is no single set of steps followed in all investigations (i.e., there is no single scientific method).
3. Inquiry procedures are guided by the question asked.
4. All scientists performing the same procedures may not get the same results.
5. Inquiry procedures can influence results.
6. Research conclusions must be consistent with the data collected.
7. Scientific data are not the same as scientific evidence.
8. Explanations are developed from a combination of collected data and what is already known.

Although science inquiry skills are encouraged in formal and informal settings as main “strands” of science learning (NRC, 2012), the literature on science inquiry is dominated by classroom-based inquiry (Capps & Crawford, 2013). Research that supports the use of inquiry-based instruction ranges from positively influencing student achievement (Endreny, 2010) to
improving students’ knowledge, attitudes, and overall position towards science (Doppelt, Mehalik, Schunn, Silk and Krysisnki, 2008; Rivera Maulucci, Brown, Grey, & Sullivan, 2014).

Conversely, there is some literature that leads to inconclusive results on inquiry-based teaching. For example, a study of an inquiry-based curriculum in a large urban school district by Borman, Gamoran, and Bowdon (2008) found no major effects on overall student achievement. The study contrasted the same curricula in (a) schools randomized to receive teacher development sessions targeted to coach and mentor inquiry-based teaching with (b) schools offered curricula with no professional inquiry-based teacher development. The findings compared the exam results of 76% of students in control schools (3,091 of 4,016) and 79% of students in treatment schools (3,555 of 4,503). The statistically significant negative estimate of the treatment relative to the control (negative .05) translated into an average five percentage point advantage for control schools. This is not to discredit the importance of science inquiry; inquiry-based instruction that fosters more genuine scientific practices such as exploration, using and analyzing data, and drawing conclusions are skills not only essential to the scientific community but to the global community. However, with informal venues offering inquiry-based experiences, it is time for researchers to explore these environments more deeply and to document the impact they have on learners’ understanding and development of science inquiry.

Science Identity

Just as identity is a fluid and continuously evolving construct, science identity can also change and evolve over time. Students endlessly navigate through societal factors that have the potential to support or degrade their science identity (Aschbacher et al., 2010). Science identity, a non-cognitive measure, explores the ability for a person to think of him or herself as a science learner. A noteworthy distinction in science identity is “doing science” and “being a scientist”
while students may enjoy science, they may not necessarily associate themselves as being a scientist (Archer, Dewitt, Osborne, Dillon, Willis, & Wong, 2010; Fraser & Ward, 2009). This negotiation of how students perceive themselves and are perceived by others is at the core of identity research. This construct of recognition is explained by Carlone and Johnson (2007), “One cannot pull of being a particular kind of person (enacting a particular identity) unless one makes visible to (performs for) others one’s competence in relevant practices, and, in response, others recognize one’s performance as credible” (p. 1190).

The science identity framework recommended by Carlone and Johnson (2007) was developed from research done with underrepresented, female college students in science. This framework includes three interrelated components of science identity—competence, performance, and recognition (Figure 1). Competence is defined as the “possession” of science content, skills, and practices. Competence leads to performance, which is defined as the social performances of scientific practices, such as using scientific tools and engaging in scientific discussions. Lastly, recognition is defined by the internal and external recognition as “a science person”. Moreover, keeping in mind that science identity is an evolving construct that is different for different groups of students with different sets of experiences and contexts (Gilmartin, Li, & Aschbacher, 2006), Carlone and Jonson’s (2007) Science Identity Framework acknowledges that other aspects of one’s identity, such as one’s racial/ethnic identity or gender identity, also influences their academic identity.
Figure 1

Model of Science Identity Guiding the Framework of This Study


In science and engineering, using science identity as a lens and theoretical grounding offers a complete and holistic understanding of students’ nuanced trajectories (Herrera, Hurtado, Garcia, and Gasiewski, 2012). Existing literature has identified science identity as a salient component related to student-learning outcomes (Aschbacher et al., 2010; Kane, 2012, 2015), persistence in science (Chang, et al., 2014; Martin-Hansen, 2018; Rosa & Mensah, 2016), as well
as intention and decision to pursue a science career or graduate science program (Estrada et al., 2011; Rosa & Mensah, 2016; Stets, Brenner, Burke & Serpe, 2017; Vincent-Ruz & Schunn, 2018). Moreover, a person’s identity as a scientist has been linked to positive outcomes in persistence in the science academic pipeline for underrepresented students (Aschbacher et al., 2010; Hazari et al., 2010; Watkins & Mensah, 2019). Given evidence that Black, Hispanic, and Native American students are consistently less likely to proceed through the science academic pipeline than their White or Asian counterparts (Estrada et al., 2011), the importance of fostering science identity in underrepresented students is a critical means to establishing and reinforcing a sense of belonging in the science community.

**Science Identity and Underrepresented Students**

Within formal settings, ethnicity is seen to play a significant role in the formation of students’ science identities (White, Altschuld, & Lee, 2006). Structures within these settings may or may not resound with a student’s racial or ethnic identity, resulting in the fostering or hinderance of students’ developing their science identity. This is especially true for students from diverse cultural and ethnic backgrounds who are underrepresented in the science and STEM fields. For the purposes of this study, underrepresented students in science include African-American, Hispanic, Native American/Alaskan Native, and Pacific Islander heritages. Moreover, gender is also included. Having established that reinforcing students’ science identities aids in their persistence and retention in science fields (Aschbacher et al., 2010; Estrata et al., 2016; Stets et al., 2017), it is therefore imperative to know the factors that positively impact and foster the development of underrepresented students’ science identities.
Factors that Positively Impact Students’ Science Identity

Research has suggested a variety of factors that foster science identity development in students of color. These factors range from family support (Carlone & Johnson, 2007) to receiving college preparation in high school, and having kind teachers (Brown, 2002). Compared to their White counterparts, students of color share some common factors that positively impact their science identity; however, some are unique to the identity of these underrepresented students. The items in Table 1 (Nealy, 2018, pp. 36-37) list the general factors that the literature has established as positively effecting the science identity development of students of color.

As a reference, entries in Table 1 also indicate whether or not these factors encourage science identity development in White students. While these general factors are important for fostering science identity, the factors that have the greatest impact on students of colors’ science identities are school support and supportive teachers, familial support, mentorship, and research experiences. Other researchers have found similar factors (Rosa & Mensah, 2016; Watkins & Mensah, 2019). The factors that are also important for the purpose of this study as they support the development of the participants’ science identity are mentoring and research experiences in an informal setting.
Table 1

Factors that Positively Affect the Science Identity Development

<table>
<thead>
<tr>
<th>Factors affecting science identity development</th>
<th>For students of color</th>
<th>For White students</th>
</tr>
</thead>
<tbody>
<tr>
<td>• An emotional connection to the subject</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>• Apprenticeship</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>• Coaching</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>• Demonstrated competence in mathematics and science</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>• Extra-curricular activities involving science (not associated with school)</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>• Faculty-student interactions</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>• Familial (STEM) role models</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>• Familial support</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>• Having an honors program at school</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>• Having caring teachers</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>• Having challenging and interactive curriculum</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>• Having small class sizes</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>• Inherent motivation</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>• Internship</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>• Media</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>• Receiving information</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>• School STEM experiences</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>• School support</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>• Strong pre-college preparations</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>• Tutoring</td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>


**Mentoring.** The act of mentoring refers to the relationship between an experienced person, or a mentor, who guides a less experienced person, or a mentee or protégé (Rhodes, 2005). For students of color, mentors can provide guidance and support that significantly impacts
their academic and social integration into science (Graham, Frederick, Byars-Winston, Hunter, & Handelsman, 2013; Watkins & Mensah, 2019).

Findings from a study by Robnett, Nelson, Zurbriggen, Crosby and Chemers (2018) indicates the importance of mentorship and highlights how the type of relationship between the mentor and the mentee can have a positive or negative impact on science identity. In their study, Robnett et al. (2018) examined how instrumental and socioemotional mentoring can impact undergraduate college students. Instrumental mentoring was defined as task-focused mentoring, meaning it involves providing the mentee guidance with skills and resources, while socioemotional mentoring is more general, where the mentor provides general support and guidance to the mentee. Of the 66 undergraduate participants in that study, most (75%) identified as women, and 70% identified with at least one ethnic group that is historically underrepresented in science fields. Positive effects of mentor-mentee relationships on science identity was reported across all genders and ethnicities for both instrumental and socioemotional mentorship (Robnett et al., 2018). By the same token, negative mentoring, such as canceling meetings and ignoring the mentee, were seen to negatively impact student science identity. The students who had the greatest positive impact on science identity were those who reported receiving instrumental mentorship, highlighting the importance of skill-based, task-focused guidance (Robnett et al., 2018).

Suggested by the findings of Robnett et al., (2018), mentorship can be particularly important for women in science (San Miguel & Kim, 2015). A study conducted by Hernandez et al. (2017) used a prospective, longitudinal, multi-site matched research design to compare mentoring and persistence outcomes for women in and out of a mentoring program (N = 116). Their project, entitled PROmoting Geoscience Research, Education, and Success (PROGRESS),
shed light on the impact mentoring can have on women’s science identity. Hernandez et al. (2017) also found that students receiving mentoring support reported having higher levels of scientific identity and higher levels of interest in the earth and environmental sciences compared to their counterparts who did not receive mentoring.

**Research experiences.** Research experiences for students of color have been found to positively influence students’ science efficacy, identity, and value (Estrada, Hernandez, & Schultz, 2018). In a two-year study involving 253 ethnically diverse undergraduate students, Robnett, Chemers, and Zurbriggen (2015) found that higher levels of research experience at Time 1 (fall of year 1) led to a higher science identity at Time 3 (spring of year 2); an association that was found to be mediated by science self-efficacy at Time 3 (spring of year 2). Moreover, Robnett et al. (2015) found that research experience led to heightened science self-efficacy, which in turn enhanced the learner’s science identity. With science self-efficacy reflecting one’s self-perceived likelihood of successfully completing a science task or achieving a science outcome, it is reasonable to believe that research experience helps foster science self-efficacy.

From a situated learning perspective (Lave & Wagner, 1991), these research experiences are ways in which students are integrated into the science-related community of practice and gain the skills and knowledge needed to perform science like a scientist. An example of enculturating students into a science-related community of practice via research experience is illustrated in a study by Hunter, Laursen, and Seymour (2006). Students described an intensive summer research experience as a program that taught them to think and work like a scientist. In addition to the narrative provided by students, mentors also reported that the students began to develop a skillset and sense of self similar to that of a novice scientist (Hunter et al., 2006).
While the bulk of existing literature on research experiences impacting science identity has focused on undergraduate students, some studies also bring in high-school students. Salto, Riggs, De Leon, Casiano and De Leon (2014) evaluated and compared the impact of a summer research experience on high school and undergraduate female students of color. The Loma Linda University Summer Health Disparities Research Program involved students in a research project and provided them personalized mentoring as well as targeted career development. Data from 96 high school and undergraduate participants were analyzed using a General Linear Model (GLM) to compare pre and post mean scores. Results of the GLM revealed that both high school and undergraduate participants experienced statistically significant gains in research skills and self-efficacy ($p < 0.001$) and identified the hands-on research and mentor experience as the most valuable aspects of the program. Moreover, the findings suggest some sort of behavioral impact; such that both groups of participants reported increased science skills, an increased confidence in science, and enhanced motivation to pursue a science career. When followed-up, 67% of high-school participants and 90% of undergraduate participants graduated from college with a STEM degree (Salto et al., 2014).

In the current study, the BioBus internship can be categorized as a community-based informal program. It was designed and implemented as a research experience with BioBus scientists, who hold Ph.D.’s and master’s degrees, guiding, mentoring and working side-by-side with interns on their independent research projects. The theoretical framework used for understanding the impact of the BioBus Internship on participants’ science identity comes from research conducted by Carlone and Johnson (2007) and the constructs they defined. Identity theory and this framework is further defined and examined in the section below.
THEORETICAL FRAMEWORK

Identity Theory

Before defining science identity and the way it is used as the framework for this study, it is useful to first explore identity theory. Identity theory is a philosophical and sociological framework used to explore and explain human behavior (Stets & Burke, 2000). Identity can be described as what it means to be a certain kind of person (Gee, 2000); or more specifically, the categorization of the self into a certain role, taking on the meanings and expectations associated with that role, and ultimately performing that role (Stets & Burke, 2000). For example, a person claiming to have an engineering identity possesses and displays the characteristics of an engineer, such as designing and building prototypes, has recognition in the field of engineering, and a career in the field of engineering. Identity, however, is far from this linear or stable representation.

Individuals can take on multiple identities, and it can be one for each role they play in society (Stryker, 1980). To continue with the example above, if the individual with an engineering identity is also a mother, she takes on that identity as well, enacting characteristics as caretaker, role-model, and mother among others. Each aspect of an individual’s identity is placed within varying levels of a salience hierarchy. Identity salience is defined as the likelihood that an identity will be pronounced across situations (Stryker, 2010). Identity theorists thus hypothesize that individuals have a greater probability of enacting behavioral choices in accordance with a specific identity if that identity has a higher identity salience relative to other identities incorporated into the individual (Stryker, 2010). To continue with the example introduced earlier, if the female engineer mother is approached by her employer and offered a promotion for leadership that would involve longer work hours, her decision to accept or decline
the promotion will be made based on the saliency of her multiple identities-- “mother” or “engineer.” If she identifies more as “mother” she may turn down the promotion so that she can spend more time at home with her children; however, if she identifies more with being an engineer, she may decide to take the promotion even if it means spending less time at home. Ultimately, identity salience shapes human behavior. The more pertinent an identity is, the higher the identity is on the salience hierarchy, and more likely that behaviors associated with this identity will be displayed or performed more frequently.

Although how identities are organized in a salience hierarchy is intrapersonal and specific to the personality of the person at play, there are factors that influence identity salience across multiple situations (Stryker & Serpe, 1982). Commitment, support, the given network of relationships to an identity, and intrinsic and extrinsic rewards all influence the order of identities across the levels of the salience hierarchy (Stryker & Serpe, 1982). Although commitment is the most important influencer on decisions or actions made within the identity salience hierarchy (Burke & Stets, 2009), support and network of relationships are imperative in validating an identity.

Though identity is defined through the individual self, it greatly involves identification by others (Stone, 1962). An identity is established when others identify an individual as the same social identity they identify with (Stone, 1962). The importance of external recognition cannot be under emphasized. It is vital in supporting and fostering commitment to an identity. Essentially, the more an identity receives external support (hence, the importance of a large network of relationships relevant to a given identity), the more the identity is developed, and the individual commits to that identity. In turn, the individual will display and enact characteristics of that identity.
Identity as an Analytical Lens

Gee (2000) paved the path for identity as an analytic lens for research in education by sketching an approach of identity as a methodical tool for understanding schools and society. The four aspects of identity as defined by Gee (2000) are nature identity (N-identity), institutional identity (I-identity), discursive identity (D-identity), and affinity identity (A-identity).

Nature identity, or the “nature perspective” refers to one’s identity defined by nature, not by one’s doing. An important point that Gee points out is the significance of recognition in natural identities, stating “natural identities can only become identities because they are recognized” (Gee, 2000, p. 102). In explaining the importance of recognition Gee uses the following example. Gee is an identical twin; this is an aspect of his N-identity. By the same token, thanks to “nature”, Gee has a spleen, something we are all born with; however, because possessing a spleen is not recognized as being uniquely his, it does not make up Gee’s N-identity. It is only because certain institutions (e.g., the medical profession) has recognized him as an identical twin, or because certain people respond uniquely to him as a twin, that his N-identity becomes an identity at all (Gee, 2000).

Institutional identity is not determined by nature but by institutions that the individual is associated with (Gee, 2000). I-identity refers to “a position” attained by a set of “authorities;” for example, being a student is a position obtained by many individuals, but the source of the power is not nature (N-identity); it is an institution. As a student, in this case, it is the university, the faculty advisors, and others in positions of power.
Discursive identities are what Gee (2000) calls the “discursive perspective” that are individual traits or one’s “individuality.” Only when validated by other’s recognition of the traits through dialogue does an individual trait compose one’s D-identity.

Lastly, A-identities (affinity-identities) result from an individual’s affinity groups. Gee (2000) defines affinity groups as members who have allegiance to, access to, and participate in certain aspects that allow them to share an understanding of distinctive experiences. For example, an individual who identifies as an engineer may use organizations such as the National Society of Professional Engineers (NSPE) to identify with and belong to. In constructing their A-identity through involvement with the NPSE; they can attend events, share information, and new procedures and practices within their group of other engineers. A-identities focus on unique social practices that create and sustain group affiliations, rather than an institution or dialogue, as seen in I- and D-identities.

At the core of the four identities set forth by Gee (2000) is recognition. How others acknowledge individuals correlates to the identities they belong to. Throughout the four identities, recognition is conceptualized slightly different. Recognition is filtered through a particular perspective on “nature” in N-identities, the workings of a larger entity in I-identities, through discourse and dialogue in D-identities, and being recognized as being a part of a group in A-identities. At the root of identity, individuals must be seen as a particular “kind of person” to serve as an identity of any kind. Within science education, how students see themselves as scientists also rests a great deal on how they are recognized as scientists. Gee’s (2000) framework of identity within educational research has been greatly influential in developing science identity models. Specifically, the science identity framework set forth by Carlone and
Johnson (2007) is widely used in science identity research and grounded in the work of Gee (2000), and it is used in this study.

**Constructivism**

Constructivism is rooted in the belief that learning does not happen through transmission of information from one person to another. Instead, knowledge is constructed by the learner as a result of interactions with one’s environment (Vygotsky, 1978), and through a process of actively integrating new experiences within existing cognitive frameworks and percepts. Individual constructivism, based on the works of Jean Piaget (1970), expresses the mechanics by which knowledge is created and cognitively internalized by learners. Piaget’s work was influenced by cognitive studies based on information processing. Information processing provided a model that could generate hypotheses about how students learn meaningful and complex material. Evidence from research employing information processing psychology, first suggested that one’s schema, or prior knowledge, and its organization plays a considerable role in learning new material (Hiebert & Carpenter, 1992). Piaget suggested that through processes of assimilation and/or accommodation, individuals construct new knowledge from their prior experiences in relation to novel or immediate sources of information (Piaget, 1970). Assimilation occurs when the students’ learning experience is aligned with their internal representation of the world; thus, they more readily assimilate the new learning experience into their schema. Or, when the new experiences are not consistent with existing schema, students either reject the non-consistent information or actively accommodate it by adjusting their schema to be more compatible with the new information. In the process of reframing the learner’s mental representation of the world to be more compatible with the new learning experience – the initial failure of encoding leads to learning through the accommodation process (Piaget, 1970).
However, a limitation of individual constructivism is that it insufficiently takes into account the social and situational influences on learning, it focuses primarily on the individual.

**Social Constructivism**

Social constructivist approaches to learning highlight not only the interdependence but also the interrelationship of social and individual processes in the building of knowledge (Blumenfeld, Marx, Patrick, Krajcik, & Soloway, 1997). Social constructivism highlights the role of social context in learning, whereas, cognitive constructivism focuses *primarily* on the individual. The fundamental idea in social constructivism lies in its emphasis on discourse, community, and context. Thus, knowledge is contextualized and cannot be removed from the situation in which it develops (Blumenfeld et al., 1997).

Fundamentally, social constructivism as particularly presented by Vygotsky (1978) highlights that in a learner’s zone of proximal development (ZPD). Through guidance and discourse, knowledge is co-constructed by the learner and a more advanced individual. Vygotsky (1978) identified the ZPD as the distance between an individual’s actual developmental level and their potential level, given assistance from a more advanced peer in the learning community. Vygotsky stated, “The zone of proximal development defines those functions that have not yet matured but are in the process of maturation” (p. 38). Thus, the ZPD offers a construct in which teachers assist students to higher levels of learning by recognizing and facilitating their current potentials that are not yet more fully realized. As stated by Bruner (1997), the ZPD is where pedagogy and social interaction intersect.

**Social constructivism and science education.** Established by Saunders (1992), four pedagogical strategies have been shown to promote constructivist teaching and learning in science education. They include authentic hands-on activity, discussion, group work, and
problem-solving forms of assessment. While “hands-on” can take on several meanings, Saunders (1992) refers to investigative experiences. A key aspect of investigative experiences is they involve more than concept verification. Integrated and usable knowledge develops when learners create multiple representations of ideas and are engaged in hands on activities that require them to use this knowledge (Blumenfeld et al., 1997). Thus, authentic, hands-on tasks are a key pedagogical component of constructivist learning theory. Furthermore, because learning is situated in tasks and contexts, it is imperative for the subject-matter tasks students undertake to have meaning beyond the context of school (Blumenfeld et al., 1997). Authentic, hands-on learning may also be referred to as situated learning. In situated learning, students are immersed in an authentic activity that reflects the regular practice of that culture (Brown, Collins, & Duguid, 1989); in this case authentic activity is activity at least representative of what scientists do or aspire to do within the community of scientists. An example of an authentic hands-on activity would be to have students work in a science research lab alongside members of the science community. In such a setting, the learner becomes encultured within the scientific community.

Discussion supports and facilitates meaningful learning through communication, explanations, interpretations, and expansion (Saunders, 1992). As explained by Bruer (1995), when students engage in conversation, they draw on the expertise of others, appropriate the knowledge of others, reflect on their own knowledge, and then internalize modes of knowledge practiced in the community of the discipline. Thus, particularly for science, discussion lends clarity to interpreting and sense-making of concepts that emerge from investigations.

Group work is a key component of developing shared understanding. Group work through collaboration encompasses a wide community of learners that can include students and
teachers, but can also include students, teachers, community members, or other experts (Blumenfeld et al., 1997). Collaborative work not only builds communication skills and encourages learning from others, it also promotes a sense of community, which often produces significant improvements in student achievement (Saunders, 1992). Moreover, collaboration does not necessarily lead to the reproduction of knowledge with students sharing answers in order to understand a concept, it can also encompass the actual production of knowledge (Blumenfeld et al., 1997).

Lastly, problem-solving as assessment encourages and challenges learners to move away from decontextualized knowledge and develop a deeper understanding of content (Blumenfeld et al., 1994; Saunders, 1992). From a social constructivist perspective, assessment is continuously ongoing as students produce artifacts that not only allow them to represent their conceptual knowledge in different ways but also emphasize the students’ ability to explore, inquire, reflect, and re-question (Blumenfeld et al., 1994; Saunders, 1992).

**Social constructivism in informal science settings.** ISE research draws attention to the different contexts (physical, personal, and social) of informal settings and highlights that most learning happens when there is consolidation and reinforcement of previous concepts rather than the creation of new schema (Falk & Dierking, 1997). In informal environments, constructivist theory is often used as a framework for learning because these settings acknowledge and use an individual’s experiences as an essential component in knowledge construction (Appleton, 1993). Bruner (1997) explained that social constructivists believe learning to be a sense-making process by which learners add and synthesize new information within existing schema structures through dialogue. Thus, social constructivist theory is generally accepted as being employed in informal settings not only due to the fact that it recognizes the active involvement of prior knowledge and
experiences in the construction of conceptual schemas; but also, because it highlights the social process of learning – highlighting the physical, social, and personal contexts of the learner (Anderson, Lucas, & Ginns, 2003).

**Conclusion**

This chapter presented a review of the literature and the theoretical framework as it relates to this study. This study aims to shed light on the impacts ISE has on students’ understanding of science inquiry and their science identity. Specifically, for students of color, the study aims to show how ISE programs can foster their science identity, a relationship underexplored in existing literature.

The utilization of identity theory and social constructivism as a theoretical framework allowed for a comprehensive analysis of the study’s research questions. The combination of identity theory and social constructivism play an important role in students’ science identity development as well as cognitive development in understanding science inquiry. The next chapter presents the methodology used in this research, and contextually considers the strengths and shortcomings of previous research, while simultaneously applying the theoretical frameworks to design a research methodology appropriate to investigating informal science education programs. Consequently, it is intended to contribute to a broader understanding of science inquiry and the development of science identity in students, generally, and for students of color, specifically.
CHAPTER III

METHODS

The purpose of this study was to explore how a yearlong BioBus research internship impacted learners’ science identities and their understanding of science inquiry. This chapter provides a detailed description of the methods and research design. The methodological approach is first described, followed by a description of the setting and participants. Afterward, the methods for data collection and analysis are presented in detail. Finally, the chapter finishes with strategies for trustworthiness as well as the ethical considerations that were considered.

Qualitative Research Design

Qualitative research emphasizes an emerging approach to inquiry. One which involves collecting evidence in the natural setting sensitive to the people and places under study. The evidence is then analyzed both inductively and deductively to establish patterns and themes (Creswell, 2014). Qualitative research is further characterized by the critical role of the research participants in the research process, bringing the language, values, and behaviors of the participants to life (Stake, 1995). Specifically, qualitative researchers are “interested in understanding the meanings people have constructed; that is, how people make sense of their world and the experiences they have in the world” (Merriam & Tisdell, 2016, p. 15). Thus, the purpose of this study, understanding how experiences in a yearlong BioBus internship impact participants’ science identities and understanding of science inquiry, aligns to the defining characteristics of qualitative research. The rich, descriptive information given from the qualitative approach gave this study a holistic viewpoint of understanding participant experiences in an informal science education internship.
One of the cornerstones of qualitative research is gathering multiple forms of data rather than relying on a single data source, including mixed-methods combining qualitative and quantitative sources of evidence. The usage of multiple forms of data allows the researcher to go through a series of complex reasoning steps through inductive and deductive logic to ultimately explore nuanced topics that lend themselves to qualitative research (Creswell, 2014). The multiple forms of evidence in this study included observations, semi-structured interviews, an open-response questionnaire, and a Likert-style survey. The incorporation of quantitative measures was done purposefully to add another dimension in the rich and deep analysis of the participants’ experiences, and to explore complex constructs such as identity and inquiry more intricately. Lastly, because the study measured growth over a period of time, the multiple forms of data were collected at three time points (pre, mid, and post), which allowed growth analysis of affective and cognitive development of the learners over the course of the year.

Case Study

This study required in-depth descriptions of the participants and their perceptions and understanding of science and their science identity; therefore, a case study design was deemed appropriate. In qualitative research, a case study design is described as an “in-depth description and analysis of a bounded system” (Merriam, 2009, p. 40). According to Yin (2014), case study research is distinct from experimental studies because questions are investigated in context or examined in a “real world setting” (p. 16). Consequently, this approach provides a “thick” description that is concrete and greatly contextualized (Merriam, 2009). Methods often used in achieving this goal include observations, interviews, focus groups, and artifact analysis (Merriam, 2009; Stake, 1995; Yin, 2014), which are then used to generate emergent themes and a nuanced case description (Creswell, 2014).
Yin (2014) classifies case studies as being explanatory, exploratory, or descriptive. Explanatory case studies are often used to explore presumed causal links in real-life interventions that are often too complex for survey or experimental strategies, which differs from exploratory, where the researcher is exploring situations in which the intervention has no clear, single set of outcomes (Yin, 2014). In addition to being explanatory, exploratory or descriptive, case studies can also be classified as intrinsic, instrumental or collective (Stake, 1995). Intrinsic case studies are utilized when the researcher’s intent is to understand the case, as opposed to undertaking the case because it represents other cases or a particular trait or problem. This contrasts with instrumental case study, in which the case is of secondary interest and its primary use is to provide insight into an issue or help refine a theory (Stake, 1995). Collective case studies are similar in nature and description to multiple case studies, in which the researcher can explore differences within and between cases.

This research used an explanatory multiple case study. The case study was explanatory as the questions being explored were causal; exploring the extent to which an informal science experience impacted students’ science identity and understanding of science inquiry. Moreover, this was a multiple case study, in which three study participants operated as separate cases. The three participants were chosen purposefully to better answer the study’s research questions. The use of multiple cases allowed me to analyze within and across instances to provide the rich, thick narrative unique to case study research. In this way, I give the reader an understanding of how learners’ science identity and science inquiry evolve during a research internship.

As addressed partially above, case study research was further deemed appropriate for this study due to its use of multiple methods. Merriam (2014) and Yin (2014) acknowledge that the use of both quantitative and qualitative methods in case study research help reveal details about
the phenomenon of interest. The use of multiple methods to collect and analyze data are encouraged in case study research as it has been found to be mutually informative in providing a more synergistic and comprehensive view of the case(s) being studied (Merriam, 2009; Stake 1995; Yin, 2014). Lastly, in combining qualitative and quantitative methods, the accuracy of the findings are further enhanced due to triangulation across different methods in examining the same case, expanding and elaborating on findings, and uncovering potential contradictions that may arise from the use of different methods (Creswell & Plano, 2011; Tolan & Deutsch, 2015).

**Case study as methodology, not product.** Because case study research has often been used as a “catch-all” category in social science research, there is little agreement on what constitutes a case study or how this type of research is generally done. Merriam (2009) argues this confusion stems from the fact that case study is often equated with fieldwork, ethnography, participant observations, qualitative research, naturalistic inquiry, grounded theory, or exploratory research. Conflating the process of conducting a case study with both the unit of study and the product has aided in this confusion. Merriam highlights that while a case study can be defined in terms of the process of conducting the inquiry (case study research), the bounded system or unit of analysis selected for study (the case), or the product (the end report of a case investigations), it is imperative to distinguish how case study is being used in one’s work. Case study was appropriate for this study as a process of inquiry to study the bounded system (i.e., the BioBus research internship). This study draws a picture of how group and individual change occurred over the course of a yearlong BioBus internship. Findings were based on “description, interpretation and identification of recurrent patterns” (Merriam, 2009, p. 12) and are presented in the form of themes, as opposed to an end product of a case.
Setting

This case study was anchored and bounded by the experiences that the youth had from participating in a yearlong science internship at BioBus. BioBus is an informal science education organization with a mission to help students discover, explore, and pursue science. Moreover, founded with a mission of social justice, the majority of BioBus programs target underrepresented, low-income K-12 and college students.

BioBus began its mission as an innovative mobile laboratory equipped with upwards of $75,000 invested in microscopes and visual data processing technology, staffed by professional scientists. As the BioBus parks in front of schools, entire classes of pre-k through twelfth-grade students climb on board for inquiry-based, hands-on lab sessions that allow them to “discover” their love for science. Today, BioBus has grown to two mobile laboratories and continues to visit schools throughout the tri-state area delivering hands-on, inquiry-based science experiences to roughly 50,000 students per year. Eight to 12-week BioBus “Explore” programs are given at schools and community centers providing students the opportunity to develop their own research practice. Lastly, BioBus supports students in becoming tomorrow’s scientific leaders through their “Pursue” internships for high school and college students, where they develop and implement a science research project.

BioBus Pursue internship. The BioBus yearlong Pursue internship was the setting for this study. The internship takes place within the BioBase (a community education center housed in the ground floor of the science center of a University located within a major Northeast metropolitan area). The BioBase is equipped with custom-built science stations that have advanced research microscopes, computers, and high definition monitors. In addition to these science stations, the interior was custom-built and designed to resemble a university-level
laboratory space. There are laboratory supplies and research equipment available for interns to design and explore their topic of research. Lastly, a major component of the internship is a teaching component. The internship is held weekly on Saturdays and Sundays, with two different cohorts attending each day. The focus of the internship for both days is research and teaching; however, the style of teaching differs between the Saturday and Sunday internship. Saturday interns teach monthly at large community events open to the public called Saturday Science, while Sunday interns teach more structured weekly classes, called Sunday Science. Figure 2 represents a timeline of activities for the BioBus Pursue internship.

**Figure 2**

*Timeline of activities for Saturday and Sunday Pursue internship*

<table>
<thead>
<tr>
<th>Fall 2018 (September - November)</th>
<th>Winter 2018 (December - February)</th>
<th>Spring 2019 (March - April)</th>
<th>Late Spring 2019 (May - June)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Saturday Internship</em></td>
<td><em>Saturday Internship</em></td>
<td><em>Saturday Internship</em></td>
<td><em>Saturday and Sunday Internship</em></td>
</tr>
<tr>
<td>- Introduction to experimental design</td>
<td>- Begin project and data collection</td>
<td>- Data collection continues</td>
<td>- Complete data analysis and interpretation</td>
</tr>
<tr>
<td>- Brainstorm research topics and develop research questions</td>
<td>- Monthly Saturday Science</td>
<td>- Begin data analysis and interpretation</td>
<td>- Create research poster</td>
</tr>
<tr>
<td>- Monthly Saturday Science</td>
<td><em>Sunday Internship</em></td>
<td>- Monthly Saturday Science</td>
<td>- Present poster at end of the year public symposium</td>
</tr>
<tr>
<td><em>Sunday Internship</em></td>
<td></td>
<td><em>Sunday Internship</em></td>
<td></td>
</tr>
<tr>
<td>- Introduction to experimental design</td>
<td>- Develop research question</td>
<td>- Data collection continues</td>
<td></td>
</tr>
<tr>
<td>- Brainstorm research topics</td>
<td>- Begin project and data collection</td>
<td>- Begin data analysis and interpretation</td>
<td></td>
</tr>
<tr>
<td>- Sunday Science section I</td>
<td>- Begin teaching Sunday Science section II</td>
<td>- End Sunday Science</td>
<td></td>
</tr>
</tbody>
</table>
Participants

Participants for this study were interns of the 2018-2019 BioBus internship. All participants voluntarily applied to the BioBus internship. Those who applied and were accepted, were assigned a pseudonym to maintain anonymity and were located within a major Northeast metropolitan area. The application process involved students providing BioBus with basic demographic information as well as answering seven open-ended questions pertaining to their general interests, interests in science, and interests in science outreach. After the application deadline, phone interviews were conducted with applicants. Upon the completion of interviews, four BioBus scientists (those who run the internship program) used a rubric to assess the applicants’ overall application (Appendix A).

Among approximately fifty applicants who applied to the BioBus Internship, eleven students were accepted, two of whom were returning interns from the previous school year (see Table 2 for participant demographic information). Thus, participants for this study were primarily selected using purposeful sampling from an applicant pool. BioBus interns were then randomly divided into two groups – Saturday interns and Sunday interns.
Table 2

Student Participant Demographics Listed by Assigned Pseudonyms

<table>
<thead>
<tr>
<th>Name (Self-Identified Racial/Ethnic Identity)</th>
<th>School Level</th>
<th>Gender</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adam, Other</td>
<td>Sophomore, High School</td>
<td>Male</td>
</tr>
<tr>
<td>Alex, Hispanic/Latino</td>
<td>Junior, High School</td>
<td>Male</td>
</tr>
<tr>
<td>Amanda, NR*</td>
<td>Junior, High School</td>
<td>Female</td>
</tr>
<tr>
<td>Anna, Caucasian</td>
<td>Senior, High School</td>
<td>Female</td>
</tr>
<tr>
<td>Ava, Afghan</td>
<td>Freshman, College</td>
<td>Female</td>
</tr>
<tr>
<td>Kerry, Black</td>
<td>Senior, High School</td>
<td>Female</td>
</tr>
<tr>
<td>Melissa, Black</td>
<td>Junior, College</td>
<td>Female</td>
</tr>
<tr>
<td>Nora, NR*</td>
<td>Senior, College</td>
<td>Female</td>
</tr>
<tr>
<td>Sara, Asian/Pacific Islander</td>
<td>Sophomore, College</td>
<td>Female</td>
</tr>
<tr>
<td>Serena, Caucasian</td>
<td>Junior, College</td>
<td>Female</td>
</tr>
<tr>
<td>Tiffany, Black</td>
<td>Senior, High School</td>
<td>Female</td>
</tr>
</tbody>
</table>

*No Response

Role of the Researcher

In qualitative research, the researcher is the primary instrument for data collection and analysis; thus, disclosure on the background and role of the researcher is essential (Creswell, 2014). Prior to, and during this study, I served as Director of Program Evaluation for BioBus. In this role, I was responsible for developing and implementing evaluation plans for a range of BioBus programs, ranging from one-time discover programs to more in-depth pursue programs. Within the context of this study, my role as researcher preceded any other role. Quantitative data was only shared with my direct manager and Executive Director of BioBus, and anonymity was always maintained. Moreover, while the relationship between the researcher and BioBus staff can be interpreted as a form of bias, it may be also an element for establishing trust and a familiar understanding of the program. As participant researcher in the study, I was centrally located in the research, recording observations and reflections from a personal and professional
perspective. Limitations of this study stemming from researcher bias and assumptions are discussed in Chapter V.

Data Collection

Instrumentation, interview procedures, and observation protocol. Yin (2014) highlighted six possible methods of data collection for case study research: documentation, archival records, interviews, direct observation, participant observation, and physical artifacts. Of the six data collection methods highlighted by Yin, this study used two methods—interviews and direct observations. In addition, data was also collected from an open-ended inquiry questionnaire and a Likert-style survey. These data sources were used to triangulate data pertaining to the study’s research questions. All eleven participants completed the Likert-style survey and open-ended inquiry questionnaire at three time points over the course of the year. The three time points are referred to as pre (start of the internship), mid (middle of the internship), and post (end of the internship). Of the eleven interns, three participated in one-on-one interviews with the researcher at the pre, mid, and post time points. These interviews were conducted one week after the survey and questionnaire were administered. Thus, the interns independently reflected on their time at the internship by completing the science inquiry questionnaire and science identity survey before they began the more in-depth interview. This data helped capture the evolution and understanding of the interns’ science identity as well as understanding of science inquiry. Lastly, there were direct observations of the internship experiences throughout the year, occurring bi-weekly, beginning in September 2018 until the completion of the internship in June 2019.

Views About Science Inquiry Questionnaire. The first quantitative measure this study used was the Views about Scientific Inquiry (VASI) questionnaire (Lederman et al., 2014). The
questionnaire was used to address the first sub-question of Research question one: How do students develop an understanding of science inquiry during a yearlong internship? This specific inquiry questionnaire was chosen because it has established face, content, and construct validity (Lederman et al., 2014). The VASI questionnaire was also chosen in part because the seven items (Appendix B) comprising the questionnaire are open ended and seek to reveal respondents’ understanding of the eight components of scientific inquiry mentioned prior and recognized in existing literature and U.S. learning standards (Lederman, Lederman & Antink, 2013; NRC, 2000).

The researcher scored the questionnaires, which were administered at three time points (pre, mid, and post). The “pre” VASI questionnaire was administered on the first day of the research internship (September 2018), the “mid” VASI questionnaire was administered approximately at the half-way point of the internship (January 2019), and the “post” VASI questionnaire was administered at the end of the research internship (June 2019). Students were assured the questionnaire was not graded and only the researcher saw their responses.

Science Identity Survey. The second quantitative measure used was the Science Identity Survey (SIS) (Schon, 2015). This five-point Likert-style instrument was chosen to address the second sub-question of Research question one: How do students’ science identity evolve during a yearlong internship? This survey was chosen because of its high reliability in informal science settings. Moreover, it targets the three constructs of science identity (competence, performance, and recognition) as defined by the study’s framework. This survey was also chosen because it was created and validated in a way that addressed Carlone and Johnson’s (2007) concerns about the difficulty of operationalizing science identity. The validation process employed by Schon (2015) involved students (focus groups and think-a-louds) and goodness of fit tests (confirmatory
factor analysis and a Cronbach’s alpha value of .89), which in conjunction, justified the use of
this tool to assess change in science identity in informal settings. Lastly, besides the
psychometric strength of this science identity instrument, this survey was also chosen for its
short number of items (Appendix C), resulting in ease of administration.

Similar to the VASI questionnaire, the “pre” survey was administered on the first day of
the research internship (September 2018), the “mid” survey was administered approximately at
the half-way point of the internship (January 2019), and the “post” survey was administered at
the end of the research internship (June 2019). Students were again assured that the survey was
not a graded test and only the researcher saw their responses.

**Interviews.** In classifying interview approaches, Merriam (2009) organizes them from
least to most restrictive; unstructured/informal, semi-structured, and structured/standardized.
Specifically, in case study research, interviews are regarded as being open-ended, focused, and
structured (Tellis, 1997). Open-ended interviews allow researchers to inquire broadly for the
interviewee’s opinion; focused interviews utilize a predetermined set of questions and are often
used to confirm data collected from another source, while structured interviews typically come in
the form of a demographic survey (Tellis, 1997).

The interviews that were conducted used a mix of focused and semi-structured interview
questions (Appendix D). The focused approach explored any possible changes in survey and
questionnaire responses along the three time points. It also acted as a form of member checking.
Conversely, the semi-structured approach gave opportunity to explore all research questions. The
interviews occurred the week after the interns completed the VASI questionnaire and the SIS,
and lasted approximately 40 minutes per participant. During the interviews, themes and
constructs presented in the SIS – competence, performance, and recognition (Carlone & Johnson,
were expanded upon and discussed. These interviews allowed students an opportunity to reflect upon and express their views about their science identity, while also allowing the researcher to corroborate responses on the VASI with the participant’s understandings of various aspects of science inquiry.

**Observations.** Direct observation, according to Tellis (1997), requires an investigator to make a site visit in order to gather data and is the primary observation approach used for this study. Merriam (2009) referred to this approach as observer as participant, where the researcher’s observation activities are given preference over the role of participant. Observations of the internship were done bi-weekly throughout the year long internship. During the observations, highly descriptive field notes were taken with enough detail to allow “readers [to] feel as if they are there, seeing what the observer sees” (p. 130). Observation notes were recorded into an electronic document and ultimately used to create a timeline of events that would provide readers with an accurate representation of the internship experience. In addition to the creation of a timeline of events, a main goal of the observations was to highlight and identify instances, activities, and events over the course of the internship that fostered science identity. A timeline of data collection for the study is provided in Figure 3.

**Figure 3**

*Data Collection Timeline, Including Specific Instruments and Protocols Used*
**Data Analysis**

The data set for the whole group consisted of eleven pre, mid, and post VASI questionnaires and eleven pre, mid, and post SIS responses. The quantitative instruments were analyzed using descriptive statistical methods as prescribed by the authors of the instrument. Interviews from the student participants were audio-recorded and transcribed using an audio transcription service. Across the three cases “identification of recurrent patterns in the form of themes” (Merriam, 2009, p. 12) was identified and discussed. Lastly, the bi-weekly observations created a setting narrative and provide empirically based reasoning for the growth of interns over time.

**VASI questionnaire.** In scoring the VASI questionnaire, Lederman et al. (2014) state to categorize responses as informed, mixed, naive, or unclear. If a respondent provides a response consistent across the entirety of the VASI questionnaire and is wholly consistent with the target response, they are labeled as “informed.” If a response is only partially explicated, and not totally consistent with the targeted response, or if a contradiction is evident, a score of “mixed” is given. A response that is contradictory to accepted views of a particular aspect, or provides no evidence of congruence with accepted views, a score of “naïve” is given. Lastly, for scores that are incomprehensible, or indicate no relation to the particular aspect, a categorization of “unclear” is assigned (Lederman et al., 2014). Example responses to each of the eight components of science inquiry were provided by the creators of the VASI (Lederman et al., 2014) and used to guide the grading of the questionnaire (Appendix E). A point to note about the VASI questionnaire is that although scoring can be done on a simple one-to-one correspondence between an aspect and a single item, a more holistic picture of science inquiry understanding should be gleaned by considering responses to the VASI as a whole.
Pre, mid, and post VASI questionnaires were completed by a total of eleven interns. After each pre, mid and post point of data collection, a total VASI score was tabulated. For ease of comparison across the three time points, each inquiry categorization of naïve, mixed, or informed as employed in the VASI were converted to a three-point scale representing each of the three levels (1 for naïve, 2 for mixed, and 3 for informed). A total VASI score was generated by adding up the score for each of the seven questions. The highest possible VASI score (if a respondent scored “informed” on all eight inquiry components) was 21, whereas the lowest score possible was a seven (all categories were scored 1). After total VASI scores were obtained, an average VASI score was calculated for each pre, mid, and post point of data collection. After this average VASI score was generated, descriptive statistics were reported, and the data was tested for normality. Finally, A Kolomogrov-Smirnov test was done to determine if the data were normally distributed to then use a repeated measures ANOVA to compare statistical significance differences in scores from pre to the mid and to the post (Orion & Hofstein, 1994). A statistically significant difference from pre to post indicates a change in understanding of science inquiry. The criterion value for statistical significance was \( p \leq .05 \). In addition to reporting statistical significance of the means among the three time points, a post-hoc Tukey’s test and Hedge’s \( g \) were used to examine differences between pairs of means for the pre and post scores, pre and mid scores, and mid and post scores. SPSS software was used.

**Science Identity Survey.** Similar to the VASI, the SIS was completed by all eleven interns at three time points-- pre, mid, and post. Upon their completion, an “identity score” was given by adding up the total of the 15 Likert items (Appendix C). The highest possible identity score (if a respondent replied 5 - “strongly agree” to all survey items) would be 75, whereas the lowest score possible would be 15. After each pre, mid, and post point of data collection, a total
SIS score was tabulated for each intern. Then, an average SIS score was calculated for each pre, mid, and post point of data collection. After this average SIS score was generated, descriptive statistics were reported, and the data was tested for normality. Similar to the VASI analysis, a Kolomogrov-Smirnov test was done to determine if the data were normally distributed to then use a repeated measures ANOVA to compare statistical significance differences in mean scores from pre to mid to post (Orion & Hofstein, 1994). A statistically significant difference (p ≤ .05) from pre to post indicates a change in science identity. In addition to reporting statistical significance of the differences in the three means from pre to post administration of the survey, a post-hoc Tukey’s test and Hedge’s g were used to examine differences between pairs of means for the pre and post scores, pre and mid scores, and mid and post scores. The criterion value for statistical significance was p ≤ .05. Finally, the data was broken down by science identity construct and tested for normality. Afterwards, another ANOVA analysis was conducted to compare change in means of each science identity construct (competence, performance, and recognition). Post-hoc Tukey’s test and Hedge’s g were used to examine the differences among pairs of means. Analyses were conducted using SPSS software.

**Interviews.** Lederman et al. (2014) recommend at least 20% of respondents of the VASI questionnaire be interviewed to better corroborate responses on the VASI with the scorer’s inferences about the quality and understanding of the respondents. In this study, roughly 30% of participants were interviewed to better corroborate responses. A total of nine interviews were conducted over the course of the internship. Three interns (Kerry, Melissa, and Sara) participated in one-on-one interviews at the pre, mid, and post points of the study. During the interviews, aspects of science identity and science inquiry were explored, in addition to the participants’ overall experience at the internship. These qualitative interviews provided an opportunity for
participants to reflect upon and express their thoughts and understanding about science inquiry and their attitudes, dispositions, and feelings toward science, in much richer detail than could be represented in a quantitative instrument. The interviews also served as an opportunity to compare responses of the participants’ VASI questionnaire and SIS, from beginning, middle, and end of the internship.

**Inductive coding of interviews.** The coding process can be approached through a plethora of ways. For case study research, it is suggested to choose from these approaches: pattern-matching, explanation-building, and time-series analysis (Yin, 2014). For this study, pattern-matching approach, also viewed as the constant comparative method (Glaser & Straus, 1967), was used. The interview transcripts were coded twice, once inductively and once deductively. Each to provide a deeper understanding of the study and the study’s setting.

The interview transcripts were first analyzed inductively, that is, no framework was employed as a priori scheme. Firstly, data was grouped into small units, which were then assigned a code. Secondly, these codes were grouped into categories. Lastly, themes were developed to elucidate the content of each category. Coding, categorization, and re-coding/re-clustering/ of the key themes and sub-themes were derived inductively from the data, and interconnected to reflect “stories” from the participants. This was then followed by comparative analysis (Glaser & Straus, 1967). Constant comparative analysis method was employed through open, axial, and selective coding (Strauss & Corbin, 1998). Open coding allowed the analytical breakdown of the text, and the comparing of events, interactions, and experiences for similarities and differences. This analysis ultimately provided meaning to the text in the interview narratives. The second step, axial coding, identified connections and relationships from the narratives. Categories and subcategories were developed to reveal these relationships. Finally, selective
coding established a general way of describing the open and axial codes. It was from the selective codes that themes of the data emerged. These themes reflected the inter-connectivity of the stories told in the interview narratives. Appendix F illustrates a representative example from the data as a visualization of the coding process that established the themes and sub-themes of the study. The example includes codes, categories/sub-categories, and themes that derived from the process of open, axial and selective coding. Lastly, an example of data representing each code is given.

**Deductive coding of interviews.** In addition to the constant comparative method (Glaser & Straus, 1967) that was used to inductively analyze the interview data, deductive coding was also used as a method of analysis. The interview transcripts were considered in relation to components of the Science Identity framework (Carlone & Johnson, 2007) guiding the study. The data were examined to uncover features of the BioBus internship that were associated with the elements of science identity as defined by Carlone and Johnson (2007); competence, performance, and recognition. The purpose of using the Science Identity framework to guide the analysis of the interviews was to address the study’s second Research question: How does an informal science education research experience foster science identity among participants of color? Thus, in mapping the interview data against this framework, activities and events emerged as pivotal in aiding the development of science competence, science performance, and science recognition. Appendix G shows examples from the data as a visualization of how the interview transcripts were coded as relating to science competence, performance, or recognition.

**Observations.** After each observation, I read through the electronic document and made comments along the margins. Afterwards, I wrote a reflective summary of each observation from the participants; in total 22 observations were completed and produced a case setting narrative.
and timeline of events by cross-referencing each observation. Observations were also
deductively coded in a process analogous to the deductive coding process of interview data using
Carlone and Johnson’s (2007) Science Identity framework. Activities, events, and instances were
coded as science competence, science performance, or science recognition. This process, in
addition to the deductively coded interview data, addressed the third Research question: How
does an informal science education research experience foster science identity among
participants of color?

**Rigor and Ethics**

Due to the subjective nature of qualitative research, being able to trust a study’s results
are especially important. Addressing issues of validity and reliability in qualitative research
ensures trustworthy research that produces truthful knowledge. The last section of this chapter
addresses issues of validity and reliability as it pertains to this study. Lastly, ethical
considerations are discussed.

**Internal Validity**

Within qualitative research, internal validity ensures that research findings are consistent
with reality and researchers are observing or measuring what they intend to measure (Merriam,
2009). An important point to note is that reality is not single-faceted; it is, to the contrary,
multidimensional, holistic and ever-changing. Reality is not a single, fixed, objective
phenomenon waiting to be discovered or observed; thus, what is being observed are the
interpretations of reality directly through the lens of the researcher—the primary instrument of
data collection. Consequently, as explained by Merriam (2009), the researcher is “closer” to
reality than if a data collection instrument were interjected between the researcher and the
participants. When viewed in this manner internal validity is a considerable strength of qualitative research.

Merriam (2009) offers six strategies to enhance internal validity: triangulation, member checking, long-term observations, peer examination, participatory or collaborative modes of research, and researcher’s biases. Of the six strategies, this study used three methods: triangulation, member checking, and long-term observations. Triangulation is perhaps the most common strategy to ensure internal validity. It is achieved by comparing data collected at different times and places and cross-checking them to confirm emerging themes (Tellis, 1997).

Within this study, data were compared across VASI questionnaire scores, SIS scores, interview transcripts, and direct site observations. Following a comparative method data analysis process (Glaser & Straus, 1967), the data sources reinforced each other, enhancing the internal validity of this study.

Member checks involved taking data and preliminary interpretations back to the participants from whom they were derived and providing them the opportunity to confirm or clarify interpretations. This process was done throughout the study. During the interviews, participants were asked about their VASI and SIS responses as well as interpretations made from informal conversations and continual observations in my role as the researcher. Moreover, those interns who were involved in the “whole” analysis but not the “part” (Research question one and two as opposed to Research question three) were given opportunities to member check during site observations. This was done to remedy the fact that not all interns participated in one-on-one interviews. Lastly, long-term observations at the research site were conducted. Over the course of the year, I conducted bi-weekly observations, each lasting an average of four hours. By
conducting over twenty observations over the year, the internal validity of the study was greatly enhanced due to the rich data that came from on-site observations.

**External Validity**

External validity addresses generalizability of the research findings, that is to what extent can the findings of one study be applied to other situations (Merriam, 2009). The notion of generalizability has been a point of criticism for qualitative research for some time. However, scholars within the field have argued that production of generalizable knowledge is an inappropriate goal for interpretive research (Erickson, 1986). Rather, Erickson writes, “… the search is not for abstract universals…but for concrete universals” (p. 130). In studying a specific case in detail and then comparing it with other cases in equally greater detail, we begin to formulate “concrete universals” (p. 30). What is learned in this situation is transferred or generalized to a similar situation, and eventually there is the formation of concrete universals. Thus, the highly contextualized findings of qualitative research serve as the reason to examine a phenomenon in detail. In doing so external validity is established because through the rich, thick description that defines qualitative research, readers can then determine how closely their situation match the research situation, which in turn, allows the reader to assess whether findings can be transferred (Merriam, 2009). The rich, thick narrative used within this study details the setting and addresses all research questions in a manner that enhanced the study’s external validity.

**Reliability**

Reliability refers to how replicable research findings are. Within social science research, reliability presents many difficulties, and the chief reason being that qualitative research is often not conducted to isolate human behavior. Human behavior is never static, and within qualitative
research, the desire is to describe and explain the world in a way which the participants are experiencing it. Due to the nature of qualitative research, replication of a study will not yield the same results. Thus, reliability is argued to be somewhat of a misfit in qualitative research (Merriam, 2009). Rather “consistency” provides a more appropriate lens. That is, researchers ensure that the data are consistent and dependable rather than demanding that outsiders reach the same results (Merriam, 2009). To this end, techniques similar to internal validity are employed. Triangulation was used to strengthen the reliability of this study. The multiple methods of data collection and data analysis further strengthened the consistency of the study’s findings and made them more dependable.

**Ethics**

Stake (1995) states, “Qualitative researchers are guests in the private spaces of the world.” Within qualitative research, particularly in case study, the ethics of the researcher influences the rigor of the study and is dependent upon the researcher-participant relationship (Merriam, 2009). Prior to the start of the study, there was approval from the Institutional Review Board (IRB), and consent forms were given to all participants. For participants under the age of 18, consent forms were given to the participants and their parents. The consent forms articulated the purpose of the study, the role of the researcher, and the intended role of the participants. Participants were aware that their participation was entirely voluntary, and they could remove themselves from the study at any time. Signed consent forms were received from all participants and no one chose to drop out of the study. During the data collection process, extreme effort was put forth to ensure the privacy and comfort of all participants. The interview questions were all low-stakes in order to avoid feelings of invasion of privacy, embarrassment, or any other
potentially negative effects. Lastly, identities of all participants were masked through the use of pseudonyms.
CHAPTER IV

FINDINGS

Surveys, questionnaires, interview, and observations provided a detailed description of the BioBus experience for the whole group and a select few. Chapter four details the findings that emerged from the data collected and analyzed to examine the relationship between students’ development of science inquiry, science identities, and the BioBus experience. Theory in science identity (Carlone & Johnson, 2007) provided the framework for analysis of the data. The study relied on open-ended questionnaires, Likert-style surveys, interviews and observations to explore these relationships and answer each research question. Lastly, rich descriptive detailed themes developed from the cross-case analysis of the perspectives and experiences of the three selected participants are presented.

Research Question One

The first research question sought to examine the experience of the whole group of interns. Guided by two sub questions, quantitative methods to measure significant change of the groups’ VASI and SIS scores were used. The study’s first sub question was: Is there a statistically significant difference in students mean Views About Science Inquiry score over a yearlong internship?

The null hypothesis to this research question stated that there is no significant difference in mean pre, mid, and post survey scores, while the alternative hypothesis states there is a significant difference between survey scores. Analysis of the VASI scores of the eleven BioBus interns revealed a significant positive change from pre to post survey responses.

VASI questionnaire results. The findings associated with change in VASI questionnaire scores are presented firstly in the coarsest grain form with mean changes in interns’ VASI score
Then, the survey results are broken down by the eight science inquiry components that were assessed in the VASI questionnaire (Table 4). Finally, example participant responses are given to supplement the quantitative data of the questionnaire.

Table 3 displays changes in mean VASI scores before, during, and after the yearlong BioBus internship for all participants (N=11). The questionnaire consists of seven open-ended items designed to measure respondents’ understanding of the eight components of science inquiry derived from existing literature and U.S. learning standards including, the NGSS (NGSS, 2013), Benchmarks for Science Literacy (American Association for the Advancement of Science, 1993), National Science Education Standards (NRC, 2000), among others.

<table>
<thead>
<tr>
<th>VASI Comparison of Pre, Mid, and Post Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre</td>
</tr>
<tr>
<td>M</td>
</tr>
<tr>
<td>19.5</td>
</tr>
</tbody>
</table>

n = 11
*p < .05
**p < .01

In grading the VASI questionnaire, Lederman et al. (2014) scores were converted into a 3-point scale as described in the Methods Chapter. Thus, each of the eight components of inquiry ultimately received a score from one to three, which was then combined to find a total VASI score. The combined mean scores of the cohort were as follows: 19.5 out of a possible 24 initially, 21 at the internship’s midpoint, and an average score of 22 at the end of the internship.

The 3-point scoring system was treated as an interval scale, thus a change from one to two is the same unit as change a two to three. This coarse scale was not only done for ease of presentation and comparison, but also, to reduce the amount of error when doing analyses. The
sample was then tested for normality. After the results of the VASI questionnaire met the assumption of a normal distribution using a Kolmogrov-Smirnov test, a repeated measures ANOVA tested for significant change in average mean scores. An overall strong statistical significance was observed from pre to post VASI score (p = .009). Tukey test results for pairs of means (Table 3) are reported for the pre to post VASI scores (change in mean of +2.7 points), with a large effect size (Hedge’s g = 1.18). Breaking down the VASI Questionnaire by the eight components of science inquiry provided a more fine-grained analysis of the change in interns’ understanding of science inquiry.

The VASI Questionnaire has established validity and reliability in numerous works as a holistic instrument (Lederman et al., 2014; Lederman, Lederman, Bartels, Jimenez, Akubo, Aly, … Zhou, 2019). Thus, the lack of reliability and validity on the individual components of the questionnaire made statistical tests to measure change in mean scores inappropriate. Instead, a matrix (see Table 4) was created that shows the complete set of science inquiry components and the corresponding percent of responses that were coded as either naïve, mixed, or informed. Data from all three time points are represented in this matrix as well.

Each of the science inquiry components are listed and the percent of respondents who scored either naïve (N), mixed (M) or informed (I) is listed for the pre, mid, and post assessment during the yearlong internship experience. There are eight science inquiry components.
Table 4

VASI Scores Pre, Mid, and Post BioBus Internship by Component of Science Inquiry

<table>
<thead>
<tr>
<th>Science Inquiry Component</th>
<th>Pre</th>
<th>Mid</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>Starts with a question (%)</td>
<td>N 18</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>M 36</td>
<td>36</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td>I 45</td>
<td>64</td>
<td>64</td>
</tr>
<tr>
<td>Multiple Methods (%)</td>
<td>N 0</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>M 73</td>
<td>27</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>I 18</td>
<td>55</td>
<td>64</td>
</tr>
<tr>
<td>Procedures are guided by question asked (%)</td>
<td>N 0</td>
<td>9</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>M 18</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>I 82</td>
<td>91</td>
<td>100</td>
</tr>
<tr>
<td>Same procedure may not yield same results (%)</td>
<td>N 9</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>M 36</td>
<td>36</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>I 55</td>
<td>55</td>
<td>82</td>
</tr>
<tr>
<td>Procedures influence results (%)</td>
<td>N 36</td>
<td>9</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>M 36</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>I 27</td>
<td>73</td>
<td>82</td>
</tr>
<tr>
<td>Conclusions must be consistent with data collected (%)</td>
<td>N 0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>M 18</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>I 82</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Data and evidence are not the same (%)</td>
<td>N 18</td>
<td>9</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>M 18</td>
<td>18</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td>I 64</td>
<td>55</td>
<td>73</td>
</tr>
<tr>
<td>Conclusions are developed from data and prior knowledge (%)</td>
<td>N 9</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>M 27</td>
<td>36</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>I 64</td>
<td>64</td>
<td>82</td>
</tr>
</tbody>
</table>

Note. N = Naïve; M=Mixed; I=Informed

Interns experienced growth across all eight components of science inquiry, with the highest growth occurring in components two and five, there is no single set and sequence of steps followed in all scientific investigations (multiple methods), and inquiry procedures can
influence the results (procedures influence results), respectively. Lastly, in utilizing a mixed methods approach, participant responses supplement these quantitative findings to provide rich texture to the growth experienced over the year.

In the second aspect of science inquiry (multiple methods), 73% of BioBus interns (N=8) scored mixed (2 out of 3) and 18% of interns (N=2) scored informed (3 out of 3), compared to Lederman et al. (2019) baseline group, with 86% of their participants scoring either naive or mixed (1 or 2 out of 3) and 1% informed (3 out of 3). In this aspect of science inquiry, which is a challenge for learners of all ages to understand, BioBus interns experienced great growth and improvement, with 64% of interns (N=7) scoring informed and 36% (N=4) scoring naive or informed. An example response from this study reflected the understanding of the majority of participants suggesting that there may be multiple methods of a science investigations, but any real science investigation must follow “the scientific method”:

It [science investigations] can follow more than one method, but this is an experiment because it follows the scientific method.

The results shifted on the post VASI questionnaire when students began to express that there is a scientific method, but that is not the only definitive characteristic of a science investigation:

It does not have to follow the scientific method; it is still experiment because it [the person’s investigation] can be tested and observed.

This student’s response showed a shift in understanding the scientific method. That rather than the scientific method being the driving force of a scientific investigation, the question being tested or observed required different methodologies to be employed. The shift in view can be attributed to being exposed to a variety of research questions explored by interns. Ranging from analyzing the social behavior of ants to the effects of microplastics on organisms, interns were
exposed to a variety of research questions that warranted the use of different methods, solidifying the understanding that there is no single scientific method.

The fifth aspect of science inquiry (procedures influencing results) revealed a similar trend. Thirty-six percent of BioBus interns scored naïve (N=4), 36% mixed (N=4), and 27% informed (N=3), compared to Lederman et al. (2019) data, where 38% of participants scoring naïve, 20% mixed, and 34% informed. In this aspect of science inquiry, BioBus interns also experienced growth, with no naïve responses (N=0), 18% scoring mixed (N=2), and 82% scoring informed (N=9). An example intern response from a pre point VASI questionnaire illustrated the naïve and understanding students had when asked if scientists asking the same question but following different procedures would come to the same conclusion. The intern said, “Maybe…people may get the same answers through coincidence.” At the post point, most interns (N=9), understood that through different methodologies and different modes of data collection, the data collected, and thus the conclusions drawn, can vary. A representative participant quote from this study shared the following:

They [scientists] will not necessarily get the same conclusion. They may interpret the same results differently, but also different procedures could lead to different data and different conclusions.

Therefore, similar to the prior component of science inquiry, the growth and understanding highlighted in these VASI responses showed that through authentic research and explicit, guided mentorship through the research process, interns developed a deeper, more true understanding of the nature of science and science investigations.

**Science Identity Survey results.** The second sub question of Research question one, sought to quantitatively illustrate participants’ growth in science identity by examining the change in mean SIS scores. The Research question was: Is there a statistically significant difference in students mean Science Identity Survey score over a yearlong internship? Like the
prior sub question, the null hypothesis to this question stated no significant difference in mean pre-, mid-, and post-SIS scores, while the alternative hypothesis stated there is a significant difference between SIS scores. Analysis of the participant SIS scores revealed a significant positive change from pre- to post.

The findings associated with this research question are first presented in their coarse grain size, mean changes in SIS score (Table 5). Then, the survey results are broken down for a more fine-grained analysis as results are broken down by science identity construct (competence, performance, and recognition) (Table 6).

Table 5 displays changes in mean SIS scores before, during, and after the yearlong BioBus internship. In first examining the combined mean scores of the cohort (N=11), it was observed that the average score began at 59 out of a possible 75, rose to 61 by the program’s midpoint, and ended at 65. The sample was then tested for normality. After the results of the SIS scores met the assumption of a normal distribution using a Kolmogrov-Smirnov test, a repeated measures ANOVA tested for significant change in average mean scores. The results revealed an overall statistically significant (p<.05) change in participants’ mean SIS score. After determining the results were significance overall, the post-hoc Tukey Test was done to determine exactly where the difference lied (see Table 5). Overall, the positive change of 6.5 in pre to post SIS score was deemed statistically significant with a p-value of less than .05 (p=.038), and a large effect size (Hedge’s g = 1.09).
Breaking down the SIS instrument by construct provided a more detailed picture of the change. Table 6 illustrates how each measure increased more during the second half of the internship than during the first half of the program. Beginning with competence, the interns’ combined mean score rose from 18.9 out of 25 for pre internship, to 19.5 by the midpoint, and ended with 20.8. According to Carlone and Johnson (2007), performance proceeds competence in a sense that once students have a firm understanding of science concepts, they are then able to practice knowing these concepts in ways of talking, using science language, and using science tools. Participants’ performance increased over the year from 20.5 (pre) to 20.9 (mid) to 22.6 (post-internship). Recognition, which involved both internal and external recognition, is at the cornerstone of identity research (Gee, 2000). In science identity research, recognition involved not only seeing oneself as a scientist, but also being recognized by others as a scientist. Following competence and performance, interns’ recognition increased from 19.6 (pre) to 20.9 (mid) to 22.0 (post-internship).

When each construct was analyzed using a repeated measures ANOVA, statistically significant (p<.05) changes were observed from pre to post recognition scores (19.6 to 22) with a large effect size (Hedge’s g = .821).
As previously stated, when looking at identity, skills and practices must also be taken into consideration. Carlone and Johnson (2007) distinctly point to performance as a construct of science identity, explaining how it is necessary for learners to engage in and build on their foundation of knowledge and understanding of science to develop a science identity. In exploring competence and performance, this study not only conducted onsite observations but also acknowledged the results of the VASI questionnaire as an indication of their understanding of the skills and practice of science. Interns’ understanding and practice of science inquiry were used to understand how they developed the competence and performance construct of science identity. It was also used to address the virtually nonexistent literature that focuses on science inquiry skill development in informal science education. However, while quantitative instruments are extremely useful in informal settings, which often have limited assessment tools addressing identity and lack time and resources with students, solely using one quantitative tool to address science identity is flawed. Science identity is a complex construct, influenced by a myriad of factors, for this reason, I employed a mixed methods approached using qualitative data to analyze science identity development in Research question two. This spearheaded the second research question of this study.
Table 6

SIS Scores Pre, Mid, and Post BioBus Internship by Component

<table>
<thead>
<tr>
<th></th>
<th>M</th>
<th>SD</th>
<th>M</th>
<th>SD</th>
<th>M</th>
<th>SD</th>
<th>ΔM Pre-Mid</th>
<th>ΔM Mid-Post</th>
<th>ΔM Pre-Post</th>
<th>F-ratio</th>
<th>Tukey's Z HSD</th>
<th>Hedge's Z g</th>
</tr>
</thead>
<tbody>
<tr>
<td>Competence</td>
<td>18.9</td>
<td>2.17</td>
<td>19.5</td>
<td>2.81</td>
<td>20.8</td>
<td>1.78</td>
<td>+0.6</td>
<td>-1.3</td>
<td>+1.9</td>
<td>2.35</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Performance</td>
<td>20.5</td>
<td>2.73</td>
<td>20.9</td>
<td>2.39</td>
<td>22.6</td>
<td>1.91</td>
<td>+0.4</td>
<td>+1.7</td>
<td>+2.1</td>
<td>3.08</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recognition</td>
<td>19.6</td>
<td>3.01</td>
<td>20.9</td>
<td>2.55</td>
<td>22.0</td>
<td>2.57</td>
<td>+1.3</td>
<td>+1.1</td>
<td>+2.4*</td>
<td>3.53*</td>
<td>2.65</td>
<td>.825</td>
</tr>
</tbody>
</table>

n = 11
*p < .05

Research Question Two

The second Research question addressed what influence the BioBus research experience had on students’ science identity. The Research question was: How does an informal science education research experience foster science identity among participants of color? Upon review of participants’ interview transcripts and researcher observation notes, certain themes began to materialize. The transcripts and notes were examined relative to components of the Science Identity framework (Carlone & Johnson, 2007). Activities and events emerged as pivotal sources of evidence in promoting the development of science identity, and they were categorized in relation to the three constructs of science identity—competence, performance, and recognition.

Competence

While improving a participant’s science competence, alone, does not contribute to their sense of a whole science identity, learning techniques and discipline-specific information are important in students’ feeling as if they are capable as budding scientists (Carlone & Johnson,
2007). Carlone and Johnson (2007) recognize this construct as “less publicly visible” (p. 1191), and they examined GPAs as evidence of competence in their research. This was part of the context for their conceptual framework used in this study. Moreover, because competence is challenging to measure, and not a differentiating factor in women’s science pathway; competence and performance are sometimes lumped together as one variable (Carlone & Johnson, 2007; Hazari et al., 2010).

The overlapping of constructs within the science identity framework (Carlone & Johnson, 2007) is purposefully done to illustrate the interconnectivity between competence, performance, and recognition. Although this study defined competence as evidence that the interns learned science skills and content, there were clear instances in which two or more constructs were highlighted. For example, when participants were asked the question, “at what times do you feel competent in science”, many interns responded with “when I get an A”, “when I get a good grade”, or “when I get a question right.” This began to show how interconnected the constructs are. Only when they received external recognition (usually from a greater authority figure, i.e., a teacher or professor) did they feel competent. For students of color, there is a similar response, internal recognition or realization of competence often rests on external recognition. Tonso (2006), found that extremely competent and excellent performing women in an engineering program were rarely recognized as legitimate engineers by professors.

One intern, Melissa, explained that she recognized herself as competent when she understood science concepts outside of her science classes. She stated, “When I recognize scientific concepts, I feel competent. For example, watching TV like, "Oh yeah, I remember that. I learned that." … Just noticing science in basic things”. Melissa felt competent when recognizing science in every-day life. This also highlighted how connected competence is with
recognition. Instead of the external recognition described by receiving a high test grade, Melissa began to discuss how she internally recognizes herself as a scientist when she understood science concepts.

An activity that fostered science competence (and all other science identity constructs) was the BioBus hands-on research experience. The participants’ growth in content knowledge that I observed throughout the course of the year was evidence of an increased level of competence among the interns. For example, during an early observation (October), interns were contributing knowledge and researching to come up with novel research ideas for a topic in soil science. The BioBus scientist began by explaining how the category of ‘soil’ was extremely broad, and everyone needed to first research what other scientists had learned. After saying this, one intern (Anna) spearheaded the conversation by mentioning the topic of nitrogen in soil, and how natural selection in evolution and strains of microbes in soil due to fertilizer were affecting organisms. After this, both interns (Anna and Ava) began researching and reading articles pertaining to soil. During their reading of research articles, they were writing specific terms and listing their definitions, as well as providing a summary of important information. Much of this links with their performance, as eventually Anna and Ava designed and implemented a research project that examined how lead contamination in soil impacts the growth of plants and future generations of plants. The gain in competence from researching and learning was the precursor to the science performance they later embodied. After competence came science performance. In understanding science content, students then gained confidence to develop their ability to perform as a scientist.
Performance

Performance takes place after learners grow in science competence or after they have developed a strong understanding of science knowledge. The performance dimension as defined by Carlone and Johnson (2007) is “social performances of relevant scientific practices” (p. 1191), which includes, but is not limited to, engaging in science discussions and using scientific tools. Over the course of the year, conversations with scientists were routinely observed and balanced with equal contributions from the interns and scientists. BioBus scientists engaged with the interns in conversations about the content and the design of their research project. For example, in a midpoint observation (December), I observed a conversation between a BioBus scientist and intern (Anna), where Anna was explaining how she would go about putting together her experiment. This instance involved Anna and Ava, who were researching the topic of soil. When asked how she would go about designing her experiment, Anna explained that she would pick plants with antioxidants (specifically leafy greens) and then create control and experimental groups. She continued to explain that she would plant them in lead-rich soil. The scientists interjected with some clarifying questions, such as how they’d go about getting the soil, to which the intern showed a website that had data on lead levels of soil in different areas of the neighborhood. The scientist began writing down ideas for methods and searching for what could be used for a control plant. The conversation continued with the scientist asking how they were to measure the health of the plants. Ava suggested that previous research used height, number of leaves, color, biomass. The scientist nodded and suggested to refer to the most current and relevant literature to narrow down exactly what they would be measuring.

In another group, interns and their mentor scientist went back and forth in their discussion on the small soil-inhabiting, round worm (*Caenorhabditis elegans*) – a commonly
used model organism. Specifically, Amanda, Sara, and Tiffany discussed how *C. elegans* can be altered, and then studied. The participants were describing a specific life stage of the *C. elegans* known as “dauer.” Dauer, an induced hibernation stage, was the topic of conversation between interns Amanda, Sara, and Tiffany. During this midpoint observation (December), all three interns were debating how it can be used in their experiment. All three interns were intrigued with this life stage, and they described it as similar to “arrested development”, meaning that, instead of continuing through their normal life stages, *C. elegans* move into dauer if they are experiencing stressful environmental conditions. The interns discussed how studies have shown a change in behavior of post-dauer *C. elegans* adults compared to *C. elegans* adults that do not experience this stage of “arrested development.”

In addition to observing the depth of the science discussions interns were participating in at the BioBus internship, during an interview, Sara mentioned how her science discussions were trickling into her everyday life. And it was during moments like that when she felt like a scientist because she was able to participate in discussions and bring the science content into everyday conversations with “non-science people”, Sara stated:

Sara: I feel like BioBus has really helped me, kind of with that imposter stuff, but also realize that I can communicate science. It's kind of like, I've learned how to explain science in a way that other people can understand. And I think you can see that with my suitemates. I mentioned they're non-science people, but with them, I feel like I've started to be that science person. I can talk to them about this or that. I was reading this article the other day about how studies that say breakfast is healthy for you, or eating breakfast in the morning is healthy for you. [The article was] sponsored by Kellogg's and other big cereal companies. And that they might not be as legitimate because of that. And that new studies recently have been showing that like breakfast isn't necessarily good for weight loss.

Researcher: And that's the common thing that everyone thinks.
Sara: People are like, "Breakfast is the most important meal of the day." That's actually a big cereal message. [laughter] And me and my friends, we were talking about, we were trying something called Keto.

Researcher: Yes, The Keto diet, or way of eating.

Sara: And I was like, "That's kind of... Like eating too much protein is bad for you. And if you ever go off and start eating carbs." I was talking about like the physiology of it. Your body literally changes how it metabolizes things when you're not eating carbs. So if you do start eating carbs again, you're gonna just gain the weight back. It's gonna come back. And we were talking about different ways, I guess, to lose weight. This is one of our resolutions together. It was one of those things where I was like, if this was another time period or timeframe in my life, I probably wouldn't be, like talking... or this aware. Or even like bringing in the science and like, with the drier stuff into this. I would keep those kind of interests away from my conversations with my friends.

This powerful message conveyed by Sara illustrated how her science identity was becoming heavily woven and intertwined with her everyday life, not just within science settings. She was taking information from science sources and reading articles. Then she was synthesizing and analyzing them in a way to be able to talk with her “non-science friends.” The interest and relevancy that she feels with science is evident by engaging in discussions and making them science-related.

Later in the year, the interns moved from researching their experimental topics to setting up and doing their research projects. This “performance” of using science tools was observed weekly. Interns moved throughout the BioBus space with ease and familiarity. Whether it was Serena using the microscopes to separate male and female drosophila flies (Drosophila melanogaster, fruit flies) and observe their responses in behavioral-choice chambers, or Melissa carefully removing the left or right antenna of ants to observe the change in behavior, the interns moved autonomously in the BioBus space and readily and comfortably used the materials and science tools to advance their research design. During a midpoint observation (February), I
observed Serena separating drosophila by gender, I asked if she enjoys using the microscopes, to which she responded, “It makes me feel like a scientist working with all the microscopes, in the very stereotypical way.” When using the microscopes, Serena’s comfort and self-confidence with manipulating materials was evident. Anna was observed setting up an experiment to test the gravitropism in different plants. During a February observation, I asked her to explain what she was doing. Anna explained how she was cutting up materials to begin the setup of her experiment, explaining how she needed to first create a secure backdrop for the plants. Without hesitation, Anna completed cutting her backdrop and setting up her plants and retrieved an iPad to begin monitoring her plants.

**Recognition**

Recognition is at the core of identity research (Gee, 2001), with emphasis placed on how others acknowledge individuals as embodying what identities they belong to. Carlone and Johnson (2007) echo the importance of recognition in their framework as well. In creating an identity, one not only rates themselves but is also rated by others as having characteristics associated with a specific identity (Carlone & Johnson, 2007). In order for this internal and external recognition to occur, the interns needed to gain competence and a firm understanding of science content, which they then used to perform in ways associated with a science identity (i.e., using science language, tools, etc.) (Carlone & Johnson, 2007).

In fostering recognition, both internally and externally, the two core activities of the BioBus internship (independent research and teaching) were vital to recognition. Teaching (whether public events or more structured classes) cultivated a feeling of internal and external recognition as a scientist. It did so in a way that maintained a traditional view of a teacher as the
dispenser of knowledge. During a midpoint (January) observation, I asked Serena when she felt most like a scientist at BioBus, and she stated:

Saturday Science makes you feel a lot like a scientist. And just when you're interacting with other people, ‘cause they see you as this very knowledgeable science person, and it kind of distinguishes you from the regular people, and they're like, “Oh, you're the scientist!” You're supposed to tell this person coming in not knowing anything about what's on your microscope or slide, all about it!

Her enthusiasm about feeling recognized as a scientist was palpable, and in turn, fostered her own internal recognition as a scientist. Moments such as this were necessary for the interns to gain confidence and feel recognized as scientists. Melissa also categorized Saturday Science as a time in which she feels like a scientist, “Honestly I feel like a scientist when I'm able to accurately portray, like convey, those scientific topics in a way that they [the public] can understand.” The competent feeling, intertwined with performance (teaching) worked harmoniously together in a way that caused Melissa to recognize herself as a scientist, a challenging task for women of color.

In addition to teaching, participants also felt recognized as scientists by their BioBus mentors. At times when they did not recognize themselves as scientists, the mentors helped interns develop their confidence and recognition. Melissa described how the level of autonomy in her research project was intimidating at first, but ultimately led her to recognize herself as competent in her niche:

I feel like Andrew [BioBus scientist] trusts me a lot. Andrew trusts me with my project. That's why he gave us so much freedom…And sometimes I'm like, "I don't know what I'm doing!" But it made me feel recognized and capable. And now people know me as the ant person.

Sara also describes feeling recognized by her mentor scientist:

Sometimes instead of Lisa [BioBus scientist] explaining something, she'll ask me to explain it. If it's something with stats or something that I've done before. Because I'm a
couple of years older than them [other interns], so that's a type of recognition that I think does make me feel like, "Okay, I know what I'm doing."

Ultimately, it was sharing science knowledge and being able to demonstrate science competence that cultivated feelings of internal and external recognition. During her last interview, Kerry is overjoyed speaking of her time at BioBus and how she has grown to recognize herself as a scientist, and the confidence it gave her.

Researcher: Do you feel like you're recognized as a scientist at BioBus?

Kerry: Yes. Honestly.

Researcher: How?

Kerry: My name tag says Junior Scientist.[laughter] They make me think that like, "Oh like...I'm important. I have a cool title, but it's not even just the title. Or the [BioBus] Gmail account. [chuckle] But it's not even just that, it's the fact that we're able to perform experiments, and explain, and show our experiments to the public and just show them what we've been doing this whole time, and just explaining to the public how things have been going. I feel like that's what makes me feel like a scientist even more.

Researcher: How do you feel this idea of recognition has changed from the beginning of the year to now?

Kerry: I think it's definitely increased in the sense of-- I feel more confident in what I am doing. I think I talk more. I think I really lean in more. I got myself to explain things if I knew it or volunteer to explain something or do something, and I feel like I wouldn't have done that before. It was kind of more passive and I feel like I've taken more of that active role in trying to lead.

While Kerry began with tangible aspects of recognition, such as a nametag or an email account, she was quick to describe the deeper impact BioBus had on her identity and recognizing herself as a confident participant of science. Kerry described both external recognition when she discussed “explaining to the public” as well as internal recognition, when she explains how she felt confident enough to move from passive bystander to active participant. Through
observations and interviews, teaching and disseminating knowledge was essential in recognizing oneself as a scientist. The importance of this feeling of recognition cannot be overstated. As shown by Carlone and Johnson (2007), personal recognition and recognition from others within the science community is an important factor in forming a science identity for women.

Research Question Three

Overall, the group of interns showed significant positive change in their SIS and VASI scores. Analysis of these quantitative measures suggest the BioBus internship supports student growth. In addition to quantitatively examining the holistic (whole group) outcomes, a qualitative approach was also necessary to understand how the BioBus experience related to science identity. The nuances of three specific female students of color were explored in answering the study’s third Research question: How do three female participants of color experience a yearlong informal science education research internship?

For the purposes of this study, students of color were defined as students underrepresented in science fields, including, African-Americans, Hispanics, Native American/Alaskan Natives, and Pacific Islander heritages. Moreover, gender was also included in students underrepresented in science fields. Using a combination of observational data and quantitative findings, three female participants of color were chosen as cases for this study. Kerry, Melissa, and Sara were all participants of the 2018-2019 BioBus Internship (Table 7). All three were chosen because all three identified as women of color and were at different time-points in their academic career, which provided insight into different barriers women of color face at different academic time-points. In addition to their self-identified gender and racial/ethnic identity, and school level, I also wanted to include interns from both days, Saturday and Sunday.
Although both Saturday and Sunday interns taught and completed independent research projects, the style of teaching (weekly structured classes vs. one day public events) was very different.

**Table 7**

*Student Participant Demographics*

<table>
<thead>
<tr>
<th>Name</th>
<th>Racial/Ethnic Identity (Self-Identified)</th>
<th>School Level</th>
<th>Internship Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kerry</td>
<td>Black</td>
<td>High School Senior</td>
<td>Saturday</td>
</tr>
<tr>
<td>Melissa</td>
<td>Black</td>
<td>College Junior</td>
<td>Saturday</td>
</tr>
<tr>
<td>Sara</td>
<td>Asian/Pacific Islander</td>
<td>College Sophomore</td>
<td>Sunday</td>
</tr>
</tbody>
</table>

A cross-case analysis was employed to answer Research question three: How does an informal science education research experience foster science identity among three female participants of color? Included in the cross-case analysis was participant excerpts from interviews conducted at three different time points (pre, mid, and post internship), which were then compared for similarities and differences within and between participants, and ultimately presented as themes.

**Emergent themes.** From analysis of the interns’ interview transcripts, certain themes began to emerge. Two themes emerged from the data collected: (1) students’ self-development and (2) the learning environment. The first theme, students’ self-development, encompassed three sub-themes: (a) self-awareness; (b) self-confidence; and (c) self-direction. While the second theme, the learning environment, described the safe space that defined the BioBus setting and the open design that allowed interns to explore topics of interest.

**Students’ self-development.** The first theme discovered through qualitative methods was ‘self-development’. Three subthemes emerged from the data and are presented below.

The first sub-theme was self-awareness. The interns were given the responsibility to plan, design and implement their own research projects. As a result, they developed an understanding
of their likes, dislikes, and an appreciation of science as a process. In addition to the BioBus internship goal of providing students with an authentic science research experience, there was also a teaching component that was woven through the program over the course of the year. Saturday interns taught at monthly public events held for the surrounding community. These all-day events consisted of interns teaching at different stations and leading activities to explore topics in neuroscience. BioBus interns taught monthly at these events to an audience that ranged from young children to the elderly. On Sundays, BioBus holds a more structured program called “Sunday Science,” where students aged 8-12 enroll to participate in a series of hands-on science classes. The Sunday Science classes were co-taught by BioBus scientists and Sunday interns. Kerry and Melissa participated in the Saturday teaching events while Sara taught Sunday Science. The interns identified these teaching events as enjoyable or sometimes, surprisingly enjoyable. In both experiences, the interns reflected on it fondly. Not only expressing how they enjoyed it, but how it gave them confidence in their abilities to understand and explain science and improved their communication skills. “I really enjoyed talking with the kids,” stated Sara in her final interview, “I feel like the weeks that we were working with the students were my favorite, even though I liked the research we did. I never thought I would like teaching, but it’s something I actually really enjoy.” While Sara realized her interest in teaching, Melissa looked at her teaching time as something that “intensified” her teaching interest. She shared, “It [teaching] made me want to go more into teaching. ‘Cause I was interested in teaching, but over the year it intensified.” The act of teaching went somewhat deeper for Kerry, she explained how teaching made her view herself as “capable.” In her last interview, Kerry stated:

Kerry: I would say I loved teaching the kids.

Researcher: What specifically about it did you love?
Kerry: Just seeing their faces when they're learning something new, them asking questions and how they're generally interested in what we have to say makes me feel like, wow, I'm capable of teaching other kids things about science. I'm also capable of sharing my scientific abilities and knowledge to the public.

In addition to realizing or solidifying their affinity towards teaching, the participants became more aware of their interests and aspects of the practice of science. Over the year, Melissa described that the experience made her more self-aware: “I learned a lot about myself, like my skills, my strengths and weaknesses, and I've learned a lot about where I would be most comfortable working in.” Melissa continued to explain how the internship changed her view toward science and scientists from naïve to more informed. She mentioned in an interview at the end of the internship:

At the beginning, I thought everyone knew more than I did. And then, now I just realize that people just have their niches. People have their niches and just because you don't know about that specific area doesn't mean you don't know anything. I know ants. I don't know much about chemistry or things like that, but I know about ants. And that's my niche.

A powerful change in perspective allowed Melissa to view her science knowledge as equal to other’s that she may have viewed as more knowledgeable before. Realizing that everyone is constantly learning in science allowed her to view herself as a participant of science, rather than an observer. A similar idea was echoed by Kerry at her midpoint interview:

I've learned that I don't know much. [laughter] I guess that's one of the things about science, you have to admit that you don't know everything, and you have to be open to knowledge and just open to learning from people. 'Cause also they're many aspects of science. So even if you're an expert in your field, you might not be an expert in someone else's field.

Within the same interview, when asked about her research project, Kerry brought the same mentality of openness and learning:

I think it [research project] has taught me patience. [chuckle] I think it's fine having an expected outcome, and that not happening or just having your experiment turn a completely different angle than the way you imagined it to be. So I feel like, with
BioBus, having working on this project over two years, it really helped me broaden my interpretations and what I expect of my project.

Here, both Melissa and Kerry are connecting what they learned about science with awareness.

By the middle of the internship, all the participants had gone through mapping out their research questions and piloting methods. In doing this, participants became aware of the broadness of science. And that with this broadness, comes many unknowns; the interns were aware that they might not know all the answers, and over time, felt OK with not-knowing all the answers.

Understanding the vastness of science, becoming aware that along the process of gaining science knowledge one must be open to learning and open to failures, was also discussed by Sara in an interview at the end of the internship:

Sara: I feel like I'm not as nervous going into lab or science spaces anymore. And that's something that I think comes from understanding that a lot of science is failure. A lot of it is kind of not knowing what you're doing and figuring it out. It's the process. … I started working at this new lab in spring break.

Researcher: The one that you'll be in this summer?

Sara: Yeah. And I remember they [scientists] were telling us about all the different techniques they were using. It was my first time using one of those like automated pipettes. I forget what they're called.

Researcher: I think I know which ones. Are they navy blue?

Sara: Yeah, they're huge! And I remember being like, “Wow.” They were telling me how expensive the equipment is. [chuckle] I remember thinking in my head, "It would be so bad if something happened." But I think even going into it, I was pretty confident in pipetting and we were working with stem cells. And I remember thinking about if this was a different time, I would have been so nervous; my hands would have been shaking like, “Oh my god, I’m gonna do something wrong.” And there would have always been that thought in my head of what if something happens. But I think by March or by this late spring I didn't feel that anxiety anymore of, “What if I mess up?”.

The three participants gained a powerful outlook on science. By the middle and end of the internship, the participants became aware that science and science labs are not filled with
individuals who are all-knowing and never make mistakes, but rather they are filled with people who have areas of expertise and are open to learning from one another and have become an expert in their field by learning from making errors along the way. Their awareness maps a journey beginning with surface level likes and dislikes and ending with a deep awareness of science. In becoming cognizant of this, the participants gained a sense of confidence imperative for women of color to gain in order to persist in the field of science.

The second sub-theme was self-confidence. The responsibility and freedom to work through a science research experience not only allowed participants to become more aware of their likes, dislikes, and perspective towards science, but it also increased their confidence in themselves and their abilities as scientists. Melissa attributed her gain in confidence to the process she went through in her research project. During her second interview, she explains:

Melissa: It has helped me gain independence as a scientist

Researcher: How?

Melissa: This project was mostly very independent 'cause I had to come up with my own structure. Most other people, other interns, the products they're working on were assigned to them or given to them by BioBus. …Right. So everything was somewhat given to them, the structure, what they were finding, and things like that. But for me, since my project is very new, I had to basically structure it myself, come up with the research process, and it taught me a lot. It has helped me gain a lot of independence in science.

Researcher: Do feel confident in your abilities?

Melissa: At first, I wasn't, [laughter] I was like, "Tell me what to do!" At first, I wasn't, but now I feel really confident in myself.

Melissa began her internship knowing one thing, she wanted to study ants. Throughout the first half of the internship Melissa read articles, brainstormed with her mentor scientist, and mapped out possible research questions. Her frustration in the beginning was palpable, her
research questions changed frequently, and she found the work of previous scholars confusing. She once stated: “Scientists don't tell you how hard it takes or how long it took them to actually achieve that. They just tell you, "Okay, we did this, we did that, 'cause I try to replicate it and was like, How did they, what!?". After going through a number of ants (many batches died before Melissa collected any real data) and research questions, Melissa finally landed on a research project she independently designed, planned, and executed; she studied the effects that various experimental treatments on the ant’s antennas had on their behavior. In the excerpt above, Melissa was finally able to confidently speak about her capabilities as a research scientist.

Kerry explained how her time at BioBus helped her “get out of her shell.” During her second interview, Kerry spoke confidently about her abilities to share her viewpoints and contribute to conversations. She stated:

As a person, BioBus allowed me to get out of my shell because when I first came here, I was really shy. I did not like talking to people like that [in a public setting]. [chuckle] But they really helped me with my public speaking skills, ’cause now I can talk freely in school and whenever I’m presenting or... Now I can really talk to people my own age or just not my own age, but people of any status. Yes, I can honestly say that because of BioBus I feel more... More proud and more confident in myself to say that, "Oh, I know about this science thing, I could show you." I feel like they’ve exposed me to so many new possibilities, and so many new things that I wouldn't have known from regular school.

In this excerpt, Kerry described that at one point in her life, she did not enjoy speaking in a public setting, but now, she is confident to say “Oh, I know about this science thing,” attributing her confidence to an increased sense of science competence. The gain in scientific knowledge that she attributed to her time at BioBus broke down power dynamics; as she described herself as confident to talk to “people of any status.” Saying “people of any status” implied that at one point she perceived certain people as more powerful than her or more knowledgeable than her, causing her to shy away, not speaking with them; a feeling she no longer has. Breaking down
power dynamics was also discussed by Sara in a moving description of how she no longer viewed herself as “an imposter”, reducing the impostor phenomenon she was experiencing (Clance & Imes, 1978). At her final interview, Sara stated:

Sara: I went to a research mixer the other day at [a local university] and I was like, “I don't feel as intimidated as I used to talking to people.”

Researcher: That's fantastic because I specifically remember you saying sometimes you felt like an imposter.

Sara: Yeah. I think a big part of it has been my time at BioBus and also the STEM ambassadors at [a local university]. I’m gonna be the president next year.

Researcher: Oh, congratulations!

Sara: I'm really excited because one of the sessions we had was Impostor Syndrome and Navigating Academia as a Woman in STEM. And it was really interesting because when we talked about it, one of the things we said was, "Oh, raise your hand if you've ever felt like an imposter, or you ever felt like you didn't belong or weren't qualified." And we talked about how to combat that, and how everyone is valid, and a lot of times women underestimate themselves. So, I think even if I felt that before maybe leading those kinds of workshops and having those kinds of events and being able to tackle that with other people have helped me feel like less of an impostor myself.

In this excerpt, the importance of informal environment, and engaging with other women in STEM increased Sara’s confidence in science. The safe environment (discussed later as well) of the BioBus community and the comradery Sara felt within her STEM ambassador’s program were imperative for feeling heard and supported. The results allowed Sara to persist in the field of science. Sara, a Biology major, was a sophomore in college. During the same interview, she added:

I think nowadays, especially this semester, I could say all the time that I come to BioBus and I’m like... [chuckle] "Let's go, let's do science!" I come into it with this mindset, "We're gonna do science today." Whether that's with teaching the kids or doing research or making the poster, it's kind of just like you come here and it feels like you're on, you're ready to do science. I can say that it didn't feel like that before though. I feel like sometimes it felt like I was coming in and I was like, "I don't know enough about
neuroscience or whatever to teach," even if I did. And I'd be like this, "I don't know if I'm doing this right or if I feel like an actual scientist."

As Sara and I continued to talk about her experiences as a woman in science and working as an intern on BioBus, she shared that her confidence came from having done this before. For example, doing the Sunday Science set-up was familiar and gave her confidence in preparing and teaching. The only difference was that she may not be as familiar with the content knowledge being taught. Sara stated:

I don't know. I feel like part of it has been because me either teaching food science now this semester. I didn't know anything about it, so I kind of went more out of my way to learn. And also just feeling more confident with being like, "Okay, I've done this before. We already ran Sunday Science before. I've been through this. It's nothing... The actual stations and the set-up, it's really not anything new. It's the content that's new." It's like, "I know this. You got this!"

Sara’s face glowed with excitement when she spoke of how capable she felt when stepping into the lab. The above excerpt was taken from Sara’s last interview, during this time she was visibly less stressed. In the beginning of the internship, the stress that Sara felt by constantly questioning her abilities could be seen on her face and was reflected in her low, timid voice. During her post interview, Sara reflected on her growth, explaining how she is confident to no longer call herself an imposter. The confidence Sara, Kerry and Melissa, gained in themselves, in their science skills, and in their content knowledge influenced their next-steps in science and their careers.

The last sub-theme was self-direction. Upon the culmination of their internship, participants referred to having a clearer understanding of their future decisions. Although all the participants expressed their interest in science and their research project, their next steps were not necessarily along the path of science research. Rather, the BioBus internship provided exposure and a safe environment for science research that allowed the participants to develop a clearer understanding of themselves and their future. For example, Melissa began by describing
how the idea of BioBus as a non-profit solidified her desire to engage in non-profit related work.

In her final interview, Melissa stated:

**Researcher:** Do you feel like BioBus has influenced your future decisions in any way?

**Melissa:** I'd say yes actually… the whole concept of BioBus, I find it inspiring. I feel like I really want to work for a nonprofit or in a nonprofit. I had that desire before coming to BioBus, but it’s actually solidified that desire and I feel like yeah, I just like the whole idea of BioBus. Like, research aside, just the idea of having this grant-funded research labs and from different communities. I like that idea.

Melissa had a clear love for science. She paved the path for her research project on ant behavior and spoke fondly of teaching science to the public. However, for Melissa (a college junior majoring in biology and minoring in art) her time at BioBus did not solidify a career in science, it solidified a career in non-profit work. Kerry spoke more to the impact BioBus had on her science trajectory. During her final interview, she stated:

I feel like BioBus completely impacted my decision for majoring in science. Because I feel like if it wasn't for BioBus, if it wasn't for my time being spent here and just learning about science and just getting that interest, that drive in science, I feel like I wouldn't be where I am right now…I’d probably be undecided, like going to college, figuring it out... but BioBus has definitely solidified my passion for science.

While Kerry was finishing high school as her year at BioBus was ending, Sara was finishing her Sophomore year at a local university. Although the two were of different ages and at a different point in their academic career, the BioBus experience kept science within their next step. For Kerry it was knowing she wanted to major in science, and for Sara, who was a science major, it was continuing as a science major. She had previously thought about changing her major due to a bad experience at her university lab setting. During her final interview, she recalled the incident that made her seriously consider dropping her science major, she stated:

**Sara:** The process we went through with coming up with a research question and designing our own experiment and then seeing the community that the lab had, made me be like, "Wait a minute, maybe I do like
science." I was so close to just switching out of the School of Environmental and Biological Sciences (SEBS) at [a local university].

Researcher: Oh no, why?

Sara: I was really, really, really fed up. I was like, "I'm never gonna do research again." And for my major at SEBS the Biological Science School for the Honors College you have to do research every single semester for credit. So I was in this position where I was like, "I can't graduate honors if I don't do research." And then in terms of that credit, [Sara’s BioBus Mentor Scientist] actually helped me out because she was like, "Okay you can do the research here at BioBus for credit.

Researcher: Oh that's fantastic.

Sara: And it counted! Thankfully, that happened, ‘cause I was like this close, literally this close to leaving SEBS. And then last week, or two weeks ago, right after the last semester ended, I took a health and policy class and really liked it. I was so close to switching. And then I was like, “You know what? I wanna do both. I can't let go of science, but I still wanna do health and policy.” So, I switched from a biotech major to a public health and biological sciences major.

Researcher: That's amazing. Do you think BioBus did or did not influence your future decisions when it comes to your major or your interests?

Sara: Yeah, definitely in the sense that like I can say if I had... I guess if I hadn't been working in science outreach and communications and seeing how important science is on a broader scale of things, then my bad experiences in the lab at [a local university] ...would have probably made me be like, "No, like I'm out." Why go through this? Because science, there's a lot of bad sides to it. There can be a lot of toxic bad sides to it, but then there's also so much good that science can do, especially like teaching science. I think it's empowering, seeing people learn about science and be interested in it.

Sara is not the first to describe how a negative, toxic, lab environment can cause female students of color to dis-identify and change from a science major to a non-science major (Carlone & Johnson, 2007; Hill, Corbett, & St. Rose, 2010; Mensah & Jackson, 2018; Rosa & Mensah, 2016). The most important aspect coming from Sara’s description was what caused her to stay within the field. Her newly acquired confidence and sense of self, fostered by BioBus,
empowered her to overcome her negative experience and seek new science experiences that left her feeling positive and powerful (i.e. a health and policy class). The positive learning environment that BioBus created was a common factor for Melissa, Kerry, and Sara. It allowed them to safely explore and develop themselves as women of color in the field of science.

**The learning environment.** The final major theme discovered through qualitative methods was ‘The Learning Environment.’ The analysis is holistic, and no subthemes were discovered. This theme emerged from the evidence obtained from a description of the physical space of BioBus. One that was classified as “fun”, “non-threatening”, and “open”. In addition to being described as non-judgmental, participants also enjoyed the physical space of BioBus because of the autonomy they received in pursuing topics of interest. Providing students with autonomy within the science classroom has been found to allow urban students of color to participate and feel connected with science (Emdin, 2009). Within the BioBus setting, the sense of autonomy coupled with the open learning environment facilitated their self-development (self-awareness, self-confidence, self-direction) as described above.

Melissa contrasted the BioBus environment with her formal science setting. She equated BioBus with “hands-on” compared to her experiences in the formal classroom where she noted “in school, your professors, they mostly talk at you, ‘Oh, this is X-Y-Z and your test is tomorrow.’ But this [BioBus] is more hands-on, [and] I see everything for myself, and it’s more fun.” In addition to the hands-on aspect of BioBus, Melissa also described the physical equipment which she had used for her research. She stated, “There’s so much to learn and so many really cool equipment, like the microscopes, high quality microscopes...there's so much to learn in BioBus.” Kerry makes a similar distinction between her formal schooling and her experience at BioBus. In her final interview, she stated:
BioBus to me is different than my regular science class because we actually get to choose what we really wanna focus on. We get to decide where we want the course to transition into and how we want the variables to change. It's like, learning is much more you-based instead of like, "Oh, we're doing this for a grade. We have to do this by a certain time limit."

Doing science for the sole purpose of learning and not receiving a grade is a defining characteristic of informal settings and aids in maintaining positive attitudes toward science and fostering a stronger science identity. The sense of autonomy that Kerry described is vital to students’ development as it has been linked to increased STEM identity (Vongjulluksn, Matewos, Sinatra, & Marsh, 2018) and interest development (Black & Deci, 2000). Learning without the fear of grades, coupled with the autonomy to explore one’s interests, led to the growth experienced by the participants. In the same interview, Kerry spoke more about the freedom to learn, which she attributed to the non-judgmental environment at BioBus. This is evident in her responses to the interview questions.

**Researcher:** In school, or at BioBus, are there times where you don't feel very capable in science?

**Kerry:** If I was to get that feeling at school or at BioBus, I would say it would be from situations where there would be a certain topic where I didn't fully understand and let's say my other classmates grasped it immediately and I would feel like, “Oh, how come I'm not understanding this as quickly as they are?” or “How come I'm not like engaging or just grasping the material?” So, I guess situations like that is where I would feel like, “Oh maybe I'm not up to standards like everyone else.”

**Researcher:** Do you feel like that at times at BioBus?

**Kerry:** No, not really because I feel like everyone here is learning, even the PhD scientists, everyone is learning at the same time. So I never feel like I’m not understanding or learning as quickly as others…and I really appreciate that we learn together as a community and no one tries to make you feel like you're beneath them like, “Oh, I know more than you do.” I think that's what makes it really comfortable.
Kerry described that while she learns in both her formal classroom and at BioBus, she does not compare herself to others like she does in her formal school setting. At BioBus, everyone was going through the process of acquiring new knowledge and it was not a competition to see who gained the most knowledge. Whereas, within a formal setting, competition exists, most commonly in the form of tests or other summative assessments. In removing the feeling of competition, Kerry was at ease. Although she made a point to highlight the PhDs her mentor scientists held, that did not cause her to question her capabilities or feel as though she was not as smart as them. The environment BioBus created allowed Kerry to feel equal to “PhD scientists” and learn in a communal setting. An equal learning community was also described by Sara. In her final interview, she stated,

And it'd be like we'd ask each other questions, and when we asked each other questions it wasn't to belittle each other or to bring each other down. It wouldn't be like, "Oh why do you think this would work?" But it'd be like... Like, "What do you think?" It'd be just like, "What do you think could go wrong?" Instead of, "It's not gonna work."…It's kind of like, it just instead of bringing each other down or being that really pessimistic or like, "Oh, that's so stupid. Why would you ask that?" It's more like, "That's a good question, let's talk about it."

The feeling of being recognized as peers with BioBus scientists was powerful for Kerry and Sara. By not having the pressure of grades, or being judged for not knowing information, they were able to explore ideas more deeply and grow their love for science. Sara continued by describing how the feeling of being recognized in a safe space as a scientist gave her the confidence she needed to stay in college as a science major:

This is one of those places where I feel like I am a scientist, or I am comfortable, versus in more...less friendly spaces, like back at my college at [a local university], it's not as friendly or as inviting or you don't... I don't know. I wanna learn, but I feel like there's this barrier to learning and that's just learning jargon or how to speak science.

Sara previously described how she felt like an imposter at her university. Negative experiences in her university research lab caused her to question her knowledge and capability as a scientist.
However, while the friendly BioBus pushed her to persist, Sara acknowledged the “jargon” and language that often is a barrier in science (Moore, 2008). However, Sara did not equate science with the “jargon” often seen as a barrier, she acknowledged it, but then equated science to the optimistic, communal, and friendly environment of BioBus. She explained in her midpoint interview how BioBus gave her the confidence to persist in science and be confident in no longer identifying as an imposter. She stated:

One of the reasons I even made the decision to major in a STEM major was because of coming to BioBus … I went to a bio-medical science high school. I really loved science up until I think high school, where I also felt kind of impostor-y but then coming here, I was like, "Wait a minute, I really like this. I can see myself doing this." And then I took some biotech classes my spring semester [of college] and I was like, "I could probably do this."

From the interviews, it became evident that the space and feeling fostered by BioBus was very important in shaping the positive experience of Sara, Melissa, and Kerry. This positive learning environment and overall experience the participants had at BioBus facilitated the growth Sara, Melissa, and Kerry described in the first theme of this study. In expanding upon the importance of the informal learning environment and experience, the third research question explored the ways in which the informal science experiences directly influenced the three female participants of color.

**Summary**

In this chapter, the findings related to the study’s Research questions and corresponding sub-questions were presented. The study was divided in a way to first analyze the whole group of BioBus interns (Research questions one and two), then a specific subset of female women of color (Research question three). Quantitative data was used to analyze the first Research question. A statistically significant difference in students’ VASI and SIS scores from pre, to mid, to post BioBus internship was found. This finding illustrated a significant growth in the way
students identified as scientists and their understanding of science inquiry from the beginning of the year to the end.

To highlight the specifics of the BioBus internship that corresponded to the identity framework (Carlone & Johnson, 2007) and answer research question two, qualitative analysis revealed the activities that fostered each construct of the science identity framework. The core activities of the BioBus research internship – undertaking an independent research project and teaching – were found to foster the development of students’ science competence, science performance, and science recognition.

Finally, qualitative analysis of the evidence revealed two over-arching themes for Research question three. They were: (1) students’ self-development; and (2) the learning environment. The first theme encompassed three sub-themes: (a) self-awareness; (b) self-confidence; and (c) self-direction. The second over-arching theme, the learning environment, described the safe space and the self-directed environment that allowed the interns to explore topics of interest. In the next chapter, I discuss in greater detail the quantitative and qualitative findings of the study.
CHAPTER V

DISCUSSION, IMPLICATIONS, NEXT STEPS AND CONCLUSION

The purpose of this study was to uncover the broad implications of an informal science education research program, as well as tap into the nuances of the experiences of three women of color. The Research questions this study asked were:

1. How do participants (whole group) experience a yearlong ISE research internship?
   - Is there a statistically significant difference in students mean Views About Science Inquiry (VASI) score across a yearlong internship?
   - Is there a statistically significant difference in students mean Science Identity Survey (SIS) score across a yearlong internship?

2. How does an informal science education research experience foster science identity among participants of color?

3. How does an informal science education research experience foster science identity among three female participants of color?

Research Question 1: Statistically Significant Change of the Group Experience

Views About Science Inquiry Questionnaire results. The US National Research Council’s consensus report, Learning Science in Informal Environments: People, places and pursuits (NRC, 2009), noted that informal learning experiences are essential for students to develop important skills for science learning and to learn about the natural world. The report explored how these spaces transform science into a relevant experience more than formal learning experiences, and it described the venues such as science camps and after-school programs invoke a passion for science. However, due to the nature of informal learning experiences, the field struggles with measuring learning outcomes (NRC, 2009). Given the
recent emphasis on the importance of informal learning, it is imperative to put forth efforts in assessing how informal learning programs are meeting the learning strands addressed in the NRC Report (2009). Strands 3 and 6 of the Report (NRC, 2009) were the focus of exploring the study’s first question.

Strand 3 focused on the activities and skills of science, including scientific inquiry skills (NRC, 2009). The results of the VASI questionnaire showed significant change in students’ understanding of science inquiry. The combined mean scores of the cohort was observed to begin at 19.5 out of a possible 24, rise to 21 at the internship’s midpoint, and end with an average VASI score of 22 (approximately ten percent of total score). A repeated measures ANOVA revealed a strong statistically significant (p < .01) difference in students pre to post VASI scores. The large effect size (Hedge’s g = 1.18) is encouragingly important because it shows the statistical magnitude of the relationship between students VASI scores and the time they were at BioBus. Although the change in VASI score was statistically significant, these participants started with a high VASI score. While students started high and gained significantly, this is not unusual because they had a more advanced standing initially than most typical students might have had. Moreover, some of the participants were college undergraduates, putting them at an even more initial advanced standing. Lastly, because the BioBus internship is voluntary these participants are more inclined to have a more advanced standing than most typical students who might never apply to an informal science internship.

Breaking down the scores by component revealed what parts of science inquiry were developed in the internship. By the end of the internship, 60% (N = 7) or more of participants scored informed (I) in all eight of the components of science inquiry. The most growth occurred in science inquiry component two and five: there is no single set and sequence of steps followed
in all investigations (i.e. there is no single scientific method), and inquiry procedures can influence the results, respectively.

Creators of the VASI questionnaire (Lederman et al., 2014) participated in a large-scale international research project to collect the first baseline data of beginning middle school students' understanding of science inquiry. The study spanned eighteen countries and/or regions and included 2,634 student participants. The United States was among the participating countries and contributed 164 students to this large-scale study. Although these participants were middle school aged students, BioBus interns scored relatively similarly to them on two components of science inquiry-- there is no single set and sequence of steps followed in all scientific investigations, and inquiry procedures can influence the results. Suggesting that these aspects are challenging for learners of all ages to understand.

The 46% increase observed in VASI component two, and the 55% increase in component five suggests that the multi-step process the interns went through of planning, re-planning, implementing, and editing their research projects broke down misconceptions of “the single scientific method” (science inquiry component two) and explicitly taught them how their procedures were influencing their experimental results (inquiry component five). Moreover, the increase highlights the necessity of giving explicit support in the scientific process. This confirms findings from existing literature that knowledge about inquiry is simple not developed through engaging in science investigations, it must be deliberately taught (Abd-El-Khalick & Lederman, 2000; Bell et al., 2003; Lederman & Lederman, 2012; Metz, 2000).

The growth observed among BioBus interns suggests the importance of students being given the opportunity to develop their own research question. Prior studies similar to a BioBus research experience include narratives about how scientists describe their student mentees as
engaged in the development of research methods, data collection, and interpretation. However, they were not given the opportunity to develop research questions for the investigations they were involved in. As a result, although engaged in the process of inquiry, they did not develop their understanding of science inquiry (Bell et al., 2003; Krim, et al., 2019; Sadler et al., 2010;).

Furthermore, in direct contrast to the BioBus interns, participants in the Bell et al. (2003) study exhibited a strong belief in the single scientific method, even though many of their research projects were descriptive rather than experimental. Thus, in understanding science inquiry component two, there is no single inquiry strategy nor a formal sequence of steps (i.e., there is no single scientific method), the findings in this current study suggest that the BioBus method of explicit mentorship in the scientific process from designing a research question to presenting results allows students to develop a conceptual understanding of the creative fluidity of the scientific enterprise and gain a deep and true understanding of scientific inquiry, beyond the previous canonized formal steps of scientific research.

**Science Identity Survey results.** Strand 6 focused on the importance of identity by setting the goal for learners to develop an identity as someone who uses and contributes to science (NRC, 2009). Although science identity is not an easily quantified construct, it is important for informal science centers to assess their impact on science identity development, because informal science education can help develop science identity beyond the limitations of the classroom. Students are provided opportunities to explore science in a way that is potentially hindered in the classroom because students of color often are perceived by their teachers and schools in a way that is at odds with how they’d like to be perceived (Carlone & Johnson, 2007; Gee, 2000). Interacting with new adults, new science content, and a new method of teaching (student-centered, hands-on inquiry), allows students to explore and adopt new identities.
Although science identity cannot be boiled down to one quantitative instrument, the use of a quantitative tool to assess change is extremely useful in informal settings, which often have limited assessment tools addressing identity, and lack time and resources with students to use more lengthy options such as interviews (Schon, 2015).

The results of the SIS showed significant change in students’ science identity. A repeated measures ANOVA revealed a strong statistically significant (p < .05) difference in students SIS scores. Like the VASI questionnaire, the results of the SIS had a large effect size (Hedge’s g = 1.09), illustrating the magnitude of the relationship between students’ SIS scores and the time they were at BioBus. The unique opportunities and the close community of students and researchers may contribute to the gains participants make. The statistical significance (p < .05) and substantive significance (Hedge’s g) are both important in the findings. The statistical significance suggests that the BioBus internship supported appreciable growth in students understanding of science inquiry and science identity. The substantive significance has implications for further research as it suggests that the growth seen at BioBus is generalizable.

Breaking down the scores by science identity construct — competence, performance, and recognition — revealed, beyond the inferential statistical evidence, what specific parts of science identity that the BioBus internship developed. All aspects of science identity experienced growth over the year. For competence and performance, the combined growth that occurred from mid to post was double for pre to mid. Observations suggest that this growth can be attributed to the increased hands-on research activities that occurred during that period. By the mid time point, students had finished the planning and designing of their research projects and were working their way through their procedures, using scientific tools, and collecting data. These activities are
characteristics representative of how Carlone and Johnson (2007) define science competence and performance.

The largest growth occurring in the participants’ sense of recognition is particularly important, because Carlone and Johnson (2007) find recognition to be the most salient factor in developing and solidifying a science identity and the one least developed in formal classrooms. The indication that the BioBus internship fosters recognition for its students is an important benefit as it illustrates how informal spaces offer a safe environment for combating formal science grades – a defined measure of how students perceive science recognition (Carlone & Johnson, 2007; Schon, 2015). Unfortunately, the opinions of others, and the acceptance we receive, matters a great deal when it comes to accepting oneself as a type of person, i.e., a science person. A lack of recognition has serious negative consequences for students of color regarding persistence and science degree attainment (Wade, 2012), only further emphasizing the importance of informal spaces to foster recognition in students of color. The significant growth in recognition ($p < .05$) indicates that by having scientists, who have a Ph.D. and Master’s level of accomplishments, genuinely regard and mentor the interns as scientists by external recognition, improves participants’ self-image. Interns are more likely to recognize themselves as scientists (internal recognition). Through observations and interviews, recognition was fostered by the activities of students engaging in teaching and hands-on research. By structuring the yearlong internship around these two activities, the BioBus program tapped into a construct that is at the core of identity research and is also particularly challenging to develop.

Overall, the quantitative data indicates that the BioBus program encouraged students to gain a deep understanding in their knowledge about science inquiry and develop a stronger science identity from the time they began the BioBus internship to the end. In both measures of
inquiry and identity, students demonstrated increased growth in all constructs of science inquiry and the way they view their science competence, performance, and recognition as scientists. Implications for practice in informal science education settings are discussed later.

**Research Question 2: BioBus and Science Identity**

Students’ science identities have largely been framed within the context of school science (Brickhouse & Potter, 2001); however, with identity being dynamic in nature and situated differently in different contexts (Chen & Mensah, 2019), informal science education contexts have the potential to influence students’ views of themselves as scientists. The NRC Committee on Learning Science in Informal Environments began to incorporate identity as an appropriate outcome for science learning in informal settings in their report, *Learning science in informal environments: People, places, and pursuits* (NRC, 2009). The discussion of the second Research question provides insight into the nuances of the ISE experience, and how it fostered the science identity of students.

BioBus interns were given access to various sources of social capital (peers, scientists, volunteer scientists) and material supports (using science tools through guided mentorship, teaching under guided mentorship) that allowed for a unique and meaningful engagement with science. Specifically, this study showed that through authentic science and teaching, BioBus was a place for students to refigure their view of science and themselves in science in an empowering way. With over 80% (N = 11) of participants identifying as female or an underrepresented racial/ethnic group, the BioBus experience positioned participants as capable in science in a way that fostered their internal recognition as a scientist. Recognition (of self and by others) is essential for science identity development for women, generally, and for women of color, specifically (Carlone & Johnson, 2007). Recognition is critical for women generally, and women
of color, as they have historically not been recognized as “science people”, highlighting the problematic nature of recognition by others in cultivating satisfying science identities (Carlone & Johnson, 2007; Rosa & Mensah, 2016).

**Research Question 3: The Individualized Experience**

The themes which emerged from an analysis of focal participants in the study—Kerry, Melissa, and Sarah—provide evidence of the growth they experienced as individuals, and yields a unique insight to the way these three female students of color flourished in an informal setting. The theme of self-development was divided into three sub-themes: (a) self-awareness; (b) self-confidence; and (c) self-direction. The three participants explained how their time at BioBus made them more aware of their interests and disinterests (science related or otherwise), more confident in their ability to have a voice and presence in spaces they might not have felt confident in otherwise, and lastly, the three women felt they had clearer understandings of their future and what they wanted for themselves.

When female students of color enter a science space, they not only have identities as learners, but as female science learners of color. Science departments in some colleges and universities have been noted as being aligned with White male or masculine norms, leaving students of color and White women struggling more to succeed in science than their White male counterparts (Hill et al., 2010; Rosa & Mensah, 2016). Racial microaggressions, or everyday subtle racist attacks, all-to-common in some science and STEM fields, create an unwelcoming environment for teaching and learning of students of color (specifically Black girls) who feel they are not welcome or do not belong in science (Emdin, 2010; Mensah & Jackson, 2018; Rollock, 2012; Rosa & Mensah, 2016). In their study of the educational pathways of Black female physicists, Rosa and Mensah (2016) found that women physicists of color viewed
themselves as incapable and stayed in isolation when they performed poorer and struggled with the same material as other students. This decreasing feeling of self-efficacy is a factor that causes many students of color to change from a science major to a non-science major (Hill et al., 2010; Zeldin & Pajares, 2000). Therefore, the findings of the three women of color in this current study are significant in their self-acceptance, recognition and confidence. Kerry, Melissa, and Sarah saw the BioBus internship as a safe space in which they were not afraid to make mistakes, ask questions, or receive feedback from peers and scientists. The learning environment created an atmosphere where everyone learned. In gaining this sense of confidence, Sarah, for example, spoke more frequently at STEM events at her university, and Kerry asked questions she may have been too shy to ask prior to participating in the BioBus internship program. Their voice spilled over into other settings, like teaching and sharing science with peers, suggesting that informal education grounded in inquiry and science, positively influenced the identities of the three women of color. The self-growth the participants experienced and an increased sense of identity go hand in hand with the environment that fostered it.

The second theme that emerged from participant interviews illustrates how a “fun”, “non-threatening”, and “open” environment such as the BioBus had on learners. The safe learning environment allowed participants to openly and freely speak without the fear of ridicule or criticism, encouraging them to express and explore their identities as scientists. It is important to note also that while the learning environment was safe and non-threatening, it was not free of intellectual challenge and critical reflection. The challenges and critical reflection occurred in a non-threatening, open-minded environment which challenged the interns as scientists in sharing, questioning, and deepening their identities as scientists.
Implications for Practice

Learning is as much about becoming as it is about knowing (Nasir, 2006). Identifying as a learner influences not only the activities that we participate in but also our motivations, interest and how we see ourselves fitting within different communities. Anderson (2007) believed that one aspect of learning is enculturation, which he goes on to describe as acquiring the skills, concepts, and practices of a community; what Anderson refers to is identity. Identifying as a learner, and the process of enculturation, occurs by engaging in social participation (Anderson, 2007). The research presented here indicates that extended ISE programs have the potential to successfully enculturate students of color into the field of science. In more formal science settings, students of color often negotiate a culture characterized by white, masculine values and behavioral norms (Carlone & Johson, 2007; Rosa & Mensah, 2016; Russell & Atwater, 2005). The findings here indicate that informal settings can be places that rebut the white, male science narrative that often leaves students of color marginalized. General implications from the current study add to the body of literature focused on the impacts of informal science education on students of color (Hernandez, et al., 2017; Rahm, 2012; Rahm & Moore, 2016). Specifically, this study builds on prior studies of the BioBus, which indicated that mobile lab programs (previously described as discover programs) positively influenced the science attitudes of urban youth (Fox, 2015), suggesting that informal institutions can foster positive science disposition through multiple types of programs. From the current findings, the unique structural format of the Pursue internship was related to fostering science identification in students of color.

The significant change in students’ understanding of science inquiry and science identity confirms research that shows meaningful growth occurs when learners are given guided mentorship for an extended period of time, as opposed to short time frame (most common being
eight to ten weeks) (Bell et al., 2003; Sadler et al., 2010). The yearlong duration is an important structural format that can be valuable for ISE practitioners. The first finding supporting the duration is the post-hoc Tukey analysis of VASI and SIS scores. The post-hoc Tukey’s test is done to pinpoint exactly between which time points the significant change in scores occurs. For both VASI and SIS scores, the statistically significant growth is seen from pre to post (as opposed from pre to mid or mid to post). Secondly, the continued yearlong involvement with the BioBus mentors compliments and supports their participants’ formal schooling. BioBus is a positive touchstone for participants while they are navigating sometimes unfriendly formal science environments. The most vocal about this is Sara, a BioBus intern who goes from viewing herself as an imposter to becoming a confident woman in science. She attributes this shift to BioBus and a Women in Science support organizations at her local university. The type of support at BioBus mirrors the mentoring early-undergraduates receive from faculty, which has been shown to strengthen science identity, motivation, and persistence for students of color (Hernandez et al., 2017; Robnett et al., 2018; San Miguel & Kim, 2015). Moreover, the findings suggest that informal spaces, such as the BioBus learning environment, can counter formal undergraduate research settings, that are described as a “gatekeeper” due to negative lab environments and structural hierarchy which often experienced by students of color and is related to their attrition from the STEM fields (Cooper, Gin, Akeeh, Clark, Hunter,…Brownell, 2019; Thiry, Laursen, & Hunter, 2011).

Identity has been used as a lens and a proposed solution to diversify the field of science. The greatest impact on students of colors and their science identities are school support and supportive teachers, familial support, mentorship, and research experiences (Nealy, 2018), including research experiences prior to and during college (Rosa & Mensah, 2016). This study’s
findings support the impact that mentorship and research experiences have on the science identity of students of color. Moreover, it confirms the positive impacts of same-gender and same-race mentorship. During the 2018-2019 BioBus internship, five scientists worked and mentored the interns. The scientists’ gender and racial/ethnic makeup were Black female, White male, Latino male, White female, and Latina female. Moreover, BioBus has a mission to offer comprehensive, hands-on science education to underserved K-12 students. In the past three years that BioBus has offered yearlong internships, over 80% have been female, and 53% of interns self-identified as Black, Latinx, or mixed race. Additionally, the BioBus staff reflects the diverse learners they teach. Over 75% of BioBus scientist-mentors are from underrepresented groups in STEM fields. Research has long supported the beneficial impacts of same-gendered and same-racial mentors and peers (Hernandez et al., 2017; Leitner, Ayduk, Boykin, & Mendoza-Denton, 2018; Lockwood, 2006; Watkins & Mensah, 2019).

Finally, the last aspect that heavily influence learners’ science identity is teaching. Teaching science taps into all three constructs of science identity. In having the opportunity to teach science, all the participants have to know the content they are teaching (competence), do experimentations or lead discussions and answer questions (performance), and be acknowledged as the one who is the “science expert” (recognition) (Carlone & Johnson, 2007). It is the intersection of these domains through teaching science that supports the construction of a science identity for the participants of this study.

It is far from trivial to design an informal science program that develops science identity and empowers its participants. The BioBus fosters identities in science and positive future aspirations in science that break the White, male scientist narrative. These findings have significance for researchers interested in engaging students and retaining students of color in
science. Through access to informal science education programs, students of color develop their knowledge of science inquiry and their science identity. Insight into the underlying mechanisms and structures behind the impact of the BioBus internship is not only significant for practitioners within ISE, but it also begins to shed light on the value of school to community partnerships. A growing body of research illustrates how school to community partnerships are helping to bridge educational gaps by creating active partnerships where students collaborate with experts within their local community and interface with a variety of community resources (Roberson, 2015; Taylor & Kubasko, 2019; Watters & Diezmann, 2013). Findings from this study indicate that developing school to community partnerships with informal institutions can also serve as a means of bridging educational gaps and warrant future study.

**Limitations of the Study**

While this study had several significant findings, there are limitations that need to be considered. Firstly, the participants in this study were voluntarily applied, and started with a high science identity and understanding of science inquiry. This can be seen from the pre-VASI and SIS scores, 19.4 out of 24 and 59 out of 75, respectively. Although there was significant growth from pre to post-VASI and SIS scores, it is important to denote that the interns were starting with a relatively strong understanding of science inquiry and positive feelings toward science. Having a strong, positive science identity is the first, and possibly largest, hurdle for students of color; thus, the fact that all participants started with positive feelings towards science, makes this a unique sample of students of color.

The second limitation lies within the survey used throughout the study and the small sample size (N=11). Because the survey was a self-reported survey consisting of Likert-style questions, the potential inaccuracy of information or unwillingness to share personal information
exists (Bates & Cox, 2008). This is why the study used a mixed-methods approach in which observations were conducted bi-weekly and interviews were conducted with select participants at three time points across the year. Creswell (2014) states that a sample size of less than 350 individuals limits the generalizability of the findings. The sample of eleven students in this study presents a limitation in generalizing the survey responses; however, to combat this, additional research studies verifying the survey findings are necessary.

Researcher bias and assumptions are always a potential limitation of social science research. As Director of Program Evaluation of BioBus and a previous science educator, I brought certain viewpoints and information to the research. I disclose this information to illustrate that I am aware of potential sources of bias. I am confident that the integrity of the study was upheld by carefully watching for bias in language used in communications with colleagues and students. Moreover, wherever possible, all extrapolations and interpretations of evidence were based as much as possible on the literature and not any familiarity with BioBus programs, staff, or students. I also made conscious effort to combat potential bias by presenting my interpretations based on the narrative of the participants, particularly from the perspectives of the participants, in order to develop a deep understanding of how students of color experience an informal science education program.

**Recommendations for Future Study**

Future research should begin with understanding the uniqueness of the BioBus experience as a whole. Specifically, the importance of the gender and racial/ethnic identity of the BioBus scientists need to be addressed. Understanding how the mentor scientists identify and how their identity influenced the trajectory of their science careers can add to the growing body of knowledge on people of color in science and science education.
A more critical lens needs to be addressed with BioBus participants of color. Before all else, in studying the participants (staff and students) efforts need to be taken to tease out the differences experienced due to gender, race/ethnicity and other social markers. The current study addresses gender and race as one unit, and in doing so, potentially overlooked how the BioBus Internship impacts students more from an intersectionality lens within science learning (Mensah, 2019).

In addition to taking a more holistic and critical lens to the BioBus experience, this study should also be repeated in other ISE settings. The participants of this study spoke very warmly and genuinely of their admiration for the BioBus community, and the findings suggest it is the environment that fosters the science identity development of the interns. Future replications of this study in other settings to addresses whether it is the uniqueness of the BioBus internship or the general nature of informal education that attributes to learner understanding of inquiry and learner science identity development.

Children spend almost 19% of their waking hours in a formal education setting (National Science Foundation, 2011); therefore, to disregard the impact informal education has in the formal setting would be unwise. Informal education research needs to begin rigorously researching the ways informal education impacts formal education. The current study provides insight into pedagogical techniques that increase the sense of science identity in students of color. This can be easily replicable in the formal setting by allowing students to teach the content they are learning and incorporating a greater sense of autonomy within the science classroom. However, the connections between informal and formal school learning are still underdeveloped in the literature (Fallik, Rosenfeld, & Eylon, 2013; Hebets, Welch-Lazoritz, Tisdale, & Trish, 2018). The current study did not follow the participants in school (formal education) and explore
what they brought from their BioBus experience to school science learning. Future research can comparatively look at science students of color who had informal learning experiences to those who did not have such access. By doing this, researchers, practitioners, and policy makers can isolate and replicate the informal experiences that facilitate the persistence of students of color in science. Ultimately, more research on ISE, generally, and meaningful impacts on students of color, specifically, should be at the forefront of science education research. The more research generated on students of color and meaningful ways to develop their science identity, the better members of the education community can come together to serve the needs of this population.
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Appendix A

BioBus Internship Rubric

<table>
<thead>
<tr>
<th>Attribute</th>
<th>10-9</th>
<th>8-7</th>
<th>6-5</th>
<th>4-3</th>
<th>2-0</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Science Background (6-10)</strong></td>
<td>College: Science major with strong lab experience HS: AP level with lab experience Application: Demonstrates solid understanding of biology - no mistakes or false ideas, use of details</td>
<td>College: Science major, some lab experience HS: AP level with extracurricular science experience Application: Demonstrates general understanding of concepts, no details</td>
<td>College: Science major or extracurricular participation HS: AP level or extracurricular science Application: Demonstrates understanding of scientific method, no details, possible errors/misconceptions/simple ideas</td>
<td>College: some non-scholastic engagement in science HS: Taking science class or involved in some vaguely scientific activity Application: Demonstrates little understanding of science, but some interest</td>
<td>College: no science experience of value. HS: Only in regular class, no outside interest in science. Application: lacks references to any scientific content or contains blatantly false ideas and concepts.</td>
</tr>
<tr>
<td><strong>Potential to Develop as a scientist or educator (6-10)</strong></td>
<td>Is younger, has little to no experience, and/or demonstrates willingness to learn/think</td>
<td>Has limited exposure to real PhD scientists or ideas of communication/education</td>
<td>End of HS or early college, has some experience in science and education</td>
<td>Mid to end of college, has trained extensively as either a scientist or an educator already</td>
<td>End of college, already many experiences, looking to improve resume.</td>
</tr>
<tr>
<td><strong>Interest / Enthusiasm (6-10)</strong></td>
<td>Bubbling over, specific enthusiasm</td>
<td>Expresses a lot of enthusiasm, metaphorical rather than specific</td>
<td>Calmly asserts interest and enthusiasm</td>
<td>Seems to not really want internship but has well written application</td>
<td>Didn't even finish, short answers, no enthusiasm</td>
</tr>
<tr>
<td><strong>Creativity / Imagination / Uniqueness (6-10)</strong></td>
<td>STEAM concepts, unique questions, ideas, expression!</td>
<td>Application has moments of impressive creativity or novel ideas</td>
<td>Not a dry application to read - communicates well and has interesting ideas/expressions, but lacks novelty or STEAM ideas</td>
<td>Application lacks imagination, very dry, muted expression, and questions/ideas are bland</td>
<td>None - didn't express inner scientist, didn't think outside the box, didn't work to make application special</td>
</tr>
<tr>
<td><strong>Lack of Access (6-5)</strong></td>
<td>Can't get this experience anywhere</td>
<td>Has possible access to good programs elsewhere</td>
<td>Mentions access/experience in great places</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Teaching Background (6-5)</strong></td>
<td>Has TA-ed, or run course outside of school</td>
<td>Never taught but mentored/tutored/baby sat a lot</td>
<td>Has mentored (or similar) occasionally</td>
<td>Interested, but little experience</td>
<td>None at all mentioned</td>
</tr>
<tr>
<td><strong>Overall Impression</strong></td>
<td>5 - Highly impressive</td>
<td>4 - Very high quality</td>
<td>3 - High quality</td>
<td>2 - Good</td>
<td>1 - Average</td>
</tr>
<tr>
<td><strong>BioBus Mission</strong></td>
<td>5 - They SQ get it, express the mission excellently</td>
<td>3 - Demonstrates some understanding of mission</td>
<td>1 - Doesn't express BioBus mission understanding</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total score: 150
Appendix B

Views About Science Inquiry (VASI) Questionnaire

Name: ___________________________ Date: __________________

The following questions are asking for your views related to science and scientific investigations. There are no right or wrong answers.

Please answer each of the following questions. You can use all the space provided to answer a question and continue on the back of the page if necessary.

1. A person interested in birds looked at hundreds of different types of birds who eat different types of food. He noticed that birds who eat similar types of food, tended to have similar shaped beaks. For example, birds that eat hard-shelled nuts have short, strong beaks, and birds who eat insects have long, slim beaks. He wondered if the shape of a bird’s beak was related to the type of food the bird eats and he began to collect data to answer that question. He concluded that there is a relationship between beak shape and the type of food birds eat.

   a. Do you consider this person’s investigation to be scientific? Please explain why or why not.

   b. Do you consider this person's investigation to be an experiment? Please explain why or why not.
c. Do you think that scientific investigations can follow more than one method?  
If no, please explain why there is only one way to conduct a scientific investigation.  
If yes, please describe two investigations that follow different methods, and explain how the methods differ and how they can still be considered scientific.

2. Two students are asked if scientific investigations must always begin with a scientific question. One of the students says “yes” while the other says “no”. Whom do you agree with and why?

3. a. If several scientists ask the same question and follow the same procedures to collect data, will they necessarily come to the same conclusions? Explain why or why not.
b. If several scientists ask the same question and follow different procedures to collect data, will they necessarily come to the same conclusions? Explain why or why not.

4. Please explain if “data” and “evidence” are different from one another.

5. Two teams of scientists are walking to their lab one day and they saw a car pulled over with a flat tire. They all wondered, “Are certain brands of tires more likely to get a flat?”

   Team A went back to the lab and tested various tires’ performance on one type of road surfaces.

   Team B went back to the lab and tested one tire brand on three types of road surfaces

   Explain why one team’s procedure is better than the other one.
6. The data table below shows the relationship between plant growth in a week and the number of minutes of light received each day.

<table>
<thead>
<tr>
<th>Minutes of light each day</th>
<th>Plant growth-height (cm per week)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>25</td>
</tr>
<tr>
<td>5</td>
<td>20</td>
</tr>
<tr>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td>15</td>
<td>5</td>
</tr>
<tr>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>25</td>
<td>0</td>
</tr>
</tbody>
</table>

Given this data, explain which one of the following conclusions you agree with and why.

Please circle one

a. Plants grow taller with **more** sunlight.
b. Plants grow taller with **less** sunlight.
c. The growth of plants is **unrelated** to sunlight.

Please explain your choice of a, b, or c below:
7. The fossilized bones of a dinosaur have been found by a group of scientists. Two different arrangements for the skeleton are developed as shown below:

![Figure 1](image1.png) ![Figure 2](image2.png)

a. Describe at least two reasons why you think most of the scientists agree that the animal in *figure 1* had the best sorting and positioning of the bones?

b. Thinking about your answer to the question above, what types of information do scientists use to explain their conclusions?
Appendix C

Science Identity Survey

Name: _______________________________ Date: __________________

The information that we gather will be used to help us to understand some of the things that students are learning in our program. We are very interested in your opinion – don’t feel like you have to answer in a way that will please the BioBus or any staff members of BioBus.

DIRECTIONS FOR THE SURVEY:

Science Identity Questions: Please read each statement carefully and complete it as honestly as possible. You can indicate your answer by circling the number that corresponds to your answer. This is not a test and you will not be graded for answering these questions. There are no right or wrong answers. Simply indicate how much you DISAGREE or AGREE with the following statements. Mark only 1 answer please!

<table>
<thead>
<tr>
<th>Mark only 1 answer please!</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neither Agree or Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I am good at science</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>2. I know a lot about science</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>3. I am good at most science experiments</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>4. I understand science topics</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>5. I learn new science topics easily</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>6. I can use science equipment and/or technology to collect data</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>7. I know how to use the scientific method/process</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>8. I can talk with others about science related topics</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Statement</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>---</td>
<td>---------------------------------------------------------------------------</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>9</td>
<td>I can create my own science experiments</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>I can use my observations to create a hypothesis</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>My friends see me as someone that is good at science</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>When giving a science report, I feel like a scientist</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Others see me as a scientist when I share my observations</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>When I share data I’ve collected, I feel like a scientist</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>I can help others with science related topics</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix D

Sample Student Interview Questions

Hello! My name is Roya Heydari and I am a Ph.D. candidate in Science Education at Teachers College, Columbia University. Thank you for your willingness to participate in my research study. The interview I am conducting will take approximately an hour to complete. Remember that you can choose not to answer a question or to stop participation at any point during our conversation and doing so will not affect you in any way. Your identity will be kept confidential and a pseudonym will be used in place of your name and any other identifying information. Our conversation will be recorded so I can collect all of the details of our conversations. When you are ready, I will begin to record our conversation with your permission.

Semi-Structured Interview Protocol Questions:

1. Why did you apply to the BioBus internship?
2. Tell me about times when you feel like a scientist at school?
3. Tell me about times when you feel like a scientist at home?
4. Tell me about times when you feel like a scientist at BioBus?
5. Do you feel competent in science or like you can do science well? What makes you feel that way?
6. Do you feel like your peers, teachers or family recognize you as a science person? Do they see you as someone that can do science well or is good at science? What makes you feel that way?
7. What kinds of science projects do you want to do and why?
8. I noticed that you provided this answer on your VASI questionnaire question “x”, can you explain why you wrote that?
9. I noticed that you provided this answer on your VASI questionnaire question “x”, can you explain why you wrote that?
10. I noticed that you provided this answer on your VASI questionnaire question “x”, can you explain why you wrote that?

Potential Mid and Post Interview Questions:

1. I noticed that your feelings about this statement changed on your Science Identity survey, can you explain why you think that is?
2. I noticed that your response on VASI questionnaire “x” changed, can you explain why?
### Appendix E

**Responses in both naïve and informed categories across eight aspects of science inquiry**

<table>
<thead>
<tr>
<th>Aspect of Science Inquiry</th>
<th>More Naive Views</th>
<th>More Informed Views</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Science investigations all begin with a question but do not necessarily test a hypothesis</td>
<td>“I agree with no, because they don’t always need to have a question.”</td>
<td>“Yes, because in order to know what to investigate you have to have a question asking you or telling you what to find.” “Yes”</td>
</tr>
<tr>
<td>2. There is no single set and sequence of steps followed in all scientific investigations (i.e., there is no single scientific method)</td>
<td>“because you have to have the scientific method: purpose, hypothesis, procedure...”</td>
<td>“Yes the scientist could (1) dissect frogs, observe internal organs or (2) Grow plants and change a part of photosynthesis”</td>
</tr>
<tr>
<td>3. Inquiry procedures are guided by the question asked</td>
<td>“Team B’s procedure is better because they show the tires reactions to different types of roads.”</td>
<td>“Team A’s procedure is better because it matches the question. My evidence is that both the question and Team A’s procedure involves different types of tires.”</td>
</tr>
<tr>
<td>4. All scientists performing the same procedures may not get the same results</td>
<td>“Yes they would because they’re doing the same thing step by step”</td>
<td>“If several scientists are working independently, ask the same questions and follow the same procedure to collect data they won’t necessarily draw the same conclusion because things can be different indicators to different people based on their experiences, they may also collect different data and data leads to different conclusions.”</td>
</tr>
<tr>
<td>5. Inquiry procedures can influence the results</td>
<td>“Yes because if you have the same question it must lead to the same answer no matter what the procedures are.”</td>
<td>“If they are doing different procedures they may get them different results.”</td>
</tr>
<tr>
<td></td>
<td>Research conclusions must be consistent with the data collected</td>
<td>“Plants need water, food and sunlight to grow.”</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>7.</td>
<td>Scientific data are not the same as scientific evidence</td>
<td>“They are the same because you collect both.”</td>
</tr>
<tr>
<td>8.</td>
<td>Explanations are developed from a combination of collected data and what is already known</td>
<td>“Because it is bigger.”</td>
</tr>
</tbody>
</table>
### Appendix F

**Coding Scheme for Interview Transcripts**

<table>
<thead>
<tr>
<th>Selective Codes/Themes</th>
<th>Axial Codes</th>
<th>Open Codes</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Self-Awareness</strong></td>
<td>Developing Interests</td>
<td>Asking questions</td>
<td>Well, it taught me a lot about myself. It taught me that I work best when one, I have freedom, and two, I know what I'm doing. Those two combined. If I have freedom, but I don't actually know what I'm doing, I feel like I'm not doing enough, I feel non-productive.</td>
</tr>
<tr>
<td></td>
<td>Understanding science process</td>
<td>Curiosity</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Teaching</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Patience</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Acceptance</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>More to learn</td>
<td></td>
</tr>
<tr>
<td><strong>Self-Confidence</strong></td>
<td>Gaining knowledge</td>
<td>I now know things don’t always work out the way you plan. And I’ve learned to get back up from failures. Failures are in everything.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Autonomy</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Teaching</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Self-Direction</strong></td>
<td>Future plans</td>
<td>College major</td>
<td>I feel like BioBus completely impacted my decision as to me majoring in Science. Because I feel like if it wasn't for BioBus, if it wasn't for my time being spent here and just learning about science and just getting that interest, that drive in science, I feel like I wouldn't be where I am right now…I’d be undecided</td>
</tr>
<tr>
<td><strong>Learning Environment</strong></td>
<td>Authentic Science</td>
<td>Hands-on Experiments</td>
<td>I really appreciate that we learn together as a community and no one tries to make you feel like you're beneath them like, &quot;Oh, I know more than you do.&quot; I think that's what makes it really comfortable.</td>
</tr>
<tr>
<td></td>
<td>Skill development</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Science tools</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Safe Space</td>
<td>Equal Voice</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mentorship</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Community</td>
<td></td>
</tr>
</tbody>
</table>
### Appendix G

**Coding Scheme of Interview Transcripts Against Science Identity Framework**

<table>
<thead>
<tr>
<th>Science Identity Theme</th>
<th>Example</th>
</tr>
</thead>
</table>
| **Competence**         | The beginning of the year begins with an introduction of science investigations. BioBus scientist describes how interventions are checked against a “normal”. Other BioBus scientist adds to the progression on the board (protocols, defined outcomes, controls).  
Andrew [BioBus Scientist], “while doing this you may realize that you need to redesign your experiment. Science is a very recursive process – almost like troubleshooting.”  
Melissa describes to me how her process concluded last week. She brings out her notebook and tells me exactly what she observed in her control group as well as her experimental groups – which were one with the left antenna cut off and the other with the right antenna cut off. She concludes that it’s the left antenna that is extremely important in their behavior. |
| **Teaching**           | 2:28 Sunday Science students start to arrive – interns know some of the students – greeting them with memories, etc. Students are working on their do now – interns working one on one or with a group of students – mostly with students that they know and are catching up with.  
2:40 – interns start some discussions about the do now: “can you think of any animals that do not have a brain? Draw it!” and “How can you tell if an animal has a brain?”  
2:45 BioBus scientists begins bringing everyone together |
| **Performance**        | BioBus Scientist (Mya) and Anna are setting up parameters for experiments. Anna is separating the fruit flies by male and female – Mya is setting up other test-tubes to begin experimentation.  
Anna is using the microscope to separate the fruit flies based on gender. She explained that she enjoys this part because she’s getting the hang of it and working with the microscope “feels sciency”.  
Anna continues to describe how she is looking forward to trying out the new procedure that her and Kerry put together. The new procedure she says takes certain factors in to account that remove human error – for example, using a video to count the fruit flies that move instead of estimating based off of watching. |
<table>
<thead>
<tr>
<th>Recognition</th>
<th>Internal Recognition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Melissa begins to set up for her next test on the ants which is to cross the antenna. A BioBus volunteer scientist begins helping her by providing her with a tool to glue the antenna together. As Hannah [volunteer] begins showing her the tool and how to use it, Melissa is watching carefully and smiling, when she begins using the tool she is extremely excited and says “I’m doing science”, she moves to the microscope to begin the process of gluing their antenna together.</td>
</tr>
<tr>
<td></td>
<td>External Recognition</td>
</tr>
<tr>
<td></td>
<td>In discussing the experimental design of Melissa’s experiment, Andrew suggests the hierarchy that Melissa spoke about in her proposal. “I think that’s a really interesting idea and we should try to incorporate it! We can set up a video camera on the ants to watch them 24/7.”</td>
</tr>
</tbody>
</table>
Appendix H

Assent Form for Minors

Teachers College, Columbia
University 525 West 120th Street
New York NY
10027 212 678
3000

Assent Form for Minors

Protocol Title: Science Identity and Science Inquiry Development
Principal Investigator: Roya Heydari, Doctoral Candidate, 631-312-6655,
rrh2123@tc.columbia.edu

INTRODUCTION

Hello, my name is Roya Heydari and I am a doctoral candidate in Science Education at Teachers College, Columbia University. I would like to invite you to participate in a research study called “Science Identity and Science Inquiry Development”. If you agree to participate in the study called “Science Identity and Science Inquiry Development”, you will be participating along with the other interns of the BioBus internship. You can choose to participate or not participate in this study. This study will look at how the BioBus internship affects how you see yourself as a scientist, or your science identity, as well as how you understanding science inquiry, or the process that scientists go through when they’re doing science! Audio recording is part of this study. After the audio recording is written down (transcribed), the audio recording will be deleted. If you do not wish to be audio-recorded, then you will not be able to participate in this study.

_____ I am okay with audio recording.

________________________________________________________________________________________

Signature

_____ I am not ok with audio recording.

________________________________________________________________________________________

Signature
If you agree to participate in the study “Science Identity and Science Inquiry Development”, please write your name on the line below:

I___________ (name) agree to be in this study, titled Science Identity and Science Inquiry Development. What I am being asked to do has been explained to me by Roya Heydari, Principal Investigator. I understand what I am being asked to do and I know that if I have any questions, I can ask Roya Heydari at any time. I know that I can quit this study whenever I want to and it is perfectly OK to do so. It won’t be a problem for anyone if I decide to quit.

Name:________________________________________ Signature: __________________________
Witness:______________________________________ Date: ______________

Investigator’s Verification of Explanation

I certify that I have carefully explained the purpose and nature of this research to___________ _______ in age-appropriate language. He/she has the opportunity to discuss it with me and knows that they can stop participating at any time. I have answered all of their questions and this minor child has provided the affirmative agreement (assent) to participate in this research study.

Investigator’s Signature ____________________________________________

Date ______________________________
Appendix I

Parental Permission

Teachers College, Columbia University
525 West 120th Street
New York NY 10027 212 678 3000

Protocol Title: Science Identity and Science Inquiry Development
Principal Investigator: Roya Heydari, PhD Candidate 631-312-6655, rrh2123@tc.columbia.edu

INTRODUCTION

Your child is being invited to participate in this research study called “Science Identity and Science Inquiry Development.” Your child may qualify to take part in this research study because he or she is attending a research internship at an informal science education organization. This study is exploring the science identity and science inquiry development of interns attending a yearlong research internship at an informal science education organization. Approximately 10 people will participate in the study, 5-7 students and 2 scientists. Over the course of the year, it will take 3.75 hours of your child’s time to complete.

WHY IS THIS STUDY BEING DONE?

This study is being done to investigate how organizations of informal science education impact students. The findings of this study will help understand the impact these organizations have on students’ science identity as well as students’ understanding of science inquiry.

WHAT WILL I BE ASKED TO DO IF I AGREE TO TAKE PART IN THIS STUDY?

If you decide to allow your child to participate, I will ask him or her to participate in four activities:

• First, I will ask your child to complete an open-ended questionnaire about science inquiry called the Views About Science Inquiry (VASI) Questionnaire. This questionnaire consists of seven open-ended questions that he or she will answer knowing that there are no right or wrong answers. This questionnaire will take approximately 30 minutes to complete and will be administered at three points over the course at the year, once at the beginning of the year, once in the middle of the year, and once at the end of the year.

• Second, I will ask your child to complete a Science Identity survey. The survey will take approximately 15 minutes to complete, and will be administered at three points over the course at the year, once at the beginning of the year, once in the middle of the year, and once at the end of the year. The survey is to get an understanding of how your child identifies as a scientist. The survey will give him or her 5 choices to choose from, strongly disagree, disagree, neither agree nor disagree, agree, and strongly agree.

• Thirdly, I will conduct one-on-one interview with your child where I will ask your child about his or her science identity survey and science inquiry questionnaire. The interview
will last approximately 30 minutes and will be conducted at three points over the course of the year, once at the beginning, one at the middle, and once at the end of the year. I will also ask your child general questions about science and his or her science identity. This interview will be audio-recorded.

- Lastly, at the end of the year I will utilize the National Science Rubric to assess your child’s research project and his or her ability to do science inquiry. The Natural Science Rubric uses a 5-point ordinal scale to reflect nuances within the understandings of scientific concepts, recognition and the use of scientific reasoning methods, understanding and discussion of general scientific articles and the use of mathematics in scientific reasoning and/or problem resolutions. I will also take photographs of your child’s poster and securely store them on my personal hard drive.

Your child will be given a pseudonym or false name/de-identified code in order to keep his or her identity confidential. Over the course of the year internship I will also conduct bi-weekly class observations. During the observations I will be recording descriptive notes into an electronic document. Ultimately these notes will be utilized to create a timeline of events of the internship over the year and will be conducted as discretely as possible.

WHAT POSSIBLE RISKS OR DISCOMFORTS CAN I EXPECT FROM TAKING PART IN THIS STUDY?

This is a minimal risk study, which means the harm or discomfort that your child may experience is not greater than what he or she would ordinarily encounter in daily life while taking routine physical or psychological examinations or tests. Your child might feel embarrassed to discuss issues around identity and science learning. However, he or she does not have to answer any questions or share anything they do not want to share. Your child can stop participating in the study at any time without penalty.

The principal investigator is taking precautions to keep your child’s information confidential and prevent anyone from discovering or guessing his or her identity, such as using a pseudonym instead of your child’s name and keeping all information on a password protected computer and locked in a file drawer.

WHAT POSSIBLE BENEFITS CAN I EXPECT FROM TAKING PART IN THIS STUDY?

There is no direct benefit to your child for participating in this study. Participation may benefit the field of teacher education and science education to better understand the best way to educate pre-service teachers, science teachers, and science educators.

WILL I BE PAID FOR BEING IN THIS STUDY?

Your child will not be paid to participate. There are no costs to your child for taking part in this study.

WHEN IS THE STUDY OVER? CAN I LEAVE THE STUDY BEFORE IT ENDS?
The study is over when your child has completed third and final interview. However, your child can leave the study at any time even if he or she has not finished.

**PROTECTION OF YOUR CONFIDENTIALITY**

The principal investigator will keep all written materials locked in a desk drawer in a locked office at her home. Any electronic or digital information (including audio recordings) will be stored on a computer that is password protected. What is on the audio recording will be written down and the audio recording will then be destroyed. There will be no record matching your child’s real name with his or her pseudonyms.

For quality assurance, the study team, the study sponsor and/or members of the Teachers College Institutional Review Board may review the data collected with pseudonym-coded as part of this study. Otherwise, all information obtained from your participation in this study will be held strictly confidential and will be disclosed only with your permission or as required by U.S. or State law.

**HOW WILL THE RESULTS BE USED?**

The results of this study may be published in journals and presented at academic conferences. Your child’s identity will be removed from any data your child provides before publication or use for educational purposes. This study is being conducted as part of the dissertation of the principal investigator.

**CONSENT FOR AUDIO RECORDING**

Audio recording is part of this research study. You can choose whether to give permission for your child to be recorded. If you decide that you do not wish your child to be recorded, he or she will not be able to participate in this research study.

I_________ give consent for________________________to be recorded

(Child’s Name)

________________________________________________________________________

Parent’s Signature

I_________ do not consent for________________________to be recorded

(Child’s Name)

________________________________________________________________________

Parent’s Signature

**WHO MAY VIEW MY CHILD’S PARTICIPATION IN THIS STUDY**
I consent to allow written and/or audio recorded materials of  
_____to be viewed outside of Teachers College, Columbia University. (Child’s Name)

Parent’s Signature

I ______________do not consent to allow written and/or audio recorded materials of  
_____to be viewed outside of Teachers College, Columbia University.  
(Child’s Name)

Parent’s Signature

WHO CAN ANSWER MY QUESTIONS ABOUT THIS STUDY?

If you have any questions about your child taking part in this research study, you should  
contact the principal investigator, Roya Heydari, at 631-312-6655 or at  
rrh2123@tc.columbia.edu. You can also contact the faculty advisor, Dr. Felicia Mensah at  
212-678-8316 or fm2140@tc.columbia.edu.  
If you have questions or concerns about your child’s rights as a research subject, you  
should contact the Institutional Review Board (IRB) (the human research ethics  
committee) at 212-678-4105 or email IRB@tc.edu. Or you can write to the IRB at Teachers  
College, Columbia University, 525 W. 120th Street, New York, NY 1002. The IRB is the  
committee that oversees human research protection for Teachers College, Columbia  
University.

PARTICIPANT’S RIGHTS

• I have read and discussed the informed consent with the researcher. I have had ample  
opportunity to ask questions about the purposes, procedures, risks and benefits regarding  
this research study.
• I understand that my child’s participation is voluntary.  
• The investigator may withdraw my child from the research if they feel that he or she is  
not able to complete all parts of the study or if he or she becomes severely distressed  
from the study.
• If, during the course of the study, significant new information that has been developed  
becomes available which may relate to my child’s willingness to continue my child’s  
participation, the investigator will provide this information to me.
• Any information derived from the research study that personally identifies my child will  
not be voluntarily released or disclosed without my separate consent, except as  
specifically required by law.
• I should receive a copy of the Informed Consent document.

My signature means that I agree to allow my child to participate in this study.
Parent’s Print name: ___________________________ Date: ____________________

Parent’s Signature: __________________________________________________________
Appendix J

Informed Consent

Teachers College, Columbia University
525 West 120th Street
New York NY 10027 212 678 3000

Informed Consent

Protocol Title: Science Identity and Science Inquiry Development
Principal Investigator: Roya Heydari, PhD Candidate 631-312-6655, rrh2123@tc.columbia.edu

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Thirdly, I will conduct one-on-one interviews with you over the course of the year where I will ask you about your science identity survey and science inquiry questionnaire. The interview will last approximately 30 minutes and will be conducted at three points over the course of the year, once at the beginning, one at the middle, and once at the end of the year. I will also ask you general questions about science and your science identity. This interview will be audio-recorded.

Lastly, at the end of the year I will utilize the National Science Rubric to assess your research project and your ability to do science inquiry. The Natural Science Rubric uses a 5-point ordinal scale to reflect nuances within the understandings of scientific concepts, recognition and the use of scientific reasoning methods, understanding and discussion of general scientific articles and the use of mathematics in scientific reasoning and/or problem resolutions. I will also take photographs of your posters and securely store them on my personal hard drive.

You will be given a pseudonym or false name/de-identified code in order to keep your identity confidential. Over the course of the year internship I will also conduct bi-weekly class observations. During the observations I will be recording descriptive notes into an electronic document. Ultimately these notes will be utilized to create a timeline of events of the internship over the year and will be conducted as discretely as possible.

**WHAT POSSIBLE RISKS OR DISCOMFORTS CAN I EXPECT FROM TAKING PART IN THIS STUDY?**

This is a minimal risk study, which means the harm or discomfort that you may experience is not greater than what you would ordinarily encounter in daily life while taking routine physical or psychological examinations or tests. You might feel embarrassed to discuss issues around identity and science learning. However, you do not have to answer any questions or share anything you not want to share. You can stop participating in the study at any time without penalty.

The principal investigator is taking precautions to keep your information confidential and prevent anyone from discovering or guessing your identity, such as using a pseudonym instead of your name and keeping all information on a password protected computer and locked in a file drawer.

**WHAT POSSIBLE BENEFITS CAN I EXPECT FROM TAKING PART IN THIS STUDY?**

There is no direct benefit to you for participating in this study. Participation may benefit the field of teacher education and science education to better understand the best way to educate pre-service teachers, science teachers, and science educators.

**WILL I BE PAID FOR BEING IN THIS STUDY?**

You will not be paid to participate. There are no costs to you for taking part in this study.

**WHEN IS THE STUDY OVER? CAN I LEAVE THE STUDY BEFORE IT ENDS?**
The study is over when you have completed third and final interview. However, you can leave the study at any time even if you haven’t finished.

**PROTECTION OF YOUR CONFIDENTIALITY**

The principal investigator will keep all written materials locked in a desk drawer in a locked office at her home. Any electronic or digital information (including audio recordings) will be stored on a computer that is password protected. What is on the audio recording will be written down and the audio recording will then be destroyed. There will be no record matching your real names with your pseudonyms.

For quality assurance, the study team, the study sponsor and/or members of the Teachers College Institutional Review Board may review the data collected with pseudonym-coded as part of this study. Otherwise, all information obtained from your participation in this study will be held strictly confidential and will be disclosed only with your permission or as required by U.S. or State law.

**HOW WILL THE RESULTS BE USED?**

The results of this study may be published in journals and presented at academic conferences. Your identity will be removed from any data you provide before publication or use for educational purposes. This study is being conducted as part of the dissertation of the principal investigator.

**CONSENT FOR AUDIO RECORDING**

Audio recording is part of this research study. You can choose whether to give permission to be recorded. If you decide that you do not wish to be recorded, you will not be able to participate in this research study.

I __________________________ give my consent to be recorded

______________________________

Signature

I __________________________ do not consent to be recorded

______________________________

Signature

**WHO MAY VIEW MY PARTICIPATION IN THIS STUDY**
I __________________________ consent to allow written and/or audio recorded materials to be viewed at an educational setting or at a conference outside of Teachers College, Columbia University.

Signature

I __________________________ do not consent to allow written and/or audio recorded materials to be viewed outside of Teachers College, Columbia University.

Signature

WHO CAN ANSWER MY QUESTIONS ABOUT THIS STUDY?

If you have any questions about taking part in this research study, you should contact the principal investigator, Roya Heydari, at 631-312-6655 or at rrh2123@tc.columbia.edu. You can also contact the faculty advisor, Dr. Felicia Mensah at 212-678-8316 or fm2140@tc.columbia.edu.

If you have questions or concerns about your rights as a research subject, you should contact the Institutional Review Board (IRB) (the human research ethics committee) at 212-678-4105 or email IRB@tc.edu. Or you can write to the IRB at Teachers College, Columbia University, 525 W. 120th Street, New York, NY 1002. The IRB is the committee that oversees human research protection for Teachers College, Columbia University.

PARTICIPANT’S RIGHTS

• I have read and discussed the informed consent with the researcher. I have had ample opportunity to ask questions about the purposes, procedures, risks and benefits regarding this research study.
• I understand that my participation is voluntary.
• The investigator may withdraw me from the research if they feel that I am not able to complete all parts of the study or if I become severely distressed from the study.
• If, during the course of the study, significant new information that has been developed becomes available which may relate to my willingness to continue my participation, the investigator will provide this information to me.
• Any information derived from the research study that personally identifies me will not be voluntarily released or disclosed without my separate consent, except as specifically required by law.
• I should receive a copy of the Informed Consent document.

My signature means that I agree to participate in this study

Print name: __________________________ Date: __________________________

Signature: __________________________