FROM GATES TO GREATS: HOW SCIENCE IDENTITY IS EXPRESSED BY RURAL AFRICAN AMERICAN GIRLS THROUGH THEIR PARTICIPATION IN AN INFORMAL SCIENCE LEARNING PROGRAM

Crystal Harden

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Approved by:

Janice L. Anderson

Todd R. Boyette

Sherick A. Hughes

Xue L. Rong

Jamila S. Simpson

ABSTRACT

Crystal Harden**:** From Gates to Greats: How Science Identity Is Expressed by Rural African American Girls Through Their Participation in an Informal Science Learning Program
(Under the direction of Janice L. Anderson)

The underrepresentation of women and minorities in the science, technology, engineering, and mathematics (STEM) fields is a major concern for researchers, policymakers, and educators. Many causes of this issue have been identified over the years. However, effective methods for increasing minorities' and women's participation in STEM may still be limited. This study examines the role that identity formation plays in encouraging rural African American girls to pursue STEM education, utilizing data from an informal science enrichment program that targets STEM underrepresented middle school-aged students from rural communities. A qualitative design was employed to examine rural African American middle school-aged girls' science interests, attitudes, and identities often referred to as affinities. Qualitative data included observations, artifacts, and individual interviews. The study is presented in two components: participant affinities and science identity formation. Participants had high or sustained affinities for science as compared to their initial program entry. Analysis of qualitative data of science affinities revealed several emergent themes discussed center around rural, African American middle school-aged girls' interests in science, attitudes toward science, and elements of science identities. Types of emergent science themes developed in this study (e.g., understanding, support/engagement, and career aspirations) inform different ways in which rural, African American middle school-aged girls engage with science and informal science learning.

Implications for best practice in nurturing science engagement and identities in African American middle-school-aged girls include the importance of hands-on science activities, the need for energetic, relatable scientific-career role models, and an emphasis on deep understanding of scientific principles.

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To my mother, thank you for being my backbone my whole life. This is for you, Sweet, and Willie B. To my daughters, thank you for opening my eyes to life and for your unwavering belief in your old mama. My strength lies in the two of you. To my grandson, thank you for existing. My purpose is and will always be you. To my dearest friend on the planet, Black Slim, thank you for saving my life and keeping me focused on the light. I see now because of you.

To every little black girl with a dream and a vision, never let anyone steal your joy. Keep your eyes on the light.

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CHAPTER 1

INTRODUCTION

Introduction

There is tremendous need to investigate informal science education in rural areas, which have historically been underserved and underrepresented in the teaching of science, technology, engineering, and mathematics (STEM). Very little research has been done on topics related to science and education in these communities, especially as they connect to the experiences of African American girls (Avery & Kassam, 2011).

Rural areas have yet to be fully explored as rich environments for learning science. Relatively little attention is given to rural science education, even though 11.4 million children in the United States grow up in rural areas (Avery, 2013). One-third of American public schools are rural, and one in five students attends a rural school (Avery, 2013). In addition, according to Avery (2013), in many of American's rural areas, the racial and ethnic populations are predominately Black and Latino. According to the U.S. Census Bureau, Black and Latino Americans are predicted to comprise over 40% of the U.S. population by 2045 (Colby & Ortman, 2015). Therefore, it is paramount to increase participation and improve STEM outcomes among these underrepresented populations of students to ensure that the workforce has an adequate number of qualified scientists (Tsui, 2007; Stets et al., 2017).

Over the last 50 years, the issue of girls' and women's underrepresentation in STEM fields has been a major focus for science education practitioners and researchers. According to a 2014 NSF report, African American women accounted for 6.5% of the U.S. adult population (ages 18–65), but only earned 3.5% of the doctoral degrees in science and engineering fields (Wade-Jaimes & Schwartz, 2019). Consequently, African American women hold only 1.6% of the science and engineering jobs, while White men hold 50% of these jobs (Wade-Jaimes & Schwartz, 2019). Historically, gender bias perpetuated within the STEM culture and institutionalized sexism and racism within K–12 and higher education have discouraged women—in particular, African American women—from pursuing STEM fields (Yoon, et al., 2014; McDonald, et al., 2019). The gatekeepers of STEM career fields and STEM culture hold these keys to equity and access for women and girls: the structured breakdown of racial, ethnic, and gender bias and the upliftment of informal science engagement (Philip & Azevedo, 2017). However, these gatekeepers have yet to fully resolve the disparities and unlock the barriers facing women, especially African American women. Subsequently, research continues to demonstrate that middle school-age is when girls begin to lose interest in science and mathematics (Catsambia, 1995; Young et al., 2017). Also, during these middle school years, the gender gap begins in terms of standardized STEM test scores and participation in STEM courses (Catsambis, 1995; Hughes et al., 2013). Varied results and outcomes in informal science education programs aimed at increasing students' interest and identity within STEM fields demonstrate a need for more research (Hughes et al., 2013).

Rural Science Education Barriers

Within the last decade, the proportion of rural schools in the United States has increased (Sundeen & Sundeen, 2013). Of the growth in student enrollment nationally, approximately 70% has been in rural districts. Importantly, a large population of minority and socioeconomically disadvantaged students are served in rural schools (Avery, 2013).

Every rural community has a unique mixture of social, economic, and environmental characteristics. Benefits and advantages for students and school communities in rural communities can be numerous. Rural parents are more likely than urban parents to attend school events and serve as school and community volunteers (Sundeen & Sundeen, 2013). Rural teachers often report higher levels of job satisfaction and fewer behavioral problems among their students (Avery, 2013; Schaftt, 2016). The school system is the largest employer in many rural communities (Avery, 2013; Schaftt, 2016). In addition to providing jobs, a rural school's presence within a rural community is often associated with increased housing values, employment rates, and entrepreneurship, and decreased income inequality (Schafft, 2016). Involvement in several types of school activities (i.e., academic activity, vocational activity, and student government) was related to higher achievement.

However, rural communities face various challenges in comparison to urban communities, such as lower school funding and lower college enrollment (Zuniga et al., 2005; Avery, 2013). Rural areas tend to be isolated, with lower school enrollment (students/school/grade) and low population density (Aldous, 2008; Avery, 2013). In rural areas, there exist disparities in cell phone access and broadband Internet in comparison to more urban areas (Aldous, 2008; Kormos, 2018). These technologies are not always available for many students in their homes, because access often does not exist in remote rural areas (Aldous, 2008). Additionally, exposure and access to educational opportunities and resources offered by science organizations, universities, colleges, and corporations are generally limited and the number and types of STEM-related professional and vocational jobs are low in these less populated and technologically connected areas (Annetta & Dickerson, 2006; Blanchard, 2016). Thus, many rural children are not exposed to the diverse ways in which STEM is practiced globally and may not envision STEM-related educational or career pathways for themselves.

Factors such as isolation, lack of funding, and small student populations make it difficult for rural schools to attract and keep highly qualified STEM teachers (Avery, 2013). State and federal incentives often lure professionals to urban schools, where they may receive monetary bonuses or graduate school tuition. Rural teachers with backgrounds in chemistry, physics, or calculus may be unable to teach these courses because the student enrollment is too small to support advanced courses. Due to teacher shortages, teachers specializing in other fields are sometimes required to teach STEM courses, despite their lack of preparation and comfort with teaching these STEM disciplines. As a result, student science achievement suffers when there is a STEM teacher shortage and available teachers are under-qualified for the subjects they teach (Goodpaster et al., 2012).

According to Peterson and colleagues (2015), two of the most powerful predictors of rural students' educational aspirations and attainment are their parents' education and family socioeconomic status. Students whose parents have no or little college education are less likely to pursue postsecondary options. In rural communities, adults tend to have lower educational attainment than do adults in suburban and urban communities (Peterson et al., 2015). According to Schafft (2016), a critical issue in rural communities is the limited number of economic opportunities that young people anticipate will be available to them as adults in their hometowns. Rural schools often signal to children that the only way to succeed is to leave their community (Byun et al., 2012). School choices, entertainment opportunities, and extracurricular activities may also disconnect them from their communities. On the other hand, rural youth often experience a tension between moving away to pursue educational and vocational opportunities not supported in their home communities and remaining close to family and community. Byun et al. (2012) argue that the lower educational aspirations of rural youth may be a response to the social interactive processes taking place within rural families and communities. Specifically, lower educational aspirations of rural youth may result from strong emotional attachments to their families and communities.

Supporting rural students' exploration of math and science and engaging issues relevant to their own communities might be the promise and hope of STEM for them. Through this exploration, STEM education may help students see themselves as mathematicians, engineers, and scientists who are aware of STEM career opportunities and prepared to engage in the rigorous study needed to compete in these educational experiences and career positions (Peterson et al., 2015).

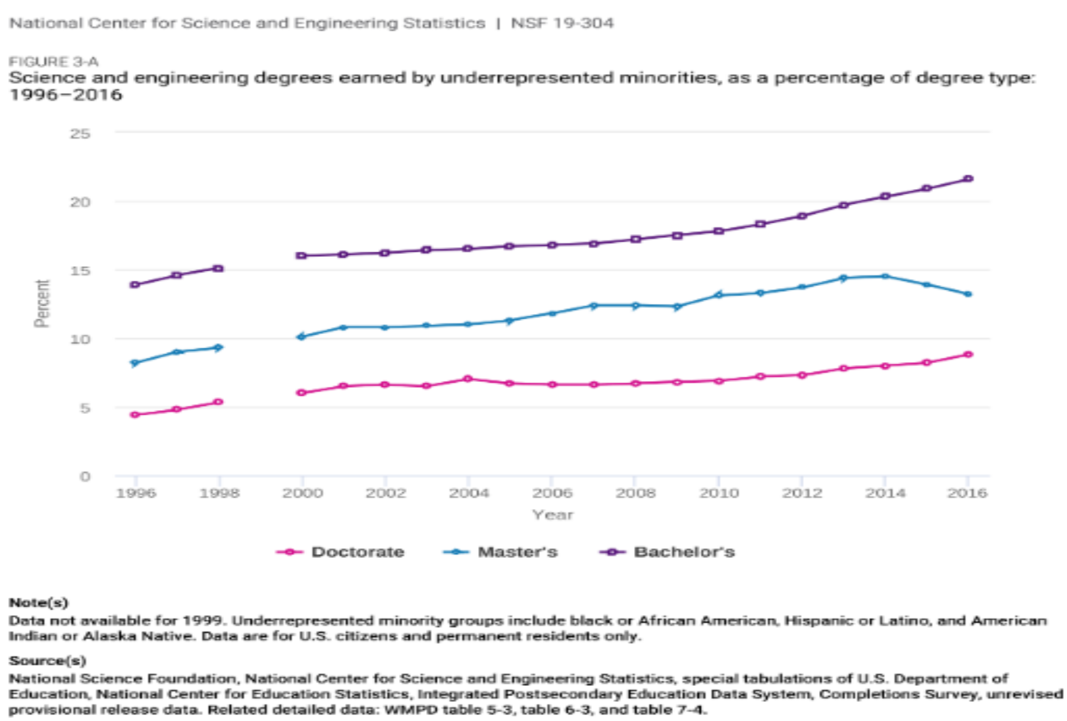
Race/Ethnicity and STEM Representation

Figure 1 illustrates that the diversity of race and ethnicity in the U.S. population is not reflected in the population of STEM professionals. Formal education qualifications reflect this disparity as they show racial achievement gaps, especially between Black and Latino students and their White peers (Young et al., 2017). According to Young (2017, p.175), "data shows that Black women and girls are underrepresented at only 10.4% of the female graduates in STEM fields." Challenges for those underrepresented in STEM include the conflict between over-confidence and poor preparation from which some African American and Latino students suffer, as well as environmental factors such as lack of family support or mentoring that impede their persistence in science and engineering programs (Taningco et al., 2008). High schools with large minority populations tend to provide science and mathematics curricula that are less rigorous. A disproportionate number of underrepresented minority students have little access to classes that are more demanding (Shakeshaft, 1995; Young et al., 2017). As a result, they are not adequately prepared for college without having taken the advanced placement classes needed. In college, these students are often overwhelmed and at risk of switching to less-challenging majors or dropping out altogether.

Science education should meet the distinct needs of African American students and the particular circumstances in which they live. To prescribe for these students the same science education as their non-African American peers is a great disservice to them (Aikenhead & Jegede, 1999; Zembylas & Avraamidou, 2008; Mutegi, 2011).

Figure 1

Science and Engineering Degrees Earned by Underrepresented Minorities



Note. Science and engineering degrees earned by underrepresented minorities, as a percentage of degree type: 1996–2016 (National Science Foundation, National Center for Science and Engineering Statistics, 2019).

Informal Science Education Environments

Informal learning environments such as science and technology centers can provide valuable motivation for students to learn science. Informal science programs have become an important means to offer quality science opportunities, such as STEM-focused afterschool programs and family science clubs (Jones, 1997; Rahm & Moore, 2016). The role that informal science programs play for underserved and underrepresented minority students addresses issues tied to educational and identity pathways (Vadeboncoeur, 2006; Rahm & Moore, 2016). Informal environments can provide underrepresented minority students with specific learning spaces to understand themselves as scientists and have more realistic experiences of how science works (Rennie et al., 2003; Vincent-Ruz & Schunn, 2018). These informal science program environments provide empowering learning situations for students to see what real scientists do, experience doing science firsthand, and realize that they can do science (Heard, et al., 2000; Sasson, 2014). These spaces and environments are most important as ways to affect students' attitudes or interests.

STEM enrichment programs in informal science learning environments are designed to improve student outcomes in STEM fields, targeting improved outcomes for underrepresented minority groups, females, and economically disadvantaged students (Merolla & Serpe, 2013). Beyond improving student performance, an important function of STEM enrichment programs can be to provide students with social relationships based on a science identity. These program environments have an impact on learning, while addressing aspects of science education that might be missing in more formal, classroom-based learning environments. Enrichment activities in informal science learning environments such as science centers are perceived as an opportunity to increase students' interest in learning (Jones, 1997; Bevan & Semper, 2006;

Sasson & Cohen, 2013). Several programs in out-of-school settings, including summer programs, have been and continue to be employed to promote career and educational awareness for students with limited access or exposure to STEM fields (Elam et al., 2012).

However, many informal science programs fail to empower students to navigate effectively among various conflicting practices of science while holding on to their positionality of self in science (Rahm & Moore, 2016). It is important to design informal science programs that empower the development of identities in science and positive future aspirations (Brody et al., 2007; Rahm & Moore, 2016). Informal science education studies suggest the need to invest more effort in understanding high school and postsecondary education pathways through the intersection of STEM identity with informal science programming (Rahm & Moore, 2016).

There exists a large body of literature connecting informal experiences to science identity development. It is a robust lens for understanding why students make certain career choices (Dou et al., 2019). More specifically, students' career-related behavior and choices are guided by whether they see themselves and are seen by others as a certain type of person (e.g., a "science person"). Similar to STEM interest, recognition plays an important role in STEM identity construction through early informal experiences. Differences in recognition provide insight into the different identity trajectories of African American middle school girls (Dou et al., 2019; Wade-Jaimes & Schwartz, 2019). Dawson (2014) found that people from minority backgrounds struggle with informal science education experiences that feel culturally distant or irrelevant. Across various contexts, different groups from minority backgrounds struggle to see informal science education and informal science education institutions as culturally relevant because of issues of power, language, content, and representation (Dawson, 2014). In addition, examples from Simpson and Parsons (2009) show that informal science environments offer a possible means of addressing the African American need in science. For example, these environments can use relevant science topics to create opportunities for cultural communication, connection, and encouragement. These environments can be seen as potential sites for engaging African American students, permitting them to learn science in settings where the cultural expectations for students can be less rigid than in formal classrooms. Because of the nonevaluative nature of informal science experiences, students may feel more at ease to participate in science in ways most relatable to and most comfortable for them.

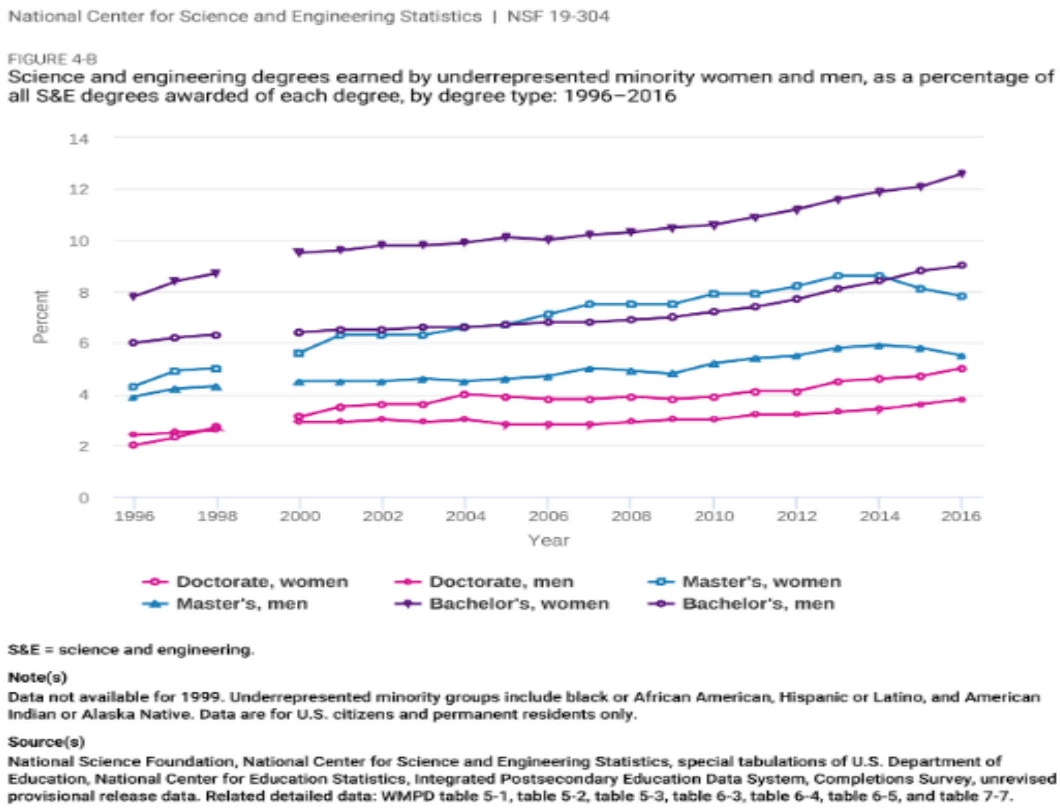
Gender and Science Identity—A Conceptual Framework

Leaks in the academic STEM pipeline, which begin early in students' academic journeys, result in STEM majors and career professionals being underrepresented in race/ethnicity and gender (Jones, 1997; Glynn et al., 2011). This is demonstrated in science and engineering, where women make up only nine percent of scientists with a bachelor's degree, as Figure 2 shows.

Kim and Sinatra (2018) argue that gender differences in STEM career pathways are connected less to girls' lack of interest or achievement than to their feeling that STEM is not a place for them. The messages they receive indicate clearly who is part of the STEM group conversation and who is not (Jacobs et al., 1998; Kim & Sinatra, 2018). The types of identity expression that girls from minority backgrounds engage in during their middle school years reflects how their potential futures in science are studied (Calbrese Barton et al., 2013). The theory of identity development provides the foundation for developing an intervention that will help African American girls build science identities.

Figure 2

Science and Engineering Degrees Earned by Underrepresented Minority Women and Men



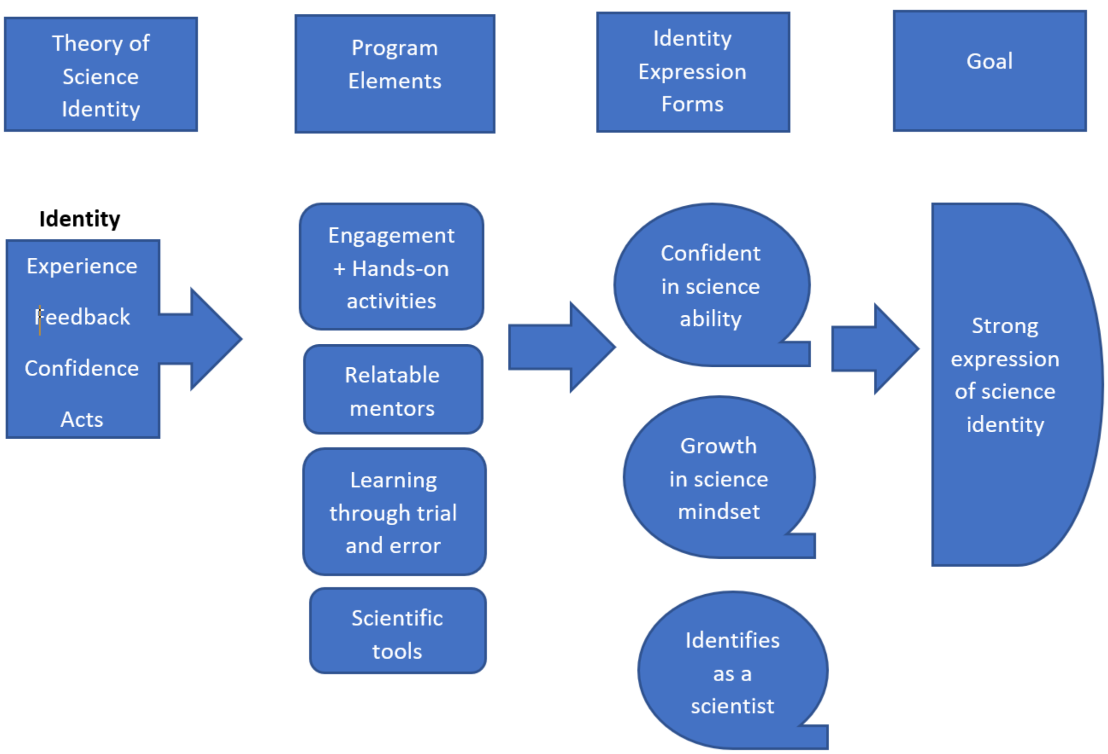
Note. Science and engineering degrees earned by underrepresented minority women and men, as a percentage of all S&E degrees awarded of each degree, by degree type: 1996–2016 (National Science Foundation, National Center for Science and Engineering Statistics, 2019).

Study Overview

This study examines the ways a year-round family science enrichment program can engage theory on how to express the science identity of rural, African American, middle school-aged girls through science in an informal science learning environment. As outlined above, girls and women, particularly among African Americans, are disproportionately represented at lower rates in the STEM pipeline. This study examines how African American girls respond to a family science enrichment program and what can be learned from their interests, attitudes, motivations, and intentions regarding science. The foundational theory employed in the outreach initiative under examination is identity theory (Tajfel, 1974; Carlone & Johnson, 2007). Identity theory provides insight into how African American girls may incorporate long-lasting science identities into their self-development, which is hypothesized to increase engagement, interest, and retention in STEM. In this dissertation, this foundational theory provides both the guidance for designing an intervention that expresses African American girls' science identity in STEM and the viewpoint through which the intervention is assessed. Figure 3 provides a logic model for how theoretical elements are activated into program elements, the expected products of a successful intervention, and the final goal.

Figure 3

Logic Model of Science Identity Expression



Note: This is a logic model for applying theories of science identity to an informal science outreach program intervention, with the expected expression forms of a strong science identity.

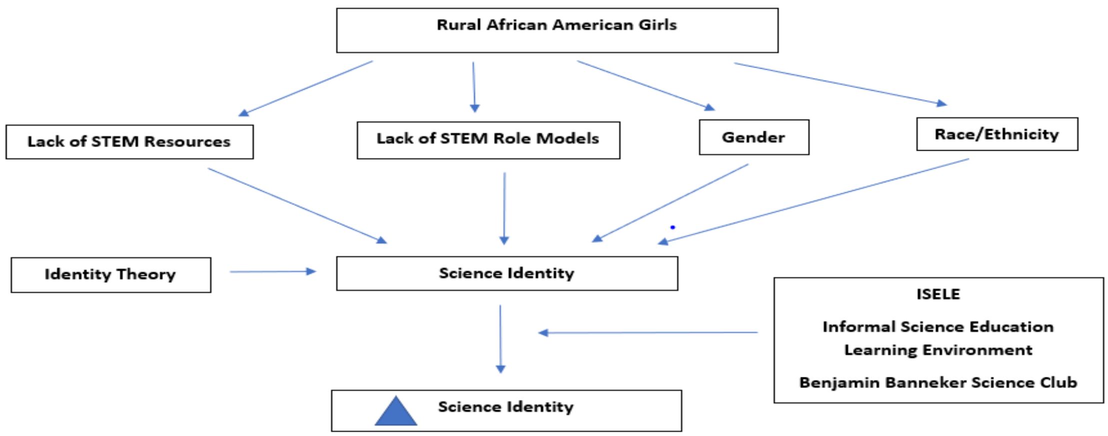
The foundational theory of identity informs this study's methods, analysis of data, and interpretation and implications of results. Practices from the worlds of informal science education, rural science education, race/ethnicity research, and gender theory also provide context for the results. The core manifestations of science identity formation—often referred in the literature and used in this study—are science affinities. These affinities are interest in science, attitudes toward science, and identifying as a scientist.

The key constructs under examination are African American girls' science identities, attitudes toward science, personal interests in science, perceptions of societal race/ethnic and gender expectations, and preferences for science engagement. Figure 4 maps the full conceptual framework. This dissertation focuses on African American girls' science identities, or lack thereof, as the disparity source of primary interest. It employs an informal science learning environment intervention targeting middle school-aged, rural, African American girls to identify and analyze methods of activating identity formation. The study and the program are also informed by recommended best practices from informal science education, rural science education, and race/ethnicity and gender experts and researchers in their respective fields. Research data collected through this study measures the desirable products of strong identity formation: science interest, attitudes toward science, and self-identification as a scientist.

Qualitative methods are used to assess program outcomes and thus determine if participants demonstrate an increase in science identities, attitudes, or interests. These methods address how these rural, African American girls develop identities, what kinds of identities they develop, and how others, such as teachers, parents, mentors, or scientists, can support science identities in these girls.

Figure 4

Conceptual Framework Map



Note. This framework map outlines the concepts informing this study's action theory.

Benjamin Banneker Science Club. The Benjamin Banneker Science Club (BBSC) is a family science enrichment initiative facilitated by a statewide informal science education learning center. This initiative targets underrepresented and underserved families in rural Modlin County, North Carolina. The program's goal is to support science engagement and provide access to science resources through informal science learning opportunities and events. The learning center collaborates with Modlin County Public Schools to offer a suite of outreach programs to all five schools (three elementary, one middle, and one high school) in the system. However, the program's primary activity is a family science enrichment program featuring 15 Benjamin Banneker Science Club participants—the Banneker Scholars—and 15 supportive adults (typically the Scholars' parents). These Banneker Scholars and adults attend monthly science enrichment and science engagement meetings led by the science center staff and held at the local middle school or high school. In addition, the Banneker Scholars participate in a one-week summer science enrichment camp based in Modlin County. The science center staff administer the program and lead or facilitate science lessons, activities, and events. It is also the science center staff's responsibility to develop science content that applies the theories of science identity.

The Banneker Scholars were selected to join the program in 2018–2019, at the beginning of their sixth-grade year at the middle school in Modlin County. The program is funded to support the Scholars through their senior year in 2025. The demographics for the Banneker Scholars are: five African American females, two Caucasian females, one Latino/Caucasian male, three African American males, and four Caucasian males. This study examines if five African American girls who are Banneker Scholars demonstrate evidence of the expected products of identity formation. This study explores these participants' interests in and attitudes toward science and their preferences for STEM opportunities and careers. This examination considers the participants' perceptions in relation to the program and to their lives outside the program.

The Banneker Scholars were recruited during the start of their middle school experience, just as the downward spiral in science attitudes and confidence is expected. Middle school can be a time for change in students' science identities. Until about middle school, students are mostly positive toward science and demonstrate confidence in their science abilities (Catsambis, 1995; Calbrese Barton et al., 2013; Hughes et al., 2013). However, after middle school, these students begin to shrink in their identities as they become disillusioned and frustrated with formal science (Catsambis, 1995; Calbrese Barton et al., 2013; Hughes et al., 2013). The decreased interest in science among middle school students can be attributed to several sources, including gender inequities in the classroom that result from content and pedagogy. Middle school is when girls begin to lose interest in STEM at higher rates than boys (Catsambis, 1995; Calbrese Barton et al., 2013; Hughes et al., 2013). Figures 1 and 2 show that this attrition rate continues throughout the entire STEM pipeline.

The goal of the Banneker Scholars program is to develop in the participants a continued interest in science that facilitates the formation of strong, stable, long-term science identities. The actionable theory for this program is that participants who form strong science identities will be more likely to enroll in advanced-level high school science courses and pursue STEM degrees and careers. The presence of strong science identities is hypothesized to increase the likelihood that participants will engage in STEM opportunities presented to them and become more likely to seek STEM opportunities themselves. Another hypothesis is that—as they acquire more experience and skill—they will begin to see science as a core component of their everyday lives and consider science as a career viable in their futures. It is also hypothesized that participants will, as a result of relatable role modeling and realistic scientific experiences early in their educational journeys, develop more grit and resilience against STEM attrition later in their educational experiences.

Research project. The goal of the current research project is to examine the extent to which the Benjamin Banneker Science Club supports African American girls in developing and expressing strong science identities. The project uses a qualitative, interview design to explore participants' interests, attitudes, and identities. The data collected includes individual audio recorded participant interviews, field observation notes, reflective memos, and artifact analysis. The research questions are as follows:

1. In what ways is the science identity of rural, African American, middle school-aged girls expressed in relation to their participation in an informal science enrichment program?
2. What actions do these girls take in support of their developing science identities?

Significance of the study. While a great deal of research is conducted on racial, ethnic, and gender disparities in STEM at various levels, there is little deliberate research on informal science interventions for rural, African American, middle school-aged girls. Studies tend to focus on school-related activities (Laursen et al., 2013), summer camp programs (Merolla & Serpe, 2013), or specific disciplines or careers. Even when looking at those studies and the literature on race/ethnicity and STEM or the intersection of race/ethnicity and gender (Jayaratne et al., 2003; Riegle-Crumb & King, 2013), one finds few studies addressing race/ethnicity, gender, and informal learning science environments intersecting with rural areas.

This study examines the program population of African American girls from a rural community participating in an informal science outreach program. The African American girls in the study have a limited range of exposure to science learning outside the program or through formal school opportunities. The results of this study will inform the program in the areas of participants' science affinities and participants' ideas about science. In addition, this study's broader implications could include examples of how to operationalize identity theory in practice, better understanding of African American girls' science interests and motivations, and a new theory about the types of science identities African American girls form. The results of this research may prove useful to informal science learning institutions, science outreach programs, K–12 school educators and administrators, parents, and STEM practitioners and researchers.

Definition of Terms

Gender. Gender tends to explain the social and cultural roles of each sex within a society. People often develop their gender roles in response to their environment, including educational attainment and family and peer interactions (Baron, Schmader, Cvencek, & Meltzoff, 2014).

Identity. An identity is a set of meanings that define a person in terms of role (role identity), of group or category membership (social identity), or as a unique individual (person identity) (Stets, Brenner, Burke, & Serpe, 2017).

Informal science education learning environments. Informal science education has been broadly defined as science programs and experiences that occur outside the classroom. These programs and experiences include, but are not limited to, museums, science centers, zoos, parks, nature centers, and community-based organizations and projects (Simpson & Parsons, 2009; Tan et al., 2013).

Race/ethnicity. Race is commonly and popularly defined in terms of biological traits such as phenotypic differences in skin color, hair texture, and other physical attributes. Race is often understood to be a mixture of physical, behavioral, and cultural attributes while ethnicity recognizes differences among people mainly based on language and culture (Ahdieh & Hahn, 1996). According to Morning (2007), race is a social invention and product that changes depending upon the political, social, and historical contexts. Yet, there is a gap between the scientific rejection of race as a concept and the popular acceptance of it as an important organizing principle of individual identity (Morning, 2007).

Rural. There is no universally accepted definition of rural. Within the U.S. Census Bureau, rural is defined as a population area outside of urbanized areas (densely settled blocks) and urban community clusters (population density thresholds). According to Ratcliffe and his colleagues (2016), rural is defined as all population, housing, and territory not included within an urbanized area. As a result, the rural portion of the United States encompasses a wide variety of settlements, from densely settled small towns and large-lot housing subdivisions on the outskirts of urban areas, to more sparsely populated and remote areas.

Summary

Race/ethnicity and gender disparities in informal STEM learning programs in rural areas persist despite the vast need for exploring science education in these environments and communities. This study examines how science identities in African American girls are expressed after participation in an informal science outreach program in their rural community. The intervention is informed by scholarly research and by best practices from recognized leaders in science education. Examination also includes participants' interests in science, attitudes toward science, and engagement with science. An individual interview design is used to gather qualitative data to answer the research questions. This study's intent is to inform the field about ways in which rural, African American girls develop science identities.

This dissertation is presented in five chapters. Chapter 1 introduces and provides a rationale for the problem addressed in this study. A brief overview of the research on science identity, rural science education, informal science learning environments, and their intersections with STEM is provided. Terms utilized throughout this study are defined, and an overview of the study, its context, and its research questions is presented.

Chapter 2 reviews the literature on the sources of science identity development, rural science education challenges, informal science learning environments, and gender and ethnicity disparities in STEM. This literature underpins the questions being addressed in this study and provides the foundation on which this study is built.

Chapter 3 details the methodologies employed in this study. These include: theoretical frameworks supporting this study, methodological frameworks aiding the research design, data types and sources collected, and analyses conducted on the data collected.

Chapter 4 presents the results of the analyses of science interests, science attitudes, and science identity formation. In relationship with the research questions, the emergent themes from the data are shared.

Chapter 5 outlines a discussion of the findings from the data presented in the earlier chapter. It also details the implications of the data as well as recommendations for key stakeholders in the field.

CHAPTER 2

LITERATURE REVIEW

Introduction

Much of the recent research on gender diversity and equity in science education has focused on formal K–12 school-based programs rather than out-of-school programs. Rahm and Moore (2016) used their study to develop a broad research narrative about students growing up in underserved communities. They found that students are still displaced too often from quality formal and informal science education during K–12 and continuing with college education. Programs such as informal science learning experiences in rural communities have emerged with an emphasis on affecting perceived deficits in knowledge and access that are grounded in visions of equity and equality, resulting in many outreach efforts that make quality science education and the science pipeline more widely accessible (Rahm & Moore, 2016). Yet, the lived experiences of these students and their contact with science primarily in schools that are not able to offer more advanced science courses impact student access to the science pipeline. More specifically, this lack of access impacts the attitudes and interests of girls in science and their engagement in STEM fields. For example, Brotman and Moore (2008) reviewed the research on issues of girls and science through 2005 and examined engagement through equity and access; curriculum and pedagogy; the nature and culture of science; and identity. One of their leading conclusions was that to increase girls' engagement we need to impact the education students receive outside the science classroom as well as inside the science classroom. The purpose of this literature review is to examine the rural science education barriers and science identity formation for those representing racial, ethnic, and gender identities and participating in informal science education environments.

This review covers literature that addresses the sources of rural, racial, ethnic, and gender disparities in STEM education and careers, as well as the nature of informal science learning environments and science identity formation. In addition, this review presents a theoretical framework centered around science identity formation. Literature from the fields of education (rural and science), psychology, racial and ethnic studies, and gender studies were reviewed to inform this study. Reports from national government and nonprofit agencies, literature from journals in the natural sciences, and educational journals for specific natural and health sciences were also included in the review of literature. Articles, reports, and books were found through searches of Google Scholar and the ERIC database using the following terms in various configurations and forms: girls, women, rural, STEM, African Americans, informal science environments, science identity, and science education. References were also found by conducting literature traces through identified articles in which the works cited for those papers were examined for additional relevant works and sources. These traces and searches yielded 103 relevant references. Libraries of online reports from relevant government agencies and nonprofit groups invested in science education were also consulted. Given the wide range of disciplines and theories consulted, this literature review is not meant to be exhaustive; rather, the key important works and their implications for this study are represented. Exclusion was based upon missing relevant key words and terms during the first article analysis. During additional analysis, exclusion was based upon a subjective determination for a lack of pertinent information for the study, such as a pedagogy and approaches.

This portion of the literature review focuses on the theoretical framework underlying this dissertation. The theories that inform the research are described and related to the issue of racial, ethnic, and gender representation in science.

Theoretical Framework

This dissertation draws on Tajfel's social identity theory (1974) and Carlone and Johnson's science identity framework (2007). These theories are employed to understand both how racial, ethnic, and gender disparities in science identity are expressed and how interventions can be designed to counteract these filters. The identity lens allows for the asking of questions about the kinds of people promoted and marginalized by science teaching and learning practices; the ways students come to see science as a set of experiences, skills, knowledge, and beliefs needed for their engagement; and the possible ways that students' developing identities in science might involve changes in their sense of who they are and who they want to become (Carlone & Johnson, 2007). A growing number of learning sciences researchers believe that, in order to show how students actually engage in learning, it is important to: (a) look at opportunities to create and enact identities, and (b) understand the interactions and potential tensions between student, school, disciplinary identities as well as learning and engagement (Barton & Tan, 2010; McDonald, 2019).

Identity Formation

In the development of social identity theory, Tajfel (1974) described social identity as the part of an individual's self-concept that derives from her knowledge of her membership in a social group (or groups), together with the value and emotional significance attached to that membership (e.g., being a female, an African American, or a chemist). This perspective recognizes that two elements are essential for developing a social identity: (a) seeing oneself as a member of the group, and (b) feeling that the members of the group accept one as a member. Students who largely identify with science are more likely to make decisions that validate that identity. These individuals may be better able to maintain their motivation to persist in STEM fields because their efforts are directed toward the pursuit of a science career that aligns closely with their science identity. Consequently, decisions that divert an individual away from a science career pathway carry the additional cost of severing part of a highly valued identity. Subsequently, individuals who arrived at the decision to major in a STEM field through a deep exploration of the field, meaning that they believe it matched their interests, skills, and prior experiences, were more likely to have positive beliefs about their competence in STEM and the value of a STEM major than those students who chose their major based on other factors such as parental pressures (McDonald et al., 2019).

Building on this perspective, a STEM identity is a socially based identity grounded in the extent to which an individual sees themself and is accepted as a member of a STEM discipline or field. Social and psychological research in education suggests that the social environment surrounding feelings of belonging in STEM may play significant roles in nurturing or limiting STEM identity (Kim et al., 2018). Another related aspect is social acceptance, or having the STEM community recognize the individual as a group member who fits in. According to social identity theory, identification with a social group is motivated in part by the desire to see oneself in a positive light. For example, girls are often operating in STEM environments where parents, peers, and teachers think and say that they do not belong and challenge their abilities even when they are academically successful (Kim & Sinatra, 2018; Kim et al., 2018). Therefore, there may be little motivation for girls to remain in STEM courses and endure marginalization as they progress through their formal educational experience. This could have important implications for college and future careers. Accordingly, Kim et al. (2018) argue that a STEM identity should focus on the field content and be constructed broadly enough to value the contributions of diverse individuals who represent many backgrounds and experiences.

Comparatively, the framework proposed by Carlone and Johnson (2007) suggests student science identity is made up of interrelated and overlapping dimensions: competence, performance, and recognition. This framework is shown in Figure 5. Competence refers to having scientific knowledge and motivation for understanding the world scientifically. Performance refers to being able to demonstrate scientific knowledge to others. Recognition refers to both self and meaningful others recognizing one as a "science person." According to the Carlone and Johnson (2007) model, a science identity is composed of different combinations of these dimensions. For example, a student may be able to perform activities that scientists do, show competence in that performance, but may not be recognized as a "science person" by others. Yet, another student who is recognized as a "science person" may in fact have lower competence and lower performance than the former individual.

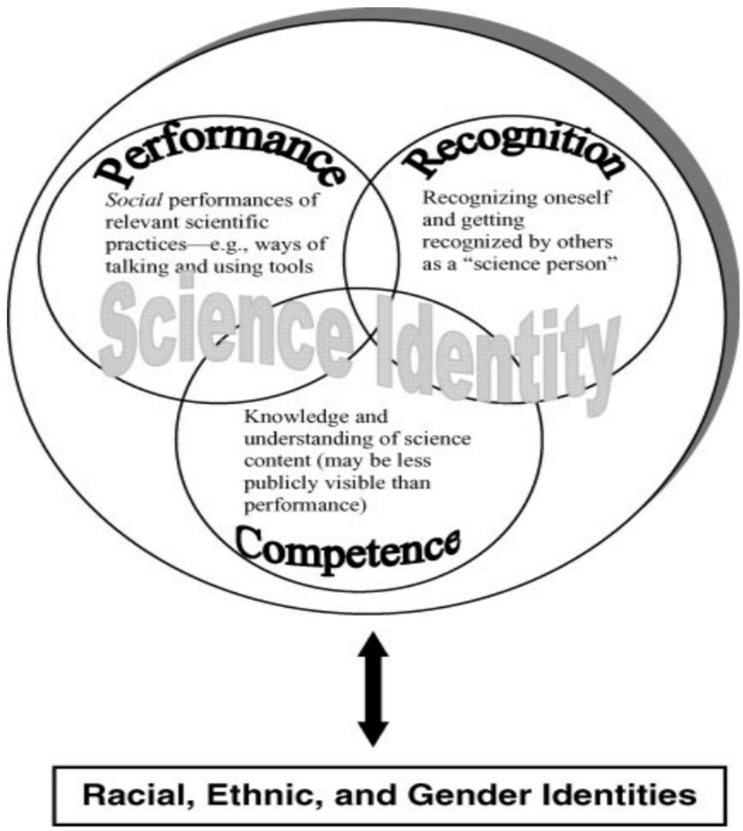
Carlone and Johnson (2007) state that science identity is the concept of migrating into STEM fields, such as what a person says about their relationships, abilities, or aspirations regarding science. Consequently, STEM identity involves an individual making personal meanings associated with their identity, along with the cultural impact of social meanings on these various identities. The current focus on identity highlights the need to unpack and organize assumptions made by access policies that assume all girls and women have the same experience in all STEM fields. Often, students who are competent in science still struggle in their ability to identify with science, because they cannot find connections to their lives and goals.

A person who has a strong science identity can be described as scientifically competent, able to demonstrate meaningful knowledge and understanding of science content, and motivated to understand the scientific world. She also has the requisite skills to perform for others her competence with scientific practices (e.g., uses of scientific tools, proficiency with forms of science communication, and interacting in various formal and informal scientific settings). In addition, she recognizes herself and gets recognized by others as a "science person." The Carlone and Johnson (2007) model accounts for the socially constructed nature of science identity: "Someone with a strong science identity would rate herself highly and be rated highly by others in each of these dimensions, but one can envision various degrees and different configurations of science identity" (Carlone & Johnson, 2007, p. 1190). For example, someone might be able to perform relevant scientific practices (e.g., science communication and uses of scientific tools), recognize themselves as a "science person," and be recognized by others as a "science person," but not have a deep and meaningful understanding of the science content.

Even though not explicitly demonstrated, the Carlone and Johnson (2007) science identity model assumes that one's gender, racial, and ethnic identities affect one's science identity. Thus, the relationship between one's racial, ethnic, and gender identities and one's science identity warrants further investigation with this study.

Figure 5

Science Identity Model



Note. This model of science identity is from Carlone and Johnson (2007).

Science identity is not simply what an individual says about their relationship to, abilities in, or aspirations regarding science. This identity arises out of the constraints and resources available in a local environment. Feelings and actions are components of science identity. Science identity is both situationally prominent and potentially enduring over time and context. It is recognized that identities are formed in practice (Rahm & Moore, 2016). Over time, people's performance, participation, and expectations become patterned and habitual. Through their years of science education, students learn to participate in similar practices in similar ways and often get recognized (or not) in similar ways. Science identity is often seen as fragile but—if it is consistently demonstrated and recognized across time and context, it can be viewed as stable (Krogh, 2013).

Multiple dynamics of the identity process and its application to the education setting advance the theoretical development of identity theory as well as identify the dynamics of one's science identity that importantly influence obtaining a science career (Stets et al., 2017). Stets and colleagues (2017) argue that an identity is a set of meanings that define who a person is in terms of role (role identity) or group or category membership (social identity), or as a unique individual (person identity). This approach focuses on science identity as a role identity given an individual's position in the student role, including: 1) seeing oneself as having a science identity, 2) holding the science identity as important to oneself, and 3) experiencing confirmation of the science identity during the school years.

According to Merolla and Serpe (2013), identity theory suggests that every individual in modern society has multiple role identities that correspond to the different social roles they fill. Identity theory separates role identities based on specific social roles (e.g., a science student), social identities based on group identification and social characteristics (e.g., racial or national identity) and person identities based on specific personal traits (e.g., a nice person). Identity theory can explain why some individuals will choose to demonstrate a particular role identity over another when there is a choice, or why some individuals choose to enter a science graduate program when others do not. According to identity theory, each individual's multiple role identities are structured hierarchically. When individuals have a choice to demonstrate one identity over another, the choice is based on identity prominence. Identity prominence describes the relative placement of a particular role identity relative to an individual's other role identities. Thus, identity theory connects individual behavior to social structure by asserting that individuals with more satisfying social ties to a particular social role will be more likely to demonstrate that role identity in situations when there is a choice. However, identity theory suggests that, for example, simply being white or male does not directly lead to a prominent science identity. Instead, characteristics serve to increase the chances that students will enter close social structures based around STEM, which makes the choice to pursue a STEM career more likely. In addition, given that students who enter college with higher levels of science identity prominence may be more likely to seek out opportunities for interactions based around science, differences in science identity prominence may accumulate over the course of students' collegiate years which lead to an advantage for students who begin college with strong science identities (Merolla & Serpe, 2013).

Lived experiences. Identity is not entirely predetermined by social or cultural context, and it cannot be seen simply as the result of maturation and adolescence. Krogh and Andersen (2013, p. 712) explain, "As part of an identity process, students reflectively and interactively construct themselves and negotiate personal experiences within school science and images of science/scientists." Depictions of scientists in the media, for instance, can strongly influence identity development by producing an image of who should be a STEM professional (McDonald et al., 2019). Studies using an identity lens offer the most complete understanding of students' pathways in relation to science (alienation or recruitment). An understanding of identity and identity formation leads to understanding why people make the life choices they do, especially in relation to the material, social, and institutional opportunity and marginalization of certain identities for certain kinds of people. Identities are the accumulations of the daily stories and positioning that result from our daily interactions with others, and they change through new experiences.

Malone and Barabino (2009) state that identity is lived experience based on historical collectives and is produced through interactions during which one is seen and heard as well as sees and listens. In terms of science identity, what is past is prologue because students carry past experiences forward that inform not only their current identities but also their future identities (Malone & Barbino, 2009). Identity is not totally at the disposal of the individual, because it is lived in relation to layers of social representations. Rather than seeing the social viewpoint of science as enabling or even relevant (other than distorting an objective viewpoint), science traditionally sees identity questions as distracting from the work of science. Yet, all individuals have the potential to develop a science identity. Science identity is a developmental process that unfolds over time. The environment informs the identity the individual develops. The point is that a science identity can imply seeing oneself as someone who engages in thinking, reasoning, and problem-solving systematically to find creative solutions to a problem. Science identity unfolds as individuals who engage in science are afforded (or denied) positive experiences and opportunities.

Sense of belonging. Understanding the role of science identity in persistence involves understanding how people negotiate the cultural norms within their communities and how they become affiliated with or alienated from science (Vincent-Ruz & Schunn, 2018). Perceived interactions with others are likely critical in influencing identity development particularly by perceptions of how others view them and how these views are built on these systemic inequities. The influence of others (e.g., family, friends, and teachers/mentors) can play a large role in providing a feeling of community and affiliation which then shapes identity especially in childhood or early adolescence.

Researchers note that a sense of belonging can significantly predict academic outcomes for youth (Reveles, Cordova, & Kelly, 2004; Mireles-Rios & Romo, 2010). Recent studies have focused on individuals' feelings of belonging in the science environment; but they have not adequately examined how the culture and context of the science environment welcomes (or does not welcome) individuals into the field, particularly those individuals who have not historically been included in science fields in representative numbers (Kim & Sinatra, 2018; Wade-Jaimes & Schwartz, 2019). Similarly, Dou and colleagues (2019) state that students' behaviors and choices are guided by whether they see themselves and are seen by others as a certain type of person (e.g., a science student, an honor student).

Interests and motivations. Interests have commonly been considered a primary driver of science identity. The greater the science interest, the more certain the science identity. When interest leads to participation in science pathways and this participation leads to the development of career goals, then a science identity exists (Vincent-Ruz & Schunn, 2018). Furthermore, these authors explain that science identity can lead to science-related choices when the learner also has strong perceptions about the value of science and high levels of science success or competency beliefs.

Chemers et al. (2011) hypothesize that a significant contributor to successful academic (and professional) work in science is the possession of high self-effectiveness for science skills, and that science success will fully mediate the effects of science experiences on student commitment and performance. They argue for the inclusion of leadership and teamwork effectiveness as an important equalizer in the STEM fields by organizing lab groups, for example, rather than setting individuals to work alone. One proposed solution is to enable students to express and improve STEM identity, which is their ability to see themselves as the kind of people who could be legitimate participants in STEM through their interest, ability, race, gender, and culture (Carlone & Johnson 2007; Hughes, Nzekwe, & Molyneaux, 2013).

Science identity can be broadly defined as the aspect of the self that relates to science (Carlone & Johnson, 2007). Most students have positive attitudes toward science. However, during childhood and early adolescence, a crucial period for making long-term academic decisions, interest in science declines for many students. This corresponds with a sharp decline in students' intentions to major in STEM fields following high school.

Rural Science Education

Communities and schools. Rural schools are sometimes seen as the community hub of engagement and activity. But, according to Avery (2013), every rural community has certain social, economic, and/or environmental issues that are unique to that community. Schools face numerous challenges in rural communities where people of color (primarily African Americans and Latinx) and lower socioeconomic status are in the majority. When compared to urban schools, rural schools have lower funding, geographic isolation, disparities in broadband Internet access, inability to attract highly qualified STEM teachers, fewer resources for STEM courses, and limited exposure and access to educational opportunities offered by science organizations, colleges, and corporations. Thus, many rural children, especially those of color and lower socioeconomic background, are not exposed to the diverse ways in which STEM is practiced in the world and may not envision STEM-related educational or career pathways (Avery, 2013).

With limited availability of resources, rural schools are required to do more with less (Avery, 2013). Rural schools are disadvantaged by limited support and resources (Mathis, 2003; Sundeen & Sundeen, 2013). High-achieving students in economically disadvantaged, rural schools can lack access to advanced coursework necessary to pursuing STEM educational and employment goals (Ihrig et al., 2018). In addition, while using the Internet can provide support to traditional classroom teaching, rural school districts struggle with accessing this instructional method. Many rural districts are in geographical areas of limited bandwidth and inadequate Internet broadband connections, which make access difficult (Sundeen & Sundeen, 2013). Even when online resources are ostensibly available, access for low-resourced teachers and their students may be restricted: “In fact, when teachers use online resources, most of their time (60%) is spent identifying and using free resources or those they pay for personally” (Sundeen & Sundeen, 2013, p. 9). Additionally, Mathis (2003, p. 5) observes, “rural districts typically have less tax capacity and lower pay schedules.” Social and cultural amenities are also often lacking. Thus, regardless of their actual performance, rural schools are more likely to be noted as failing and ultimately lose twenty percent of their federal Title I money (Mathis, 2003). Ironically, these are the schools that need the resources the most—and publicly labeling local schools in rural areas “low-performing” propels the flight from both the schools and the communities.

Students and girls. In K–12 science education, girls in rural communities, especially girls of color in these communities, often do not identify with science, regardless of good test scores and academic success. While decades have been spent addressing the academic achievement gap between girls and boys, very little time has been spent addressing the science identity gap, especially for girls of color in rural communities. This science identity gap might be affected by cultural and environmental factors that impact the daily lives of girls of color in rural communities. These cultural and environmental factors can include household income, community and school resources, and parental education level.

Rural children who want to maintain connections with their family, community, and rural lifestyle may have educational and occupational aspirations that are unavailable in their area. “As a result," Byun et al. (2012, p. 373) note, "rural youth are more likely than nonrural youth to experience conflicting goals." Specifically, rural children often desire to live near their parents but also believe their educational and economic futures are in metropolitan and urban areas. In this situation, rural children who grow up with strong parental support or strong school support may prefer to stay in their communities and thus match their goals to the educational and career opportunities in their communities. In contrast, rural children who have weak family connections may report different goals, desiring to leave for educational and career opportunities in other areas (Byun et al., 2012). High-achieving rural children do not want to leave their community more than do other rural children. Rather, many of them plan to leave their communities to gain important skills and trainings, with the intent to return and utilize those skills and trainings to better their communities. The findings of Byun and colleagues (2012) indicate that coming from two-parent families may indirectly influence the educational goals of rural children by determining the quantity and quality of family social capital (e.g., discussion with parents about college). In fact, two-parent families typically have more resources to help children achieve their educational goals. Also, children are less likely to feel that being successful in school places them on an exclusive path that leads out of a rural place in exchange for an adult life in an urban place (Shamah & MacTavish, 2009).

Jacob and colleagues (1998) suggest that some of the factors that may maintain rural girls' interests in science careers are: involvement in science activities, enjoyment or interest in the content of science, having friends who share an interest in science, and positive parental support for women in science. These findings describe the important and often underrepresented group of highly talented and academically motivated girls who are educated in very small communities with few opportunities for exposure to female scientists, female science teachers, or many other girls who are equally interested in science.

Opportunities and future implications. Integrating STEM in students' everyday lives enables them to use STEM connections, learned in and out of school, to enhance their success in science (Avery, 2013). Avery (2013) suggests fostering dialogue among rural students, teachers, families, community members, and organizations for the continuation of open pipelines to STEM higher education and career pathways for rural children. In addition, Avery (2013) suggests pursuing and cultivating relationships with various organizations, exploring funding opportunities to provide rural children with formal experiences in STEM, and collaborating with other rural districts.

Education research partnerships develop more easily when existing relationships with community members are expanded. Often, there is one individual in the community whose motivation and creativity are key to the success of a program and future partnership. According to Denner et al. (1999), developing relationships between researchers and community members requires patience and time regardless of their backgrounds. Some communities have had negative experiences with researchers in the past. Many programs have experienced what is called "drive-by research," after which researchers or evaluators leave the scene without making findings available or useful to program staff and the community (Denner et al., 1999). However, informative research might find that students involved in the development of new knowledge gain understandings of the purposes and limitations of science. Researchers, alongside students and teachers, can deliver contextually and culturally relevant science curricula. For example, community-based scientists and professionals can work alongside teachers and students in indoor and outdoor classrooms to collect, collate, and analyze scientific data for authentic (community-concerned) purposes (Aldous, 2008).

Current stereotypes of STEM fields include students' ideas about people in STEM and the work they do, recognition of income potential, and perceptions of work/family conflict in their lives (Cheryan et al., 2017). The implication for instruction may be that in some communities, classroom discussions of science applications and stereotypes are not enough. In such settings, educators may need to develop ways to involve students in doing science projects and activities that provide physical benefits (Charron, 1991). Educators need to identify community influences and build upon them. Engagement, regardless of the size of the project, helps builds within the community the expectation for learning and the understanding that science is a process of discovery for learning (Minner & Hiles, 2005). However, making science a community-wide priority and interest can be more difficult in some communities than others.

Informal Science Education Environments

Informal science education involves millions of people who visit science museums, science centers, zoos, botanical gardens, aquaria, science festivals, and other such sites around the world (Dawson, 2014). Parents can also play a critical role in informal science education by introducing children to science through trips to museums, reading relevant books, responding to everyday questions, and more (Alexander et al., 2012).

Role of informal science in learning. Informal science institutions are significant science learning resources in their communities (Bevan & Semper, 2006). They house unique collections of science artifacts and experiences, and they are staffed by educators who excel at motivating interest and involvement with science. They are trusted and valued community resources that are designed to support learners of all ages and all levels of prior science experience and knowledge. It is suggested that these science centers and museums blend scientific resources with the ability of a local nonprofit to reach underserved students of color or draw upon university outreach in order to provide programming for local and regional chapters of national youth organizations (Laursen et al., 2013).

Most informal science institutions are not systematically and consistently contributing to their communities' definitions and visions of what students need to know and learn in science, which are translated through the school curriculum (Bevan & Semper, 2006). Rather, informal learning environments such science and technology centers more often provide valuable motivational opportunities for students to learn science. These environments make an impact on learning while addressing aspects of science education that might be missing in more formal, class-based science learning environments. Enrichment activities in science centers are recognized as an opportunity to increase students' interest in learning (Sasson & Cohen, 2013). Rennie et al. (2003, p. 114) observe, "To the extent that the museum promotes uninhibited, free, playful, childlike behavior, it is an ideal environment for the study of motivation, curiosity, choice, interest, and expectations."

Considerable effort by informal science professionals has been directed at creating more interactive experiences, with the intention of enhancing visitors' learning. STEM enrichment programs build on the importance of first-hand experiences with science events and artifacts to engage the learners' curiosity and motivate further learning (Bevan & Semper, 2006). As year-round, long-established community institutions, informal science centers offer a flow of resources, support, and opportunities for strengthening science education efforts. The informal setting holds an enormous amount of possibility as a mechanism for enhancing the appeal of science lessons (Jones, 1997). Rennie et al. (2003, p. 113) assert, "Out-of-school learning is self-motivated, voluntary, and guided by learners' needs and interests, so it is critical to investigate certain aspects of this type of learning (e.g., the role of motivation, choice and control, interest, and expectations in the learning process)."

It is generally accepted that hands-on science centers are good places for attracting children, and sometimes adults, to science. The informal atmosphere of a science center encourages uninhibited interaction with friends, family, and teachers, which helps to combine learning and memory (Heard et al., 2000). Dierking & Falk (1994, p. 57) state, "Given that these institutions are popular places for many families to visit when they seek interesting and educational ways to spend their leisure time together, they serve an increasingly important role in the science education infrastructure of communities." However, it is important to note that most of the families studied by Dierking and Falk (1994) were middle class, Caucasian families. That these demographics currently reflect the majority of museum users is an issue of great concern to the informal science community as it attempts to increase public visitation by underrepresented audiences.

Engagement and experiences. Different groups struggle to see informal science education and informal science education institutions as culturally relevant because of issues related to power, language, content, and representation (Dawson, 2014). Dawson (2014) suggests that soundly narrow representations of science privilege exist among dominant social groups and alienate people from non-dominant social groups. Calabrese-Barton et al. (2013) found that out-of-school experiences are critical in shaping girls' ongoing engagement in science and in helping to level the playing field. When the outcomes of out-of-school experiences (e.g., practices and identity work) are accepted, there may be greater opportunities for girls from nondominant or minority backgrounds to consider a future in science or consider themselves as belonging to the group of people who can do science. Girls view possible future selves in science when their identity work is recognized, supported, and leveraged toward expanded opportunities for engagement in science like those found in informal science education programs.

Positive programs must be based on helping student experience academic and transformative success first-hand (Diversi & Mecham, 2005). Children need to believe they can succeed in school. Findings from Avery and Kassam (2011) suggest that within a low-income rural context, children learn science and engineering through engaged observation and hands-on doing. These children learn by observing (learning how), doing (knowing how), or both, engaging in activities such as chores, play, construction, and tinkering that take place in their home environments. For example, according to Yoon et al. (2014), the engineering design model and its implementation are needed to curb the loss of interest in STEM subjects that occurs as early as elementary school. Vadeboncoueur (2006) found positive learning and social development outcomes related to participation in afterschool programs and youth organizations.

According to Merolla and Serpe (2013, p. 579), “Research on the effectiveness of STEM enrichment programs has generally shown that students who participate in enrichment programs are more likely than students with similar academic backgrounds to sustain an interest in STEM.” While designed to develop talent and interest in science and increase retention for STEM undergraduates, enrichment programs may also increase the degree to which students identify as scientists. Data shows that participants in enrichment programs are more likely to gain research experience. Further, among these participants, students involved in research projects are more likely to matriculate into graduate school and maintain an interest in STEM careers than are participants who do not engage in research projects (Merolla & Serpe, 2013). STEM enrichment programs are designed to improve student outcomes in STEM fields, with many programs targeted to improving outcomes for traditionally underrepresented minority groups, females, and/or economically disadvantaged students (Merolla & Serpe, 2013). However, minority students of color have less access to out-of-school learning opportunities in comparison to their Caucasian peers (Tanningco et al., 2008).

Components and considerations. Accordingly, Simpson and Parsons (2009) argue that it is important for informal science programs to consider the cultural values of African Americans in program development and recruitment efforts. They state that well-intended efforts can often be in contrast with what is highly valued by members of the targeted population. Informal science education programs can develop initiatives that not only focus on science content, but also incorporate real-life contexts. These program initiatives can include components that develop the cultural identities of African Americans, such as events that highlight the historical contributions African Americans have made and events that involve other African Americans as peers and role models (Simpson & Parsons, 2009). Dawson (2014) found that people from minority backgrounds struggled with informal science education experiences that felt culturally separate or irrelevant. Dawson (2014) argues that improving equity and access in informal science education requires more than providing existing science education programs to different kinds of people. It requires taking difference into account and delivering difference-appropriate science education programs. Improving equity and access in informal science education means everyone is entitled to participate (or not) in informal science education in their own communities, as well as have meaningful informal science learning experiences during which their cultures are respected and represented. Particularly for girls of color, STEM-related interests and aspirations emerge early with culturally relevant, gender-specific STEM experiences that promote and sustain positive STEM positioning in these girls (Young et al., 2017). Therefore, exposure to high-quality, culturally relevant STEM out-of-school activities is critical. According to Young and colleagues (2017), academic success, cultural competence, and sociopolitical consciousness are required components of culturally relevant pedagogy. Culturally relevant out-of-school activities should promote academic achievement through productive struggle, which is the measured amount of academic frustration and grit necessary to build resilience without destroying student self-efficacy, as well as opportunities to succeed.

Quality hands-on, inquiry-based science education consists of opportunities for children to raise questions, design investigations, analyze evidence, and construct explanations. These opportunities are often found at informal science centers (Bevan & Semper, 2006), allowing children to develop their abilities to do science (the process) while they develop their understanding of science (the content). From high-caliber experiences taught by well-trained teachers to interactions with STEM professional role models, the components of an informal or out-of-school science program contribute to its success (Bhattacharyya et al., 2011). Gonsalves et al. (2013, p. 1094) state, “The findings indicate that classrooms and informal or out-of-school settings need to be regarded not only as sites for science engagement but also as opportunities to further students’ training in science.” In addition, these sites offer opportunities for students to engage in practices that broaden their perspectives about what counts as science and solidify their understanding of science in their own experiences and histories. Relevant opportunities and components recommended by Peterson and colleagues (2015) include, for example, inviting STEM professionals to classrooms (e.g., school science fairs). Thus, the K–12 curriculum is enriched with locally relevant scientific topics and involves local STEM professionals who collaborate on learning projects.

Informal environments can provide to marginalized students (e.g., African American girls) specific opportunities to understand themselves as scientists and have more realistic experiences of how science works (Vincent-Ruz & Schunn, 2018). Specifically, providing female role models and improving female stereotypes in science are imperative for increasing the number of girls entering higher-level science courses and careers in science fields (Ramey-Gassert, 1996). Hughes and colleagues (2013) view the added component of role models as more important for underrepresented groups in these fields because they need to see for themselves that there are people like them succeeding in STEM. These researchers believe role models affect these students' overall ability to see themselves as the types of people who fit in with STEM. In particular, girls may see the possibilities for themselves within these fields when they see the career options and the relevance of each field to their own lives.

Gender, Race, and Ethnicity Intersections

If female students and students of color are to be brought into the STEM pipeline in greater numbers, it will be necessary to reshape their early educational experiences. Focused efforts can make a difference in the lives of underrepresented and underserved students and can narrow the opportunity gap that positions underrepresented and underserved students outside of college, advanced courses, and STEM out-of-school experiences. Rahm and Moore (2016, p. 769) note: "Research has shown that participation in science is influenced by a complex set of sociocultural and systemic factors that have kept students from underserved communities at its margin line—and that, by middle school and high school, desirable identity positions are no longer available."

Aspirations and interests. Similarly, an investigation by Tan et al. (2013) reveals that girls in middle school with STEM-related career goals identify with and participate in science in numerous ways. The girls in the case studies developed identities-in-practice in science through the stories they narrated about themselves and through their performances. Tan et al. (2013) believe their data show that even though many girls do well in middle school science and express interest in a STEM career, school-based science has not yet provided the tools or resources to help girls balance who they are and want to be with what they do and think they should do in science class. Given current institutional, historical, and cultural narratives, it is less likely that even STEM-minded girls of color—especially those who have rural, African American, and low SES backgrounds—will pursue STEM careers without additional support for identity work.

Jacobs et al. (1998) describe an important and often-underrepresented group of highly motivated and academically talented girls who are educated in very small communities with few opportunities for exposure to female scientists, female science teachers, or many other girls who are equally interested in science. These researchers indicate that the plans of scientifically gifted, rural, adolescent girls to pursue science careers are related to three general factors: their previous experiences with science, societal and peer attitudes about science, and the innate interest or value of science to the girls. The relationships found in these studies suggest that some of the factors that may maintain rural girls' interests in science careers are involvement in science activities, enjoyment or interest in the content of science, having friends who share an interest in science, and positive parental support for girls in science.

Researchers have observed that girls received a greater number of science opportunities when they expressed an interest in science than when they did not. Yet their results also suggest that when young girls showed science interests, parents were inclined to provide more opportunities for science learning later in childhood rather than earlier in childhood (Alexander et al., 2012). In contrast, Catsambis (1995) suggests that boys received science opportunities regardless of their expressed interest in science. Further, there was a common recognition among children and parents that science is not “girly” and that most girls like “girly stuff” rather than science. For example, Alexander and colleagues (2012) described how gender-typed toy preferences may contribute to some of these differences, with boys gravitating toward objects such as dinosaur models, telescopes, and bug-collecting kits, which are typically are male-typed items. Consequently, “Girls’ sensitivity to the gender typing of such items may lead them to consider such objects to be personally undesirable” (Alexander et al., 2012, p. 781).

In fact, girls who were very interested in science and who held science goals recognized that their interests were not shared by most of their female peers (Archer et al., 2012). This emphasizes the importance of female role models and the negative impact of stereotypes in science. Additionally, the data suggests that building an exploratory foundation for girls is critical for increasing the number of girls entering higher-level science courses and careers in science fields (Ramey-Gassert, 1996). Carlone and Johnson (2007) support this finding when they state that developing a satisfactory science identity depends not only upon having competence and interest in science, but also upon being recognized by others as having talent and potential in science. Girls’ limited interest in science may cause a decline in their science achievement during high school, particularly when enrollment in more advanced courses is optional.

In contrast, gender differences noted in extracurricular activities and programs support the historical idea that boys tend to have more experiences in the physical sciences and girls tend to have more experiences in the biological sciences (Jones et al., 2000). From the perspective of confidence, equity, and financial resources, encouraging girls in the physical sciences can open pathways that create higher-paying jobs traditionally held by men. According to Jones and colleagues (2000; p. 189), “balancing the numbers of males and females in engineering and physical science careers can transform the environments and cultures of these fields, thus changing the field for future generations.”

Achievements and attitudes. Continuing this theme of gender equity in science, a series of studies from Krogh and Andersen (2013) evolved around the notion of school-based science identities, with an emphasis on students who belong to groups historically underrepresented in science: girls, racial and ethnic minorities, and lower socioeconomic backgrounds. Krogh and Andersen submit that social identity is interpreted through narratives about what kind of person the student is and how the student is acknowledged when establishing particular social roles (e.g., good student identity, potential scientist identity). Along similar lines, Jones et al. (2000) argue that, instead of trying to figure out how to change girls so they can become scientists in our current society, society should change to value girls’ perspectives and interests. This idea recognizes the ways in which girls’ identity work takes place in their spaces while bearing the particular structures of power, privilege, and oppression. Researchers point out that “as opposed to examining gender, sexuality, race, class, and nation as separate systems of oppression, the construct of intersectionality references how these systems mutually construct one another” (Calabrese Barton et al., 2013, p. 42).

The National Research Council gives credence to the idea that integrated education is needed as early as the elementary level to strengthen students’ STEM content knowledge and increase students’ interest in STEM fields, especially among underrepresented minorities and females who lag behind their peers in math and science (Yoon et al., 2014). High expectations combined with rigorous curricula compel girls to learn, while less rigorous curricula and poor instruction hinder achievement, especially among some minority students who have less access to out-of-school learning opportunities than do their non-minority peers (Taningco et al., 2008).

K–12 education. Mapping future implications for the field, Tan and colleagues (2013) explain that supporting girls in their pursuit of science and stopping the pipeline leak require science educators, researchers, and teachers to rethink what equitable experiences mean when considering science education reform that supports girls. The argument from Jones (1997) that supports this idea is to look for pedagogical innovations specifically suited to reach underserved and underrepresented students by recognizing that science does not occur outside of a cultural context. Educational strategies should be shaped into practices that address members of diverse groups. In addition, Calabrese Barton and colleagues (2013) suggest that any goals to "level the playing field" will not fully be met without attention to how girls from minority backgrounds engage in identity work as well as attention to schoolwide implementation efforts that support girls in challenging the traditional narrative of what it means to be a good science student and who counts as a science expert. Furthering this idea, Tan et al. (2013) argue for featuring the complex and unavoidable involvements among girls' engagement in science and their racial/ethnic identities, socioeconomic status, and personal struggles. The focus is on how these factors unfold against historical and institutional struggles as girls maneuver for meaningful science participation in their science classrooms and other science-related spaces. They encourage awareness of race/ethnicity and class issues, prejudices, bias, microaggressions, and stereotype threats. This attention is critical for all students, even those who are seemingly fully supported and doing very well.

Tan and colleagues (2013) recommend that science teachers and educators take recognition work seriously to support STEM-minded girls. According to Jones (1997), the inflexible style of much K–12 and university science instruction is unappealing to many girls and students of color. Providing equitable experiences involves creating fluid and flexible spaces where girls can leverage various resources from other spaces, as well as supporting girls' ability to maintain, build, and recreate their self-identities in pursuit of a STEM-related career. These experiences can range from expanding learning outcomes beyond traditional paper-and-pencil assessments to thoughtfully connecting and building on girls' science engagement and identity work. Rahm and Moore (2016, p.772) argue that "a strong interest in science is not enough when the science practices that students experience are disempowering, non-transformative, and irrelevant to their everyday lives." Bhattacharyya and Mead (2011) describe programs that provide an inclusive and threat-free environment where students' interactions with the instructors, staff, and counselors are likely to be more personal than in regular classrooms.

In elementary school, boys and girls are equally interested in science, and as many girls as boys say they are going to be scientists when they grow up (Baram-Tsabari & Yarden, 2011). As students reach middle school, boys and girls begin to move apart in interest, participation, and achievement in science. In addition, Alexander et al. (2012) found that boys are more likely to have had prior experience with the physical sciences, including activities involving electric toys and pulley systems. Girls are more likely to have had experiences with natural and life sciences, including such activities as gardening and birdwatching.

There is evidence of bias in minority students' assignments to teachers of different quality and effectiveness levels, including forewarnings that African American students are nearly twice as likely to be assigned to the most ineffective and least qualified teachers and half as likely to be assigned to the most effective and highly qualified teachers (Taningco & Pachon, 2008). Shakeshaft (1995) notes that minority groups may be more likely to be assigned to ineffective teachers rather than effective ones. Teachers' attitudes have an impact on how girls feel about themselves and about science, and often those attitudes are transmitted in very subtle ways. Teachers are much more likely to allow boys to call out and interrupt in class, while forcing girls to raise their hands and wait their turn (Shakeshaft, 1995). This behavior in formal and informal education settings teaches girls not to answer questions, not to express their enthusiasm or interest, and not to participate. Because male lives and preferences are typically the norm in schools, girls learn that they are less important in these settings. Similarly, one might infer that White women are the norm for gender issues, or that gender has become a code word in science education that refers to White women's ideas. African American women are usually viewed very differently by their male peers than White women are by White men (Atwater, 2000). Working with teachers to change attitudes and teaching practices, to help them build girls' confidence and make science relevant for girls, and to overcome negative stereotypes about both scientists and the students themselves can help ensure that a "science for all" ethos includes girls and students of color (Mutegi, 2011).

An ideal of science education in K–12 settings should be to engage diverse groups of students in science activities and discourses for meaningful learning. However, Zembylas and Avraamidou (2008, p. 994) assert, "School-based science as something different from professional science needs to be constructed around a culturally sensitive science curriculum." Therefore, teachers should strategically reflect upon their own identities and beliefs about teaching science in order to address their own political and cultural challenges to ensure the student's success (Upadhyay, 2009). When teachers' identities conflict with their teaching practices, they must reflect upon their identities or teaching practices. Teachers' behaviors (e.g., allowing boys to call out and interrupt) show girls that they are less important in the classroom.

Teachers' experiences, interests, and attitudes toward science can be relayed to their students, especially girls, in inconspicuous ways that can have a huge impact on the learning environment.

Science Identity Formation

Identity is a multicomponent construct through which people internalize experiences, context, membership in social groups, and intersection with their personal characteristics (e.g., gender, race, class) (Vincent-Ruz & Schunn, 2018). Consequently, young girls' persistence in advanced science coursework during high school may well depend on their earlier attitudes toward science. Vincent-Ruz and Schunn (2018, p. 11) state, "Science identity has a complex differential function in supporting student's optional science choices by gender." At middle-school age, developing a strong science identity is especially critical for girls and those with minority racial and ethnic backgrounds. "Thus," Tsui explains (2007, p. 567), "they can be perceived as incapable of handling a highly rigorous curriculum, which leads to a deficit in STEM majors."

Activities and experiences. Tan and colleagues (2013) argue that it is, in part, because of the science identity gap that girls' participation in science beyond secondary education is limited. Calabrese Barton et al. (2013) note that whether intentional or not, all students, including girls, participate in identity work while engaging in science. The longitudinal ethnographic study of Calabrese Barton et al. (2013) traces the identity work that girls from minority backgrounds do as they engage in science-related activities across school, extracurricular activities, and home during the middle school years. As previously stated, they argue that the girls view their future identities in science when their identity work is recognized, supported, and leveraged toward increased engagement opportunities in science like those found in informal science education programs.

A range of intervention programs operate on college and university campuses in response to the race/ethnic disparity in STEM participation. These programs typically involve a variety of services and activities designed to address factors affecting underrepresented minority students' interest, motivation, and skills in STEM (Tsui, 2007). Intervention strategies such as teacher professional development programs and college minority-serving programs designed to increase participation in STEM could help reduce the shortage of women and minorities in STEM (Stets et al., 2017). However, what may be missing from these intervention strategies is an understanding and examination of the extent to which students accept and embrace a science identity. Underrepresented minorities who identify strongly with academic role identities (e.g., good science student) may have greater resilience for degree completion than do underrepresented students who identify more strongly with social identities (e.g., ethnic/racial, gender, socioeconomic status) (Chemers et al., 2011). The experiences of research participation, mentoring, and involvement in a science community of practice can enhance the commitment to a science career (Chemers et al., 2011).

When noting involvement, some evidence supports the importance of informal STEM education experiences in childhood, like participating in science camps (Dou et al., 2019). Bevan and Semper (2006) suggest that students must engage in science; develop an increasing body of knowledge, skills, and experiences that allow them to become more deeply immersed in doing and understanding science; and have ongoing and connected opportunities to develop their engagement. Outside of school-based science environments, there should be spaces where girls are provided a wide variety of resources and positioning that they can leverage to author their identities (Tan et al., 2013).

Culture and narratives. According to Tan et al. (2013), individual stories should be told about the various roles and paths girls take and how race, ethnicity, class, and socioeconomic status interact in complex and diverse ways to influence how girls engage in science. In their study, Tan et al. (2013) tried to understand the kinds of experiences that shape the identity work of STEM-focused girls and the ways these experiences support or stifle the girls' future STEM trajectories. These authors argue that girls' ongoing identity work can be understood partially by noticing key events that appear to carry meaning over time and/or space, as well as how the outcomes of identity work in one event are or are not transferred to other events (Tan et al., 2013). In their identity expressions, girls reveal their perceived identities through their grades in science and through their verbal and written understandings of who they are in science (position) and who they want to be in science in the future. Rahm and Moore (2016) support an understanding that identity in practice explores students' positionality. Positionality is defined as a person's place within the social structure and how this impacts the person's identity in science. Positionality and its identity are tied to the lived experiences of students. These experiences can include growing up in urban or rural underserved communities, engaging with science through formal education learning, and having limited access to more advanced science courses. Students craft their identities by tapping into resources such as social discourses and practices from within their spaces (Rahm and Moore, 2016).

Stets and colleagues (2017) studied how individuals see themselves in terms of being a science student (the science identity), the importance of their science identity, and the degree to which their science identity is confirmed in situations. These researchers found that students change their science identity in the direction of others' views. According to Stets et al. (2017, p. 12), "When students think others judge them more positively than they view themselves, they are more likely to develop a strong science identity." When the science culture disagrees with students' relative daily lives, science instruction could interrupt students' view by trying to force them to abandon or marginalize their real-life concepts. Yet, bridging the gap between school and community partnerships can make visible to students a diverse array of people who care about, know, and practice science. Additionally, Kim et al. (2018) found that perceptions about who are the insiders or outsiders of STEM fields can be changed through science education enrichment and intervention programs.

Vincent-Ruz and Schunn (2018, p. 1) mention, "When it comes to science identity, research has suggested that it not only involves whether an individual wants to become a science type person, but also the socialization of the individual into the norms and discourse practices of science." Similarly, personal identity involves narratives around the presentation of self and perceived participation responses to interactions. Students' academic identities are formed as a strategic plan of perspectives, in which others' images of them and their own self-images are formed together (Reveles et al., 2004). Therefore, students can simultaneously gain additional competence in their academic expressions, which can contribute to the formation of their academic identities as scientists. Malone and Barabino (2009) stress that participation in science communities is important to future scientists and their sense of themselves as scientists because this participation can form their identities.

Achievements and attitudes. Motivation is defined as an internal state that stimulates, directs, and sustains goal-oriented behavior. Similarly, the motivation to learn science can be defined as an internal state that stimulates, directs, and sustains science-learning behavior. When measuring the motivation to learn science, science education researchers seek to determine why students attempt to learn science, what emotions they feel as they attempt, how intensively they attempt, and how long they attempt (Glynn et al., 2011).

By eighth grade, girls already begin to show less interest in science than do boys. Girls are often operating in environments where parents, peers, and teachers communicate that they do not belong in STEM and their abilities are challenged even when they are academically talented and successful (Kim et al., 2018). Therefore, efforts to improve girls' achievements in science and attitudes toward science should begin in the elementary grades or possibly middle grades, as well as being specifically tailored to the ethnicity of the girls being taught.

Research reveals that, for minority students, science identity is related to their interest in science, their persistence or tenacity in a science discipline, and their intention to pursue a STEM career (Stets et al., 2017). Minority students who indicate a greater intention to pursue a STEM career are more likely to enter a STEM occupation than are minority students who indicate a lower intention. Research has demonstrated that the majority of young children have positive attitudes toward science at age 10, but that this interest then declines sharply; thus, by age 14, their attitudes and interest in science have been largely formulated (Archer et al., 2010).

Science identity is a stronger indicator of out-of-school science experiences when compared to other attitudes toward science (Vincent-Ruz & Schunn, 2018). Not surprisingly, Alexander and colleagues (2012) found that from preschool to middle school, early interests in science are the best indicators of later interests in science. In addition, early informal science-learning opportunities predict later opportunities to engage in out-of-school science-related activities for both boys and girls. According to research on the effectiveness on these types of informal science learning opportunities, participating students are more likely than similar students to maintain their interest in science, perform better in science classes, and complete

STEM degrees (Merolla & Serpe, 2013). These researchers, Merolla and Serpe (2013) found that students who report more satisfying relationships with others involved in scientific pathways are more likely to see themselves as scientists and to express an interest in engaging in more science-based activities.

Summary

In the literature review above, the identity viewpoint allows for questions about those marginalized by science learning practices, the ways that students see science, and the ways that students' identities in science evolve. The literature describes disparities in STEM education represented by rural, racial, ethnic, and gender issues. The literature also addresses the nature of informal science learning environments and science identity formation. This review underpins an examination, presented in the following chapters, of rural science education barriers for African American girls and—against the backdrop of these issues and disparities—their science identity formation through participation in an informal science education environment.

In the next chapter, the theoretical framework of this literature will be used to introduce this study's methodology. In Chapter 3, the implementation of the program design will be discussed. The program design will include the sample, instruments, data collection, and data timeline. The results of this study will be presented through science affinities as further discussed in Chapter 3.

CHAPTER 3

METHODOLOGY

Introduction

This chapter discusses the research methods employed in this study and the underlying epistemological frameworks that inform these methods. The chapter also discusses the scholarly research from which the methods emerged and substantiates why these particular methods are appropriate for addressing the research questions presented in Chapter 1.

An identity lens is used to frame and interrogate students' experiences within the Banneker Scholars program and within the case study. The discussion is supplemented by descriptions of the study's context, participants, curriculum, and collaborators. Data collection, coding, and methods of analysis are outlined. The chapter concludes with a description of the research strategies used to explore each research question and a discussion of the study's limitations.

Theoretical Frameworks for Methodological Approaches

Researcher's role. As a researcher, one must be fully aware of one's own beliefs, perceptions, biases, and experiences as they relate to a study. Subjectivity could play a role in this research, because the researcher is an African American woman who is also engaged in STEM and has experienced identity disparity and achieved science agency. This researcher, who trained as a chemist, pursued a career in science education because of her desire and passion to be a role model for other African American youth. This research is personal, as the researcher has found herself the only African American woman in many settings and environments. It has been a purpose of the researcher to achieve a doctoral degree to help others who look like the researcher and have similar experiences. From a Black feminist standpoint, it is the researcher's mission to equip African Americans—especially African American women—with the perseverance to follow their dreams and achieve at the highest level.

According to Collins (1986), African American women have not been able to express their voices in spaces. They can experience discrimination, which can be reflected in the disparity of minority women in STEM careers. As a former chemistry teacher and STEM practitioner, the researcher has observed many African Americans being told that they could not do science. Many African American girls expressed their disinterest in science until their classroom or out-of-school learning experience with the researcher. As a STEM educator, practitioner, and African American woman, the researcher wants to influence African American girls' positive science identities. The researcher also acts as an encourager, a person to whom the girls can talk, and someone whom they see as a mother figure. The researcher has chosen to view African American girls through a non-deficit lens and believe that they can engage in STEM when given a space that encourages them to excel in their identities.

Identity theory. Identity is defined as a view of self that is navigated through a context informed by past experiences, life events, narratives, and background (Carlone & Johnson, 2007). A person's identity is shaped throughout life, with influences from multiple people and spaces. People have specific views of themselves that can fluctuate, depending on the situation or space in which they exist. Identity is important in exploring reasons for the disparity of representation of underrepresented populations in science. Marginalized students may not see themselves as successful in the science classroom; thus, they may find it difficult to identify themselves as future scientists (Calabrese Barton et al., 2013; Tan et al., 2013). The results of the study are presented through science affinities. The components are differentiated by the purpose that informs the related research questions.

Preferences and interests. Research questions 1 and 2 address participants' preferences and interests regarding science. Interest is a large component of identity formation. Individuals are unlikely to form an identity around a subject that is systematically discouraging for certain groups (Martin, 2004). Therefore, it is desirable to explore both how interested participants are in science and what the nature of their preferences and interests in science. In this study, the question of how interested participants are in science is addressed with a qualitative measure designed to examine personal preferences and interests in science.

Attitudes toward science. Research questions 1 and 2 address the participants' attitudes toward science. Attitudes toward a subject are expected to play a strong role in identity development. Negative attitudes toward a subject associated with an identity will tend to isolate the individual from adopting an identity. If other sources of identity formation in science are strong, negative attitudes can contribute to a confused perception of identity. An important component of science identity is not only how others recognize the performance of an individual but how the individual recognizes themselves as a "science person" (Carlone et al., 2008). Students with negative attitudes toward science are unlikely to form a science identity. Participant attitudes toward science are revealed by qualitative data from individual interviews.

Identity formation. Research questions 1 and 2 address participants' emerging science identities. The Banneker Scholars program is designed to create conditions and scenarios expected to support identity formation. These research questions address identity by direct participant query about their identities. This study seeks to answer such questions as "what," "how," and "what kind" (e.g., what do African American girls who are Banneker Scholars think about science and scientists?). This study demonstrates the differences manifested in the girls' varied identity styles and how these identity styles interact with race, ethnicity, and gender expectations.

Research Design

Case study approach. This research study is an exploratory, single case study, which may be described employing a research strategy that does not require the collection and use of any particular data set of evidence (Hutson et al., 2011). An exploratory case study is used to examine circumstances in which the intervention treatment being evaluated has no single and clear set of outcomes (Baxter & Jack, 2008). A case study is presented in a narrative format dealing with real situations while acting as a learning tool (Sasson, 2014). Through the individual interviews designed for this case study, the researcher is able to analyze the participants' narratives of their experiences in STEM addressed in these research questions:

1. In what ways is the science identity of rural, African American, middle school-aged girls expressed in relation to their participation in an informal science enrichment program?
2. What actions do these girls take in support of their developing science identities?

In a case study, methods seek understanding, explanation, and description of a unique event. This study consists of methods that can address "why" and "how" African American girls engage in an informal science enrichment program. Through the interviews and observations designed for this research study, the researcher explores how African American girls identify themselves as scientists, examines the patterns that contribute to the girls' thoughts, expressions, and feelings toward STEM, and discovers how they have been transformed because of the Benjamin Banneker Science Club. The purpose of this design is to explore specific ways in which participants build identities with science, the characteristics of those identities, and how the identities frame their experiences with science. The goal of this treatment is to gain a better understanding of participants' science identity formation process. As outlined in Table 1, evidence comes from individual interviews, participant observations, artifacts, and documents.

Table 1

Research Questions and Plan for Data Collection

Research question addressed	Q1. In what ways is the science identity of rural, African American, middle school-aged girls expressed in relation to their participation in an informal science enrichment program? Q2. What actions do these girls take in support of their developing science identities?
From whose perspective	Five African American girls from a middle school in rural Modlin County, NC.
Data	*Interviews:* in person. Short 20–30 minutes x three, instead of one-shot interviews. Includes audio. *Observations, field notes, and memos:* researcher notes of observations and reflections from monthly meetings and individual interviews. Field notes template used. *Document/artifact analysis:* activity samples from students, notes from each activity sample, activity sample question notes, meeting handouts, etc.
Why it is important	This research can influence the design and implementation of programs for underserved and underrepresented populations in rural communities. Currently, there is a need within the field of informal science learning environments to design programs that have positive long-term impacts in these various communities.
Relevant literature	Current literature on: • Science identity • Rural science education • Informal science learning programs • Race, ethnicity, and gender

Qualitative Methodologies

Qualitative research can be defined as a repetitive process that is multimethod in its focus and involves an interpretative and naturalistic approach to its subject matter. An example would be qualitative researchers studying things in their natural settings and attempting to understand, or interpret, observable circumstances and the meanings people bring to them (Aspers & Corte, 2019). Qualitative research involves the studied use and collection of a variety of empirical materials—case study, personal experience, introspective, life story, interview, observational, historical, interactional, and visual texts—that describe routine and problematic moments and meanings in individuals' lives.

Purpose of Study

The theorized purpose underlying this Benjamin Banneker Science Club intervention is to facilitate these girls' identity formation through hands-on experiences, science events and opportunities, feedback from peers, and relatable interactions with scientists. It can be hypothesized that rural, African American, middle school-aged girls with developed science identities are more likely to pursue STEM education and have a future STEM career. Research in science identity indicates that many of the women who leave careers in STEM fields such as chemistry and engineering do so in part because they have not developed strong science identities as professional STEM researchers (McDonald, et al., 2019). Developing future professional identities can be predicted by developing early, strong science identities (Vincent-Ruz & Schunn, 2018). Many current African American women STEM practitioners identify an early positive science learning experience (e.g., passionate science teacher, special STEM program, or scientist interaction) that sparked their interest in a particular STEM field (Yoon et al., 2014).

Study Context

In 2020, the United States, along with the rest of the world, found itself facing a global pandemic. The deadly virus COVID-19 has, at the time of this writing, claimed the lives of more than 410,000 people (2.06 million worldwide) and infected 24.7 million in the United States (96.2 million worldwide). The World Health Organization and the Centers for Disease Control and Prevention (CDC) established health and safety guidelines. In North Carolina, people were asked to adhere to protocols that included physical distancing, face coverings, quarantines, lockdowns, stay-at-home orders, and curfews. Closures in North Carolina affect large R1 public universities and entire public school systems, including those involved in this study. Therefore, this research study potentially faced unforeseen challenges involving online interviews, meetings, and observations via the Zoom platform only excluding the ability for in-person study. Potential adjustments to the study protocols in light of COVID-19 were noted below. However, this research study was able to be conducted in-person with approved (in accordance with large R1 university policies) COVID-19 protocols and guidelines in place.

Program: Benjamin Banneker Science Club. As an informal science enrichment program, the Benjamin Banneker Science Club is not necessarily connected to particular learning objectives. While all science activities are designed to create science engagement and develop skills, the program's approach is to maintain enthusiasm and excitement around science. Activities are designed to be hands-on with minimal lecture and instruction. Activity design encourages participants to explore and experiment. Program coordinators are trained to act as facilitators and advisors. The themes of the enrichment meetings and summer camps shift from meeting to meeting and summer to summer, based on feedback from campers and the interests of the program coordinators.

Every year, the Benjamin Banneker Science Club adapts its curriculum goals and increases its rigor. As a result, the program's curriculum is extensive, covering a range of topics and pedagogical approaches. However, the coordinators work closely to ensure that each meeting agenda meets program standards for providing identity-building opportunities, such as guest scientist interactions and field trips that feature those underrepresented in science. In one example, the participants and their families rotate between two sessions led by visiting researchers from two large state public universities. The visiting scientists share their personal stories and then lead games and activities on topics relevant to their current research in the microbial world and antibiotic resistance.

Each monthly enrichment meeting is organized around a theme. On Football Tackle Day, for example, the participants and their families learn about the physics behind football tackles, perform calculations in the classroom and experiments on the field, and then learn how tackles could lead to concussions and traumatic brain injury. In another example, Mini Golf Geometry, the participants and their families practice measuring angles and use the law of reflection to determine how to hit a hole-in-one in miniature golf. They then build their own miniature golf course to test the accuracy of their geometric calculations. The program coordinators select activities from an existing pool of quality content and develop new activities to enable participants to explore each meeting's theme. Typical program activities are hands-on, explore subject matter through inquiry, and use the tools and language of science. Activities include deductive reasoning, rigorous building of new skills, and data collection and analysis. A list of example activities and agenda is provided in Appendix A.

In addition to curriculum-based science activities, program coordinators also prepare a host of fun, science-themed games for the group to play. Examples are Science Pictionary and

Science Kahoot, two online games that invite participants to guess answers to science questions and draw science pictures on paper, then share with their peers on screen. Such games provide a break between activities and fill in the schedule when an activity takes less time than expected. Program coordinators have found that games help students refocus and relax if they become disengaged from a challenging activity. An additional, unplanned benefit of the science-themed games: they helped students remain connected during virtual monthly meetings when COVID-19 led to school closures and social-distancing protocols.

The program coordinators for the Benjamin Banneker Science Club are staff members of a leading science center funded to administer and facilitate this program. The two lead coordinators are responsible for setting the schedule of activities, designing science content, and directing activities. They test the curriculum, consult with program partners, and meet monthly to plan and discuss the program. These coordinators have degrees in science disciplines. One coordinator, for example, has a degree in science education and over 25 years of experience and expertise in formal and informal science education. They have also attended a series of trainings annually through professional development opportunities. Each program event includes at least one additional staff member from the science center to assist in the instruction of activities and coordination of the events. Because engagement and enjoyment are major tenets for this program, coordinators are empowered to redesign activities that do not adequately engage participants. They are trained to gauge participant enthusiasm in the group as a whole and among individual participants. Coordinators can decide to take a break or adapt an activity if this will increase the overall engagement among participants. Similarly, if an activity is popular with participants, coordinators have latitude to extend the activity or reintroduce it later, depending upon time constraints. If an activity is not engaging a majority of the participants, the coordinators are encouraged to speed up the activity and move it along. If any particular participant consistently shows disengagement across multiple activities, the program coordinators are trained to investigate the sources of participant discontent and make appropriate adjustments.

Participants. This informal family science outreach program serves 15 scholars (currently eighth graders) and a supporting adult for each Scholar (parent, grandparent, or other). The program provides monthly family science enrichment meetings for this group every second Saturday from September through June of each academic school year. The program is free to the participating Banneker Scholars and their families.

All the Banneker Scholars were recruited when they were in sixth grade at the only middle school in the county, with the expectation that they will stay with the program through their senior year of high school. This initial cohort consists of 15 scholars (five African American females, three African American males, four Caucasian males, two Caucasian females, and one Latino/Caucasian male). Fourteen of these students have remained with the program for two entire years, while one participant left the program.

Applications for the program were submitted in paper format to the school's guidance office. The application required contact and demographic information, as well as answers to essay questions. A selection committee reviewed applications and selected final candidates for interviews. Final candidates were interviewed in an interactive process, and 15 Scholars were selected to participate.

Selection of participants. The researcher sought participation in this study from all African American females in the program. In order to seek participation and consent, the researcher emailed parents to detail the purpose and process of the study. Consent forms were attached to the email. The researcher followed the email with phone calls to the parents to explain the study and discuss any questions the parents might have. Parents who agreed to participate were asked to email the consent forms to the researcher or deliver hard copies to the researcher at the monthly in-person meeting.

Gaining access. The compliance monitors for this study include the researcher, faculty advisor, and UNC Institutional Review Board**.** Approval for research with human subjects was obtained from the UNC Institutional Review Board prior to data collection. Consent forms detailing the study purpose and activities were collected from parents and participants. The research project was described directly to the Benjamin Banneker Science Club study participants (five African American girls) by the researcher in person (adhering to COVID-19 social-distancing protocols) and by phone and email. Written assent was obtained. So that only the researcher can link responses to specific participants, pseudonyms for individual interviews were used. Participants were informed that individual interviews would be kept confidential.

The researcher was included as personnel in the approved human subjects protocol and transcribed interviews. Transcription and analysis took place on a secure computer and server provided by the UNC Information Technology Department. No sensitive data was collected during this study. Precautions were taken to protect participants' identities. A secure UNC server was used to store any electronic study materials. Any hard copy forms of study materials were stored in a locked file cabinet in a locked office within a locked suite located in a UNC building that requires OneCard key access.

Data sources. Data sources employed in this study include research field notes and memo notes from observations of monthly meetings, artifact field notes and analysis, field notes and memo notes from individual interviews, and individual interview audio transcripts.

Additional data, such as demographic information, were collected from program administrative data. This research study details each research data point, the means by which data collection was administered or completed, the research data crosswalk (shown in Table 2), and the research study timeline (shown in Table 3).

Observations. Observations using the "Participant Observation Guide" were made in three monthly meetings from October to December 2020. The research observer focused on evidence for the elements of identity formation. The research observer: (a) paid attention to how participants approach problem-solving and respond to challenging tasks; (b) looked for ways in which the participants develop scientific mastery through hands-on exploration; (c) was alert to demonstrations of participants' engaged learning with their coordinators and peers; and (d) examined how participants respond to social persuasion in science activities and how their responses in language and behaviors indicate identity development. The research observer took handwritten field notes and transcribed them into electronic research notes for inclusion in the qualitative data set (included in Appendix E: Participant Observation Guide). The researcher used audio recordings of the meetings to assist with reflective memoing after each monthly meeting and for timestamping purposes.

Audio data. Audio recordings were used during the individual participant interviews, monthly meeting observations, artifact analysis, and documentation of field notes and memos. The recordings were transcribed after each participant interview, monthly meeting observation, and artifact analysis. The transcripts were used to analyze for themes that express the science identities of the participants. In addition, these transcripts were used to document the fluidity of the participants' science identities.

Interviews. Interviews with the five participants were conducted in October and December 2020. These occurred in-person in Modlin County with approved (in accordance with large R1 university policies) COVID-19 protocols and guidelines. These interviews were semi-structured, with a list of questions. The researcher used an Individual Interview Guide that outlines structured questions but allows for question follow-up after initial responses from the participants. The questions allowed the participants to express themselves about their experiences of engaging in STEM in both school and the informal science enrichment program. The researcher hoped to better understand how the participants interpret and negotiate these spaces through the lens of identity development. The pool of five rural, African American, middle school-aged girls was selected for these in-depth interviews. These interviews took place in several settings, including the local middle school and local community center (with approved COVID-19 protocols and guidelines in accordance with large R1 university policies). Interviews, which lasted approximately one hour in total for each participant, were separated into shorter 20- to 30-minute segments to allow for greater access to participants' focused attention. Interviews were guided by a script (see Appendix B: Individual Interview Guide) but allowed for conversational directions that develop from the participants' thoughts and interests. Interviews were audio-recorded and transcribed. Field notes were taken during the interviews and electronically transcribed after the interviews. In addition, reflective memoing occurred after each interview to allow the researcher opportunities to document reliable details from the interviews.

Artifacts. During the monthly meetings, the researcher collected artifacts after completion of innovations or products by individual participants or by groups. These artifacts and documents included scientific models, designs, experiments, and written handouts. They were analyzed by the researcher for competence, experience, and confidence supporting identity formation and development. The researcher examined a minimum of six products per participant and gave the participants the opportunity to explain three out of six of their innovation and talk about the process they followed to create it and ways to improve it. The researcher took field notes regarding the artifacts and engaged in reflective memoing about the artifacts after each monthly meeting (see Appendix D: Artifact Analysis Protocol).

Field notes. Field notes were taken during and after each monthly meeting observation, individual interview, and artifact analysis. The field notes summarized the meetings' start processes, observations of the participants' reactions, and group and activity assignments. It is likely that most field notes focused on the participants' activity during the meeting. Pictures taken during the meeting day were added to each field note. Adding pictures in the field notes is intended to give visual insight into the participants' thought trajectory and artifact creation throughout the meeting. Field notes taken after each meeting, interview, and artifact analysis represent the researcher's recorded observations for that event (see Appendix C: Field Note Protocol). The events described (meetings, interviews, and artifact analysis) were audio-recorded. After an event, the field notes were completed and pictures added to depict the important occurrences of the day. Using field notes to document observations provides an important research study diary, enabling the researcher to view the fluidity of the participants' science identities and how these identities are expressed by the participants.

Table 2

Data Crosswalk

Research Question	Methods	Data
Q1. In what ways is the science identity of rural, African American, middle school-aged girls expressed in relation to their participation in an informal science enrichment program?	observations field notes interviews (audio)	field notes transcripts artifacts memos
Q2. What actions do these girls take in support of their developing science identities?	observations field notes interviews (audio)	field notes transcripts artifacts memos

Note. Research data in this crosswalk were informed by research questions.

Data Collection Timeline

As shown in Table 3, the research activities outlined were conducted between October 2020 and February 2021. The researcher is familiar with identity formation and works diligently to ensure an exceptional level of data collection. The researcher conducted the observations, facilitated the interviews, recorded and transcribed the field notes, and transcribed the audio recordings.

Table 3

Timeline for Research Study

	April 2020	May 2020	June 2020	July 2020	Aug 2020	Sept 2020	Oct 2020	Nov 2020	Dec 2020	Jan 2021	Feb 2021	Mar 2021
Proposal writing	x	x	x	x	x							
Proposal defense					x							
IRB approval						x						
Interviews *(Total time per participant: 60 minutes)*							x	x	x			
Observations							x	x	x			
Artifacts							x	x	x			
Transcribe audio data								x	x	x		
Data analysis and Writing									x	x	x	
Dissertation defense											x	

Case Study Analysis

Data from this research study consists of qualitative measures. Below, details of how the data was analyzed are organized by research component. Because girls may approach science differently and place emphasis on different aspects of science as it pertains to their identities, analysis focused in part on how these identity types influence these girls' experiences and feelings about science. Matrix codes and visual representations of data were employed. Key themes were assembled into notes that link back to the primary data sources.

Observational data. The research observer reviewed field notes, memos, and transcripts for clarity. Summaries of observed themes in activities were added to the notes. Final research notes were added to the qualitative data collected, coded, and used in this analysis.

Artifact data. Models, designs, experiments, and written handouts completed by the participants are reviewed by the researcher. Summaries of proposed themes in the artifacts are noted. Final artifact notes, memos, and transcripts are added to the qualitative data collected, coded, and used in this research analysis.

Science affinities data. The analysis of data for science affinities involved qualitative data such as field notes, memos, and transcripts from audio recording of interviews, observations, and artifact analysis. The qualitative results for each research question are presented in the results section of this dissertation (Chapter 4). The same methods and techniques are used to address each research question. Emphasis is placed on understanding how the five participants relate to and engage in science and express their science identity. Evidence of how the program does or could better support the ways these rural, African American, middle school-aged girls engage with science and express their science identity is the researcher's main interest.

Coding qualitative data. The researcher conducted the interviews with audio recording and complete field notes during non-Benjamin Banneker Science Club monthly meeting times with the five African American female participants. The researcher conducted observations and artifact analysis and complete field notes during the monthly meetings of the Benjamin Banneker Science Club. After completing the field notes after each data event, a memo was created to show which research question had been addressed, with documentation provided (picture and/or quotes from the participants) from the interviews, observations, and artifact analysis.

After the data collection was complete, the researcher coded each data source by looking for specific patterns that emerged from the transcribed interviews, field notes, and memos. Emerging patterns relate, for example, to the girls' STEM engagement or social interactions within the informal science enrichment program. A simultaneous descriptive approach with various methods of coding was used to code observation field notes and memos, artifact field notes and memos, and individual interview transcripts (Saldana, 2021).

Following an initial round of coding, the emergent codes were organized into hierarchies according to the theoretical framework. The researcher used axial coding to find emerging themes in the combined initial coded data. Coding and the subsequent qualitative analyses were performed using Delve, a qualitative data analysis software that helps organize, analyze, and find insights in interviews and other qualitative data. After all the documents were coded, matrix queries were run to examine the frequencies of codes and search for codes with overlap. The researcher used themes to organize the data, especially for the cross-case analysis, to help find the relationships between the data and proposed theoretical framework. After looking for similarities and determining themes, the researcher was able to generate theoretical constructs for identity development. The final codebook and the numbers of mentions are described in Table 4.

Table 4

Final Codebook

Themed Codes		
Interests	**Attitudes**	**Identity**
Thought process (213)	Teamwork (33)	Understanding (97)
Problem solving (198)	Enjoyment (45)	Careers (39)
Engagement (180)	Challenges (175)	Support/Encouragement (28)
*Pandemic (20)		

Qualitative reliability. It was important to the researcher that data validity and reliability be maintained within the research design. The researcher needed to be alert to and address any personal biases and reactivity. As an African American woman, she brought to the research beliefs and experiences that could influence how the interviews were conducted and how the participants were observed. Being a participant observer, the researcher was fully immersed in the research and Benjamin Banneker Science Club; therefore, it was imperative that the researcher not influence the research setting or design. By acknowledging these concerns, the researcher could inform and find strategies to eliminate these concerns in the study.

The researcher adhered to the “Big-Tent” criteria for excellent qualitative research from Tracy (2010) to strengthen the validity and reliability of the research and assist in ensuring the data’s accuracy. There are eight “Big Tent” criteria: (a) worthy topic, (b) rich rigor, (c) sincerity, (d) creditability, (e) significant contribution, (f) ethical, (g) resonance, and (h) meaningful coherence. Table 5 describes the ways in which this research study addresses these criteria.

Table 5

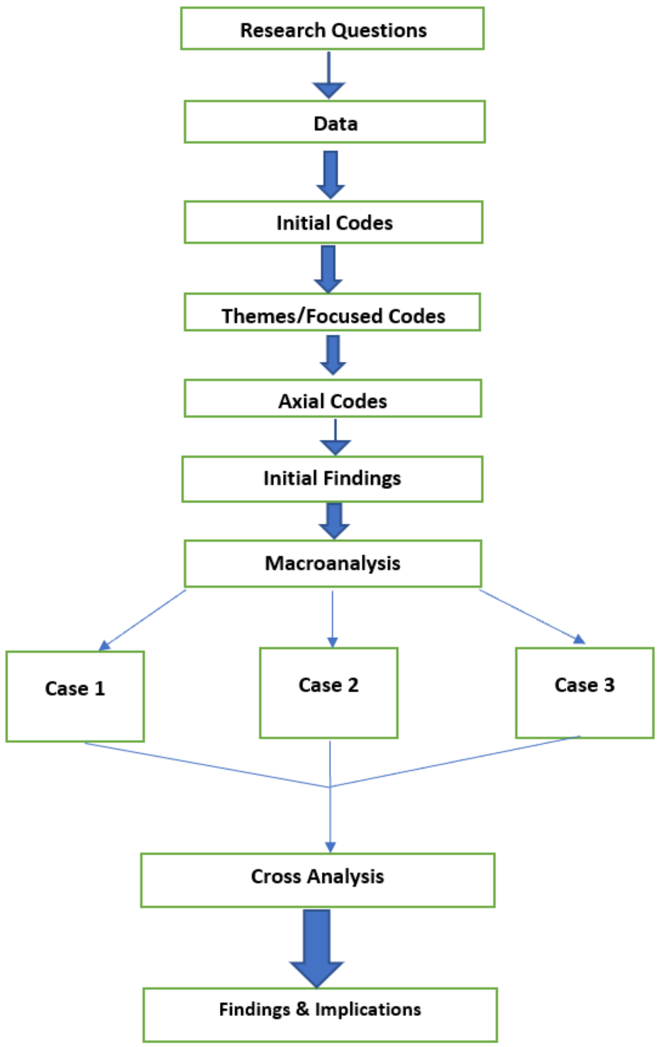
How This Study Addresses Criteria for Excellent Qualitative Research

Criteria	Methods for This Study
Worthy topic	This study is focused on the science identity expression of rural, African American girls.
Rich rigor	The informal science enrichment program being examined has been established for over two years, with a new second cohort of students beginning in fall 2020. The researcher has been involved with the program since its inception.
Sincerity	The biases of the researcher, an African American woman engaged in STEM, have been fully acknowledged and documented.
Creditability	There are multiple data sources to ensure triangulation. There are multiple interviews, observations, field notes, reflective memos, and artifacts. The researcher used a secondary coder, a current doctoral student in learning sciences, to validate initial codes and themes.
Significant contribution	This study provides a conceptual framework and has the potential to inform the informal science education field with its results.
Ethical	This study follows and adheres to all ethical procedures and processes necessary and required by UNC's IRB.
Resonance	This study will be able to transfer connections and meanings from the reader's experiences to those of the participants in the study.
Meaningful coherence	This study connects the research questions to current literature on the expression of science identity of underrepresented students participating in informal science enrichment programs.

Data analysis plan. The researcher used the data analysis plan shown in Figure 6 to analyze the data for this research study.

Figure 6

Data Analysis Plan



Limitations of Study

A limitation of this study could be the researcher's role as a full participant observer. It may be difficult at times for the researcher to focus on what the participants are experiencing during the Benjamin Banneker Science Club monthly meetings because of attention being paid to other participants in the program. Being in the program and researcher environment for the past two years might help alleviate this limitation, because of the relationships with the study participants and the ability to ask them questions after a meeting or during an interview. Being the program coordinator as well as the researcher might at times create biases in viewing how the lessons are taught and how the participants engage in the monthly meetings. The researcher allowed for reflective time after each session to complete field notes and reflective memos. However, the researcher's privilege could have seeped into the reflective process.

Another limitation could be the unevenness of the data sources. Though the participants should be consistent, there might be instances where one or more of the girls might not be able to vocalize and communicate their thoughts in a manner that allow the researcher to find themes and collect enough data for effective analysis. However, having an established relationship and rapport with the participants enabled the researcher to gather enough data from each of the participants to analyze for themes.

As an African American woman in STEM, the researcher brought her own values and beliefs to this research study. When conducting interviews and observations, the researcher was aware of her biases, experiences, and beliefs. She was aware that she related to the girls' experiences, lives, and education. Having faced adversity as an African American woman in STEM, the researcher is passionate about influencing and inspiring other African American women to pursue a STEM pathway. Recognizing the potential influence of her own background and sentiments, the researcher worked to avoid letting them cloud or skew her perceptions regarding the experiences of the African American girls in this informal science enrichment program.

Summary

Throughout the duration of the program, the researcher used multiple methods to capture holistic data from the participants to examine their science identity development and expression. Using the research questions, which are supported by the Carlone and Johnson (2007) model, the researcher selected methods that permit relevant data to emerge for the purposes of the program. Allowing the research questions to guide the selection of research methods streamlined the process and prevented the production of an abundance of data that were not useful for the study. The following chapter shares the findings generated from the data that emerged through this methodology. These findings are presented in relation to the study's research questions.

CHAPTER 4

RESULTS

"What makes a good scientist is if you enjoy it. I think it all depends on, like, if you enjoy what you are doing—because if you do not enjoy what you are doing, then it makes it less fun. And then, you do not think it matters that much to you anymore. So, you have to enjoy what you are doing in order to be good at it." —Mali, age 12

The purpose of this study is to examine the affinities of rural, African American, middle school-aged girls for science and their science identity expression in an informal learning environment. Identity theory (Tajfel, 1974; Carlone & Johnson, 2007) provides the conceptual framework for identifying signs of these girls' science affinities and the factors that may contribute to their persistence in STEM education and careers.

This chapter reports the results of the study's qualitative data analysis. It addresses the primary research components, science affinities and science identity formation, as they relate to the research questions:

1. In what ways is the science identity of rural, African American, middle school-aged girls expressed in relation to their participation in an informal science enrichment program?
2. What actions do these girls take in support of their developing science identities?

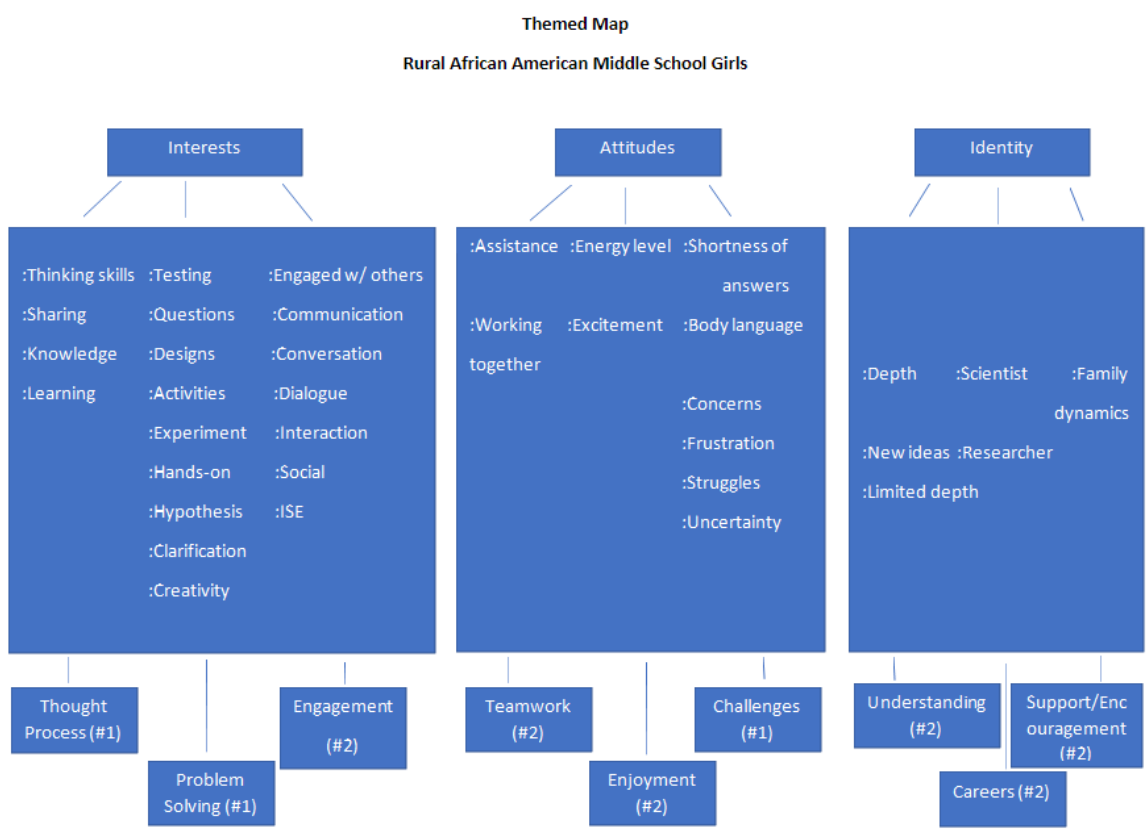
Reporting of the results begins with analysis of the data that addresses science affinities.

Mapping Emergent Themes

What do these African American girls' science interests, attitudes, and identity formation map tell us about how intervention programs should be structured to support the building of science affinities and identities? Figure 7 maps the emergent themes of science affinities and identities as informed by the experiences and reflections of five rural, African American, middle school-aged girls. Science affinities and identities were explored through the BBSC program, and the relevant elements and components were developed through interviews with the BBSC girls, as well as through the researcher's observations, field notes, and memos. The interviews focused on the girls' science affinities and identities. The girls were encouraged to provide a holistic view of their experiences and ideas about science while participating in the BBSC program.

Figure 7

Emergent Theme Map



The following sections revisit BBSC girls' science affinities and identities for the purpose of mapping these affinities and discussing how the program support or might support African American girls in these areas.

Component 1: Science Affinities

This component addresses BBSC program participants' interests, attitudes, and identities around science, sometimes referred to collectively as science affinities. Data used to analyze participants' science affinities includes qualitative elements derived from individual interviews, artifact interviews, observations, field notes, and reflective memos.

At the time of this study, the BBSC program participants were males (*n* = 7) and females (*n* = 7) between the ages of 12 and 14. Of these, five females took part in the research described here. Table 6 and Table 7 provide demographic overviews of BBSC program participant and research participant characteristics.

Table 6

Demographics and Descriptive Information about BBSC Program Participants

Variable	Number of Participants (*N* = 14)	Percentage of Participants
Years with BBSC (2 years)	14	100
Grade Level (8^{th} grade)	14	100
White	6	43
African American	7	50
Hispanic	1	7

Table 7

Demographics and Descriptive Information about BBSC Program Research Participants

Variable	Number of Participants *n* = 5	Percentage of Participants
Years with BBSC (2 years)	5	100
Grade Level (8th grade)	5	100
White	0	0
African American	5	100
Hispanic	0	0

Qualitative analysis of BBSC participants' science preferences and interests. BBSC participants showed higher interest in science after participation in the BBSC program. The qualitative findings presented here address themes in BBSC participants' preferred ways of engaging with science.

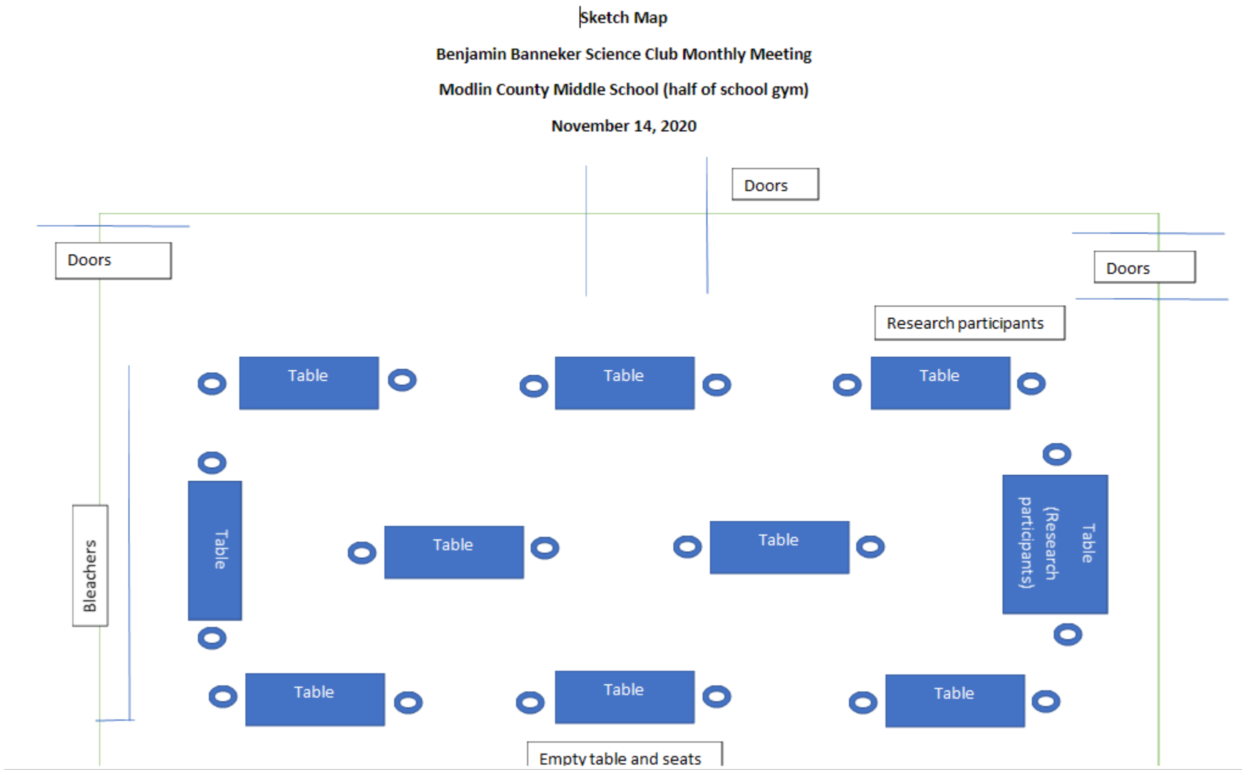
The five African American girls came to BBSC with a range of previous experiences and backgrounds. Some were engaged in science opportunities in school (school-based science club) and outside of school with organizations like 4-H. Most had minimal exposure to science in elementary school beyond their formal school experiences. In addition, there were few opportunities in their rural community, other than those already mentioned. Despite the differences in their experiences, there was substantial overlap in the ways they preferred to engage with science and how they chose to think about and solve problems. Three primary themes for the girls' science preferences emerged from the qualitative data: the girls' preferences for engagement with science, problem-solving, and their thought process.

Engagement. Data from the interviews with and observations of all five participants (Egypt, Ghana, Kenya, Mali, and Sierra) demonstrated their engagement with each other, as well as with their supporting adults as they developed their science identities. Interactions through conversations, dialogue, and communication created social opportunities and engagement with others while in this informal science learning program. For example, when asked about their participation in science before and after entry in the program, Kenya stated that she "started being more interactive in science." She began doing at-home science activities provided by the BBSC program as well as became a participant in school-based and out-of-school based science clubs. However, the data also found the African American girls communicated a change in interactions due to the COVID-19 pandemic. Ghana noted that "it changed the interaction with each other. […] For us, doing hands-on experiments was interaction." The interactions were Sierra's favorite. Yet, COVID-19 guidelines and social distancing protocols (shown in Figure 8) required limited interactions as seen below.

The conversations, communication, and dialogue of these African American girls led to social connections. All five of the girls were very vocal with the facilitators throughout each monthly meeting, whether asking for assistance or sharing thoughts and ideas. These research participants also had conversations with their supporting adults. Often, each table exhibited laughter and enthusiasm that led into robust discussion of the activities.

Figure 8

Monthly Meeting Location Sketch Map



When asked what kinds of science they enjoy and what makes them excited about science, the response most often repeated by the participants was a strong preference for hands-on interactions and social communication and connections through their engagement. There is a definite link between their preference for engagement and their deeper understanding of how the natural world works. According to Kenya, "It helped me find myself in science a lot of different ways because it made me think about more than just typical stuff." All five of the participants referenced their preferences for engagement in the interviews, observations, field notes, and memos. Most importantly, four out of five participants explicitly mentioned their preference for engagement and learning. Mali states that "Science is active and it is a very curious thing." Also, their enjoyment of science was directly linked to engagement. For Kenya, her favorite part of the program, she said, “has to be the hands-on part when you do the experiments.”

These findings are consistent with previous research on girls’ science preferences (Carlone et al., 2008; Archer et al., 2010). However, research also shows that African American girls are less likely than their male peers to have the opportunity to directly engage with science (Alexander et al., 2012). The BBSC participants preferred to learn through social interactions with communication and dialogue as they sought more engagement in science. It is hardly surprising to discover that exploratory engagement was more interesting to rural, African American, middle school-aged girls through this informal science learning program than were formal school activities.

Problem-solving. When the BBSC girls talked about what made them want to be good at science and participate in the BBSC program, they often spoke of solving problems through creativity, questioning, experimenting, testing, hypothesizing, and clarifying with hands-on activities. According to Ghana, “I like experimenting and testing to see if I am right or see if I am wrong” and her favorite part of the BBSC program is when “I make like a hypothesis of what I am going to be able to do.” This data is present in interviews, observations, field notes, and memos. The research participants were very intrigued by the idea of discovering new things through science. According to Ghana, people are good at science “when they make a hypothesis and then when they test their experiment.” Her favorite parts of the program allowed her to “make, like, a hypothesis of what I am going to be able to do. And then I like experimenting and testing to see if I am right or see if I am wrong.” Describing the program, Kenya observed that “it helps me learn better, and it kind of is very interesting when you use your hands and you know you do the experiments yourself.”

For the BBSC girls in this research study, the act of doing science through hands-on activities was a critical component of being a scientist. They expressed a preference for learning science from hands-on science activities. For the BBSC girls, not only are scientists doing science through activities, they are also doing science through activities. That this was a favorite part of the program for them was communicated numerous times. Discussing hands-on activities, Kenya said, “It gave me a visual and a hands-on, and that is what I love about this program.” In addition, the visual learning opportunities that these hands-on activities create also demonstrate the ability to support student’s attention focus. Mali said, “When we do hands-on activities, I believe—I learn better when it is hands-on because I focus more. So, when we do more hands-on activities or if we go visit a place, those are my favorite parts.” Moreover, hands-on activities provide assistance and doing of science for learning as shown by Sierra and Egypt. Sierra discussed how the activities in the program had helped her: “The activities that we did—I learned a lot from it and I can use in school.” Egypt found the activities interesting “because we actually did stuff with science. We did activities with science.”

The BBSC girls demonstrated the need for clarification by having questions for further understanding. For example, Egypt and Sierra exhibited, at times, moments in the interviews when they needed clarification of questions for understanding purposes. Mali had an initial understanding “that science was just there for people who question things.” However, through their participation in the program and with a better understanding of science, the BBSC girls associated being good at science with being creative. The use for creativity is one of the key characteristics of a science person as someone who wants to create, innovate, and discover. For these girls, creativity is the spark that can start a scientist on her path. Kenya and Mali had rich dialogue around creativity. Mali discussed her definition of a good science person, including herself. She stated:

> I believe I am also very open-minded and creative. Science stands for curiosity or wide thinking, because to be a scientist you have to have a really open mind for everybody around you and you have to be really curious about the things you look into. Open-minded because when you cannot be a scientist and have not a very good creative way of thinking of things. Science is active and it is a very curious thing. We are always curious when it comes to science and I would also say that science is very intriguing.

According to Kenya, she is creative and thinks that a good science person has to be creative. Moreover, she thinks that "sometimes they had to be out of the box as well." These two BBSC girls demonstrated creativity in their artifact naming, as well. Mali used the name "Life Raft" for one of her designs because it reminded her of a raft like the sides of boats. Kenya used the name "Shingles" for one of her designs because it reminded her of the shingles on a house. Their data shows that creativity drives actions like problem-solving.

The BBSC research participants also valued the ability and opportunity to solve problems through experimentation and exploration. Problem-solving was a recurring theme for Ghana in interviews about her changed thinking as a result the BBSC program. Ghana explained:

> I am thinking deeper into a problem and situation after the program. Before, I would just want to solve the problem, but now I want to go into detail of what the problem is about. What other way there is to figure out what ways to solve a specific problem.

Mali spoke about problem-solving with clarity, which suggests her excitement for a challenge to overcome:

> *Interviewer:* So, what were you trying to do with this activity? What problem were you trying to solve?
>
> *Mali:* The problem I was trying to solve is, what animals should I choose and how many of them? Because if I choose too many, I would have less money to build with. So, the problem I was trying to solve is, how can I save as much money as possible.

The BBSC girls also enjoyed the challenge of redesigning their activities, such as the construction sites. Their redesigns required them to further engage in problem-solving techniques through their experimentation with the construction site materials. This activity also allows them to enjoy the redesign process and exhibit their excitement to participate in this process.

The BBSC girls' interests in problem-solving relate to the resilience aspects of identity formation (Carlone & Johnson, 2007). They discussed their preference for being allowed to solve science problems and expressed strong preference for being permitted to engage in problem-solving with depth on their own terms. They associated problem-solving with being a science person and a participant in the BBSC program.

Thought process. The requirement for knowledge and skill in science careers was interwoven throughout the BBSC girls' discussions of ideas and interests related to science. They directly referenced the thought process, thinking skills, sharing thoughts and ideas, learning, and knowledge throughout their interviews. This construct was evident in their conversations and observations about science, scientists, and the BBSC program. The BBSC girls shared their ideas and interests with each other, supporting adults, and program facilitators about activities. Two of the BBSC girls, Egypt and Kenya, expressed a dis-interest in science before the program while Ghana joined the program due to her interest in science. However, all three of the girls communicated an increase in interest after their participation in the program. The increased interest represented a positive change from their initial communication of interest before participation in the program.

For these girls, what made a good science person is what she knew and learned while participating in this informal science learning program. When asked about learning in the program and during the activities, all five research participants gave responses demonstrating their level of thought and thinking. Sierra and Kenya stated that the program helped them learn about activities (e.g., hands-on, experiments, visual, verbal) and other science things (e.g., force, gravity). They were able to learn with more ease before the pandemic than after, according to Sierra, Egypt, Kenya, and Mali. In her interview, Sierra highlighted a benefit to others from learning:

> *Sierra:* "I really think, I just have that thought, because when other people learn stuff, they can teach me that stuff. Like, I can teach somebody else that stuff. Because other people can benefit from which you learn.
>
> *Interviewer:* "And you think in science that it is important for other people to benefit?"
>
> *Sierra:* Teaching other people what they have learned. Because sometimes the lessons we learned, like some things are more difficult to do to me than other things. Because of everything I learned in science. Like with the space and stuff.

For the girls, another critical component of doing science was found in thinking skills and thought process. Ghana conveyed this as she explained her thinking and thought process regarding her program involvement: "My thinking has become more advanced. I am thinking deeper into a problem and situation after the program." Mali communicated her mindset on thinking about new ideas and her thought process as she discussed the zoo design activity:

> *Interviewer:* What are some changes that you would make to your zoo?
>
> *Mali:* I would add more animals and spread them out a lot more.
>
> *Interviewer:* Okay. Are there any other new ideas you would add or change?
>
> *Mali:* I would change how many snakes I have. The thing is, I only have one, which is not going to last very long, because when that one dies out I would have to buy another one. So, it would be best to buy two so they can breed and go on, not to buy as much.
>
> *Interviewer:* What materials would you need with your changed zoo?
>
> *Mali:* I need a bigger environment for the snakes. And I would have to keep the hedgehogs and the snakes away from each other next time. They could possibly get out and try to eat the hedgehogs.

Ghana, Kenya, and Mali were observed giving thoughtful and rich answers to questions about their supporting family members' ease with science, as well as their thoughts on problem-solving and idea development. One of the problem-solving activities was the rocket design and launch activity where the participants were given materials (water, Alka-Seltzer tablets, paint dyes, colored construction paper, tape, glue, and camera film containers) to construct a rocket for launching. Ghana explained the thought process involved in her rocket design: "I thought that if we had enough paint with more colors that would be bolder. But since it was too much paint, it was too thick. And the Alka-Seltzer tablet, they do not really combine with much water, so it did not explode that much." (Figure 9 illustrates the rocket activity.)

The BBSC girls' ideas about problem-solving, thinking skills, and the thought process as they relate back to interests build on a wealth of experiences in the BBSC program. Their interests demonstrated to themselves and others that they can enact the roles needed for identity formation.

Figure 9

Rocket Design and Launch Model for Mali from October Monthly Meeting

Preferences and interests summarized. Participants in the BBSC program had higher interest in science than they did before participating in this informal science learning program. The BBSC girls expressed strong preferences for forms of hands-on engagement science learning. They appreciated having a better understanding of problem-solving and experiencing the development of their thought processes.

Science attitudes' analysis of BBSC participants. This section addresses the participants attitudes toward science. The interview and observational data allow attitudes to be addressed not simply in terms of "positive" or "negative"; rather, it allows an exploration in terms of ideas these African American girls had about science and how those ideas influenced their choices. In interviews, the girls were asked what came to their minds when they thought about science, scientists, BBSC, and themselves. When their responses were examined more deeply, it became apparent that the girls had many complex ideas around teamwork, enjoyment, and challenges. Overall, these three ideals formed the science attitudes across the study.

Teamwork. In the observations of all five participants, the data demonstrated them working together and with each other and their supporting adults, to support their science identities. One activity required partners to work together as a team to create the design for their own rocket. In the conversation that follows, it demonstrates that Egypt and Sierra worked together as a unit assisting each other: *Egypt*: "How do you want it—long or short?"

Sierra: Longer.

Egypt: It goes that way.

Sierra: Fold like this? I cannot get it to fold around that way.

Egypt: Cut a piece of tape. Put a piece of tape on the first one right there. At the top.

Sierra: Like this?

Egypt: Yeah. That spot right there.

Mali demonstrated working together as a team and exhibited team leadership skills with her other supporting adult for the program, her mom, through this conversation:

Mali: Make sure that you put it down far enough so that your top can still pop on like that. I am saying do not forget you got to take your top on and off.

Mom: Oh, yes.

Mali: Make sure it is easy to put it on and off is what I am saying.
Mom: I forgot.

Mali: They can go on either way. If you want long ways, then you want them this way.

Egypt demonstrated her willingness to assist her activity partner, Sierra, with the rocket design by showing her how to fold and cut. Mali was eager to work with her mom as partners in the same activity. She offered guidance to her mom in their demonstration of teamwork.

Beyond their interests in science and the BBSC program, these African American girls remarked on how working together and having assistance produced an attitude of teamwork for them. Science identity expression, its forms and actions, are represented for these African American girls through their teamwork involving working together and assisting each other. These actions of teamwork exhibit for them science attitudes that encompass their science affinities.

Enjoyment. The level of excitement and energy among the research participants, this a direct indication of their enjoyment of science and the program. All five research participants communicated their "fun" level for science mainly through their participation in this program. When asked about their views of science and science activities since participating in the program, Sierra and Ghana both communicated about fun:

Sierra: Because they were fun and I learn more stuff.

Ghana: It is a fun subject and is different from all of the other ones, and it uses more than one subject.

The energy level for these research participants ranged from normal to low, depending on the interview date and time of day. The participants tended to have less energy during the morning interviews. However, during afternoon interviews, they seemed to have higher, or normal, energy levels. From the field notes, the researcher noted less enthusiastic and low energy level for the girls during their interviews. One participant, Ghana, noted a particular cause of the low energy levels as she discussed the effects of COVID-19 protocols on the program: “The energy was kind of different because we had to do Zoom meetings, though.”

In contrast, by their conversations during the observations demonstrated the research participants’ excitement about dyeing their branded hoodies and designing their zoos. Their tables had laughter and conversation around their rocket designs and constructed buildings. For example, one conversation showing the laughter involved Egypt working with her supporting adult and program facilitator:

Male adult: It is not a jet plane going to the moon, is it?

Egypt: [chuckles]

Male adult: Your rocket going to the moon. So, who cares?

Egypt: My rocket is going to Mars.

Male adult: We all can get on to my ride and went go off now. You know that, right?

Facilitator: Who is sending their rocket tomorrow?

Egypt: Me.

Facilitator: Yeah? You got to be on it when it goes tomorrow?

Egypt: Yep.

Male adult: [laughs] Go to Mars.

Egypt: And I am not coming back.

Facilitator: That is bold.

Male adult: You are not coming back?

Egypt: Mm-mm.

Male adult: Right.

Facilitator: Okay, if we had actual space travel and you could just go to Mars for a vacation, would you do it?

Egypt: Yes.

The interviews of the African American girls reveal various ideas about who has easier times with science and what is most enjoyable about the program. They felt that their family members and scientists have easier times with science because they enjoy it and it is fun to them. According to Kenya, Mali, and Ghana, scientists put more effort into science. Kenya stated that "they enjoy it. They put more effort and time into figuring something out." Mail stated that "it could be fun and games [...] if you really enjoy doing it." Ghana stated that "even though scientists have to put work in, it is still fun." Sierra believed that her dad has an easier time with science because he tells her that he enjoyed science and math even when he was her age. Yet, it was Mali who, when interviewed, really summarized enjoyment as it relates to science attitudes:

> What makes a good scientist is if you enjoy it. I think it all depends on, like, if you enjoy what you are doing—because if you do not enjoy what you are doing, then it makes it less fun. And then, you do not think it matters that much to you anymore. So, you have to enjoy what you are doing in order to be good at it.

Challenges. African American girls face many challenges when engaging with STEM disciplines, even at an early age. The participants in this study conveyed many of those challenges through the following examples: struggles, shortness of answers, changes, body language, uncertainty, and frustration. According to Sierra, "Sometimes their challenges seemed more difficult to them than other things." These challenges were indicators of their science attitudes. They indicate their ability to overcome obstacles with resilience and grit.

Egypt and Sierra struggled and provided very short answers to many of the questions. These responses were sometimes one word or one sentence. In addition, they, at times, had much uncertainty in their question responses. "I don't know" was the answer given for several questions. They required question rephrasing during many of the interviews. Their body language during the interviews and observational settings involved various body movements: eyes looking up into the air for a thought, handwringing around a scrunchy, picking nail polish off nails, putting their head in their hands on the table, and grunting sounds. In comparison, Ghana, Kenya, and Mali entered into conversations and interviews with confidence, looking the researcher directly in the eyes and providing informative responses.

There were responses to concerns and changes. Concerns about the activities were raised by Kenya and Sierra in the following conversation:

Kenya: I could not do this for a living.

Ghana: I could.

Kenya: I could not. I do not have the patience.

Sierra: We have never learned this before.

On the other hand, Kenya and Ghana noted in interviews how changes in science and program design were good avenues and positive experiences for them. This suggested movement in science attitudes toward a greater end result. According to Kenya, someone good at science is "someone who takes feedback well, so they can change their designs or methods." Ghana's favorite part of the BBSC program was when she was told what to do and then was allowed the space to make a hypothesis:

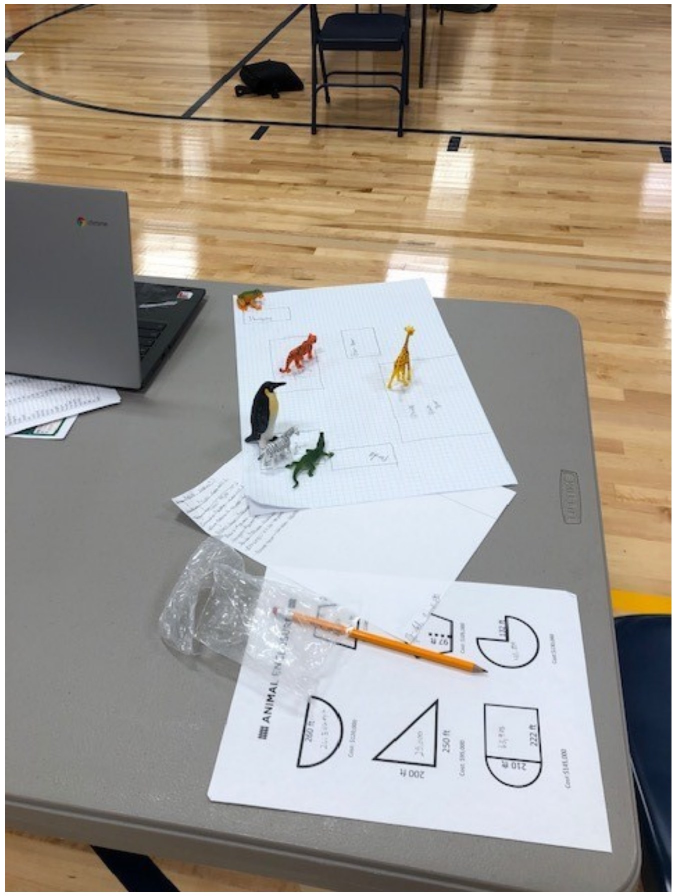
> But then, what we are doing changes and sometimes I am wrong, but sometimes I am right. [...] And then I, like, how—after I get to think about how I was wrong and, like, what I was thinking, how it changed.

As well as being observed during their monthly science enrichment meetings, the participants were asked about themselves as a science person and their reasons for joining the BBSC program. Struggles and frustrations were cited by these African American girls in the interviews, observations, and field notes. Sierra noted in her interview that "sometimes I struggle with things. Like some things are easier than the struggles. I learn faster." Giving her reason for joining the BBSC program, she stated, "I really thought it would benefit me with science because I was kind of struggling before."

The struggles and frustrations were communicated in tone and words through their inability to understand science activities. Mali and Egypt voiced frustration with the construction building materials and their design process during the monthly science enrichment meeting. Egypt, Sierra, and Kenya communicated frustration through their words and body language over the amount of math calculations involved in the zoo design activity. (This activity is pictured in Figure 10.) According to Kenya, "this is way too much work for me." There were also notes of determination in many of the girls' discussions of frustration. They discussed science as a process of persisting through frustration with trial and error. Some had a take that confusion is just another part of being a scientist.

Figure 10

Zoo Design Activity



Struggles and frustrations are problems in science. No one enjoys a struggle or frustration, and children are not known for their patience. Too many times, struggle and frustration have led girls to turn away from science. Yet, all five participants reported specific activities that they actively enjoyed due to positive experiences. As these girls accumulate positive experiences their chances of persisting in STEM grow. More access to meaningful science experiences in conjunction with positive events can have a powerful impact.

Attitudes toward science summarized. The BBSC research participants' attitudes toward science in the informal science learning program were expressed in ways and actions through teamwork, enjoyment, and challenges. The ideas expressed by the BBSC research participants form a general narrative of their conceptions of science, scientists, themselves, and the BBSC program. These girls provide examples of how teamwork can overcome challenges in science while leading to enjoyment in the discipline.

The BBSC girls demonstrate that teamwork is critical in the BBSC program as they completed activities. They assisted each other and their supporting adult for the purpose of science knowledge gain. They also provided examples of how working together created exemplary models of teamwork. Teamwork proved to be one driving force for their science attitudes.

A future in science can involve a lot of challenges. Some girls found the prospect of these challenges—birthed from their own real experiences of learning science—a major threat to their final choice of science study. However, others may have valued challenges as a critical part of the process. Some agreed that figuring things out is rewarding and enjoyable. This enjoyment helped sustain their positive attitude toward science.

Our data are consistent with existing research about science attitudes for girls in general. Major themes include: the African American girls' preferences for engaging in teamwork and assisting each other; their enjoyment of science and how it is done by their family members, peers, and scientists; and their preference for learning through challenges even when these might present frustrating situations.

Component 2: Science Identity Formation.

Science identity. The themes discussed thus far relate to African American girls' interests and attitudes toward science, scientists, themselves, and science education in the BBSC program. These are the foundation upon which their identities as scientists will or will not be built. Many of these areas are connected and similar as has been reported. Interests of these

African American girls relate to their science engagement, problem solving, and the thought process through the activities and events in an informal science learning program like the Benjamin Banneker Science Club program. These African American girls' ideas about science enjoyment, teamwork, and challenges in an informal science learning program relate to their attitudes in science. Their ideals and attitudes about science are directly connected to the messages they receive about their competence and belonging in science.

In examining the emergent science identities in the BBSC research participants, three elements were present in program interviews and observations about their developing identities: understanding, career aspirations, and support/encouragement.

Understanding. The BBSC girls value a deeper understanding of how the world works. When asked about the activities and what they remembered, the BBSC participants responded with understanding in question depth and new ideas. Three out of five girls conveyed in their interviews and observations the importance of understanding science. When asked about their change in thinking and understanding due to the BBSC program, Kenya responded:

> I understand a lot better, a lot more stuff, because we went through it. I think it helped me understand more about how things are and like with the DNA, it helped me. [...] I start understanding stuff more, especially when I am in my class. I understand stuff easier because nine times out of ten we already went over it in the program and it makes me understand way easier and learn better. I started being more interactive in science and understanding more.

Ghana felt she "understood more in this program and it made school like easier because we learned it in the program and then the way we broke it down made me understand it more in class."

Depth in understanding and thought is an ideal that the data projects through the interviews and observations. However, two of the research participants, Egypt and Sierra, at times gave short answers that possibly demonstrated a lesser level of understanding and depth. The following exchange is an example:

Interviewer: How did you come up with that name?

Egypt: I just used my name and design. I just took my name.

Interviewer: How did you come up with that name?

Sierra: Just because of my name.

In contrast, Ghana and Mali exhibited a great memory of the activities, with a depth of understanding in communicating that information. Mali discussed her reasoning for her zoo design:

> I tried not to get too much of anything. So, I stick with the minimum. Besides, with some of them, I went over the minimum, bought one or two. But I just figured, the less I use, the less space is required, which means the less money I have to use in the exhibits.

The interview explored her reasoning further:

Interviewer: Okay. What are some other things you needed to figure out about your zoo?

Mali: I need to figure out which animals can be with other animals. Which ones I have to keep separate? I also have to decide if I do put them all together, should I have to close off some of the spots so they cannot get to each other? And I also have to decide where am I going to place the different spots, so they are all gathered up?

Interviewer: What are some changes that you would make to your zoo?

Mali: I would add more animals and I would spread them out a lot more.

Interviewer: Okay. Are there any other new ideas you would add or change?

Mali: How many snakes I have. The thing is, I only have one, which is going to not last very long, because when that one dies out I would have to buy another one. So, it would be best to buy two so they can breed and go on, not to buy as much.

Interviewer: What materials would you need with your changed zoo or when you work for your changes?

> *Mali:* I need a bigger environment for the snakes. And I would have to keep the hedgehogs and the snakes away from each other next time. They could possibly get out and try to eat the hedgehogs.

Ghana gave the following example of her changed thinking:

> My thinking has become more advanced. I am thinking deeper into a problem and situation after the program. Before, I would just want to solve the problem, but now I want to go into detail of what the problem is about. What other way there is to figure out what ways to solve a specific problem. Coming up with different ways and seeing how the different ways would reflect on my outcome.

Mali and Ghana both demonstrated their ability to dive deeper into a problem and engage in the reasoning process. Their increased understanding of science through the BBSC program was evident with this display of communication regarding their reasoning and thinking. They conveyed their ability to explore with depth into the activities as an example of their deeper understanding of science by their participation in the BBSC program.

Examination of new ideas presented by the research participants showed three of the five participants communicating critical data about program improvements, changed thinking, and views of science. Mali shared:

> Because of science there is so much we do not know yet. And the further we get in the year or maybe in, like, a few more years, we could learn something that we never knew. Like, maybe in a few more years somebody might figure out a cure for cancer or they might discover a new rock or a new animal in the sea.

When discussing scientists, she shared:

> They are people who try to find new things in the world and make the world better. But now that I have enrolled in the program, I realized that is not all they do. They do, actually, a lot more, like, they might make new things for us to use in our daily life or make a cure for cancer. [...] Because to be a scientist you have to have a really open mind for everybody around you, and you have to be really curious about the things you look into.

In talking about program improvements, Ghana had an idea that she really wanted to share.

> I have had this idea to add more people to the program, because when I first thought about signing up for this program, I did not think it was going to be like this. It was kind

> of unexpected. I was thinking it was just gonna be like a class or something. I thought it was just going to be like another science class. But no, this is way more advanced than this. And I wish there was some way that we can actually show other people how this program actually is—it is not just a class or anything—so that we can have more participants willing to join in. I just want the program to be bigger.

Ghana wanted to see the expansion of the program so that it can benefit more students in Modlin County. She demonstrated her understanding that an informal science learning program like the BBSC program should be a resource for more students to increase their access to equitable and quality science education.

Career aspirations. As previously discussed, career aspirations in science for girls, especially African American girls, can be stymied by deterrents at early ages especially the middle school years. In this data, the research participants use topics such as research and scientist to convey their career plans and understanding of a future career in science. When asked to explain how one becomes good at science, Egypt states "because they do research. Everybody can do research if they put their mind to it."

Sharing their thoughts on scientists as they relate to their own understanding of science and science careers, three of the African American girls (Ghana, Mali, and Sierra) had similar responses. According to Ghana, a good scientist is one who makes a hypothesis and tests it correctly. In addition, the physical attributes of a scientist are "tall, goggles, gloves, mostly the hair pulled back because you do not want anything to get on you. Have long pants. I think people should wear long pants because they do not want anything getting on their skin. Closed shoes, goggles to protect your eyes." Ghana thought these scientists have an easier time with science "because they know what they are doing, and I am just kind of learning how stuff works. Most scientists have already done an experiment. They already know the outcome." Sierra described scientists in this manner:

> I did not really think that scientists were that cool or whatever because of the experiments they did. But when I got into the program, I started looking online more about scientists and what they found out that was new.

Mali expressed her thoughts about scientists, including a famous one in particular:

> For example, Albert Einstein. He might have had it hard. We might have it easier than him because we have more stuff to work with when he did not have that much. So, it would be harder for him because he did not know as much as we do now.

When discussing their direct career plans, four out of the five African American girls had concrete thoughts and plans for themselves or had concrete plans projected upon them by others. Sierra was clear about her change in career path: “I wanted to be a teacher before the program and now I want to be a scientist.” However, Mali’s career plans had not changed: “So, ever since I can remember, I have always wanted to be a vet.” Yet, Egypt communicated the career plans expressed for her by her family member:

> *Interviewer:* When your cousin talks to you about working with science stuff because he is an engineer, what do you think about that?
>
> *Egypt:* He wants me to be something in life.
>
> *Interviewer:* Okay. Do you think he wants you to be something in life related to science?
>
> *Egypt:* Yes.

Support/encouragement. The family dynamics, structure, and support are a critical component of the BBSC program as an informal science learning program that features family science. From the data, it is evident that this family structure and support are factors in defining the science identity expression for these African American girls regarding the actions the girls take to support their science identities. Sources of support and encouragement were not only documented from the family members, but also from each other and the meeting facilitators for these African American girls. This is exemplified in two conversations between Kenya and Ghana as well as Mali and the meeting facilitator:

Kenya: Is it supposed to be like that? You are not helping me.

Ghana: I am so sorry. Yes, it is supposed to be like that.

Kenya: Is this all right?

Ghana: I think it should be smaller. The tighter you make it, the smaller it is going to get.

Kenya: I am just going to pull it a little bit.

Ghana: See. That was big there and then you pull it, it got small. You got it! See. Look at that!

Facilitator: Is this the original design you were imagining?

Mali: No.

Facilitator: You had to change and adapt it?

Mali: Yes.

Facilitator: That is good. That is what engineers do if something is not working, right?

Mali: Well, actually, it kind of is.

In a continuation of science identity expression and formation through family dynamics, three of the five participants commented about the science career nature of family members. Sierra talked about her dad helping her with science because he enjoys it now and at her age. She found it helpful to have him assist her. Kenya highlighted her family members with science backgrounds when discussing people who have an easier time: “My aunt, because when she went to college, she studied science. And my cousin, because she is studying to be, I forgot what it is called, but she is studying science, too.” As previously discussed, Kenya talked about her brothers doing science experiments at home and having good grades in science. In addition, she discussed her cousin, the engineer, and his desire for her to have a career in science. The science identity formation of these girls was influenced by the science career pathways and at-home science engagement of family members. By the program design of family involvement at monthly meetings, there was family support to engage and inspire these girls in science. In the monthly meetings, family members were observed encouraging these girls with words and body language as they complete hands-on science activities.

Science identity summarized. The BBSC girls might define their career paths based on their understanding of science and scientists as well as the support and engagement from each other, program facilitators, and family members due to their participation in this informal science learning program. With their understanding of science, they envision what scientists do and want to do those things in their future careers. They sustain their career aspirations through the support and encouragement from their peers, program facilitators, and family members with the activities presented by their participation in the BBSC program. The optimal setting for building science identities for these girls is one where they can obtain understanding of science and maintain the support and encouragement from their program community to pursue a science career.

The data are consistent with research about girls and science identity formation. Major themes in the data include the African American girls' ability to understand science with depth, the support and encouragement of their program community especially the family structures, and science career planning can help support the formation of science identities.

Interpreting the results for the analysis of science identity formation. This analysis focused on what kinds of science identities the BBSC girls displayed and what these identities imply about how to support African American girls in science. The emergent science identity and affinity concepts were mapped in this chapter. Based on the data collected in this study, BBSC girls who demonstrated evidence of science identity formation fall into three categories. All three of these science identity categories are underscored by an understanding of science and scientists, support and encouragement from their program community, and a strong preference for pursuing a science career pathway.

COVID-19 Pandemic

One unexpected topic that diverged from the original individual interview questions was the effect of COVID-19 protocols and guidelines on the educational learning environment for the research participants. At the time of writing this dissertation, the US-infected numbers total 24.7 million, with 410,000 deaths. In North Carolina, the current surge has 699K infected and 8,397 deaths. In these interviews, the African American girls were asked about their changed thinking and the differences they perceived since March 2020.

All five of the research participants communicated responses for this topic that provide a deeper insight into the magnitude of these effects on science identity. For Egypt, the hardest transition for her during the pandemic has being asking questions over a computer. She is clear that she does not like working on a computer. She preferred in-person “because it is hands-on.” Yet, for Ghana, things were a little different. Her interest is the same even though it is over the camera. She felt that “the energy was kind of different because we had to do Zoom meetings, though. But it was still fun, because we were still learning and still experimenting and testing, so it was not that much change.”

However, when Sierra, Kenya, and Mali were asked the same questions about changed thinking, additional insights were communicated. According to Sierra, the pandemic had caused a negative change for her. She lost a grandparent during the early parts of the pandemic in the spring 2020. This negative change had made her “feel bad about myself, because I could not really turn out all the work in one day.” She continued:

> I felt really good about school before the pandemic. And after it is—I don't know. It was kind of crazy after. Before the pandemic, we did not really have that much work to do in one day and now they assign a lot of things in one day and are all due one day.

Sierra's favorite activities in the BBSC program, like field trips, had been drastically affected. She commented, "We cannot really do anything with the pandemic around, because most places are closed or you cannot go in without a mask or something." She had found some solace in the weekly virtual homework sessions with one of the program facilitators: "Because of Mondays and Wednesdays, we have a little session that helps us and [the program facilitator] helps us with the work."

According to Mali, the pandemic and the educational environment that it had created, "makes me question if I am actually good at science, or is it just because of what I want to be, that I am trying to excel in science?" The switch to virtual learning did not allow her to get together with classmates and work as partners on projects. She maintained her interest in science, "but I just have not really thought about science as much as I would have if we were not in a pandemic. Because I could actually go out and question things, when now I cannot really go anywhere." Similarly, Kenya stated:

> Zoom is a little bit harder than face to face. Because normally, you could just get up and ask [the program facilitator] or someone to help you with it. But when you are on Zoom, you have multiple people talking, multiple noises, and it tends to be harder to figure things out here.

Since March 2020, Kenya had "missed [the program facilitator]—somebody to help me." She continued:

> But now it is kind of hard—because I am only at home and, you know, nine times out of ten, I just have the computer and her telling me what to do, or I just have an instruction of paper and sometimes it is difficult to learn.

The effects of the COVID-19 pandemic might have some lasting effects on the science identity formation and science attitudes of these African American girls. From this data, it is evident that there are current effects on their attitudes toward science and virtual learning. In addition, there appears to be some effect on how they view themselves as a science person which is a factor in their science identity formation.

Overview of Results

Emergent identity themes provide a guide for how individual girls prefer to engage with science and what kinds of support they need. Examination of the measures of science affinities in this study shows that participants had higher starting science affinities than that found in the literature. Participants' science interests and attitudes improved from pre-participation to current participation. The direction of science identity formation was dependent on the understanding of science, science career aspirations, and the support and encouragement from their peers and program community.

The BBSC girls reported a strong preference for engagement in science through problem-solving and their thought process. They communicated that engagement in science influenced their ability to solve science problems and think about science learning. Generally, the BBSC girls most associated with their science identity by engaging in science.

The BBSC girls' discussions of their science identities, which focused on interests and attitudes, were consistent with identity formation theory (Tajfel, 1974; Carlone & Johnson, 2007). Teamwork, enjoyment, and challenges were key elements of science attitudes that these girls related to strongly. Working together as a team, creating enjoyment, and overcoming challenges appealed to these girls and their forming science identities.

In this chapter, the researcher mined multiple sources of data, using both conventional means of data analysis through open-coding hard copies of transcripts and qualitative data analysis software to better organize the codes. Implications of the major findings reported in this chapter will be discussed in the next chapter. Particular emphasis will be placed on the implications of girls' science affinities as they aligned with the BBSC program and the interaction of the science identity formation themes and expectations.

CHAPTER 5

CONCLUSIONS AND IMPLICATIONS

Chapter 5 summarizes this research study, presents the study's significance, and discusses the results. In addition, study limitations and future implications for practice are discussed.

Understanding rural students' science identity, especially among African American girls, as an important driver of choice for their present and future is critical to the field of informal science education (Vincent-Ruz & Schunn, 2018). As the literature has previously mentioned, rural students—especially those underrepresented in STEM, like the African American girls who participated in this study—need to see the relevance of science in their daily lives. Opportunities that connect STEM to their everyday lives inside and outside school enhance student success in science (Avery, 2013). Rural school districts, schools, and classrooms have notable obstacles to overcome, such as reduced access to science-related resources and opportunities (Sundeen & Sundeen, 2013). These obstacles have been made underscored in the wake of COVID-19 sweeping across the nation.

Overview of the Study

Chapter 1 of this dissertation began a discussion about the problems of gender, race, and ethnicities in STEM. The statistical data demonstrating the representation of women and minorities in various STEM disciplines were presented. A brief overview of the informal science outreach intervention under examination, including the Benjamin Banneker Science Club program, was presented. Finally, the research project and research questions were presented.

The purpose of this study was to examine the Benjamin Banneker Science Club program participants' science affinities and the relationship of these affinities to the science identities of five rural, African American, middle school-aged girls. Information about these African American girls' science affinities and the types of science identities they are building was explored, as this could provide valuable insight for researchers, policymakers, educators, parents, and other science allies in how to better support African American girls in science. This information could also be used to improve informal science outreach interventions like the Benjamin Banneker Science Club program. The study was divided into two components and two research questions. The two components were: science affinities and identity formation (explored through research questions 1 and 2).

Chapter 2 presented literature addressing explanations for gender, race, and minorities disparities in STEM. The literature was organized according to four themes of disparities in STEM: rural science education; informal science education environments; gender, race, and ethnicity intersections; and science identity formation. The theoretical framework integrating theories by Tajfel and by Carlone and Johnson was presented. Finally, the conceptual framework incorporating the foundational theories was presented, as were the expected outcomes.

Chapter 3 described the methods used in the study, including design, instruments, and analysis of the qualitative data. The study's qualitative approach employed observations, individual interviews, and artifacts. Chapter 3 also presented the design for the qualitative portion of the study, including the data collection timeline and case analysis.

Chapter 4 presented the results of the two study components described above. Analysis of the data showed that, overall, the level of implementation of the program goals was evident in the science identity expression of the African American girls who participated in the study.

Analysis of the BBSC participants' science identities found that the BBSC African American girls' science identities demonstrated growth following their science club participation. Chapter 4 also presented these girls' interest in and preferred ways of learning science, their attitudes toward science, and their sources of science identity.

Significance of the Study

Racial, ethnic, and gender disparities in STEM have been a national conversation for many years (Laursen et al., 2007; Merolla & Serpe, 2013). Educators, researchers, policymakers, and parents all have a stake in addressing this issue. Arguments for greater inclusivity in STEM range from economic benefits for women and minorities, to broader societal benefits of equitable participation in the STEM workforce (Jayaratne et al., 2003; Riegle-Crumb & King, 2013). This research study sought to better understand how rural, African American, middle school-aged girls build their science identities and how an informal science learning intervention might support that process.

The results of this study provide slightly more insight into how African American girls relate to science and what can be done to support African American girls' persistence in STEM. These results informed the BBSC program in the areas of participants' science affinities and their ideas about science. Following is a discussion of the results reported in this study and their implications.

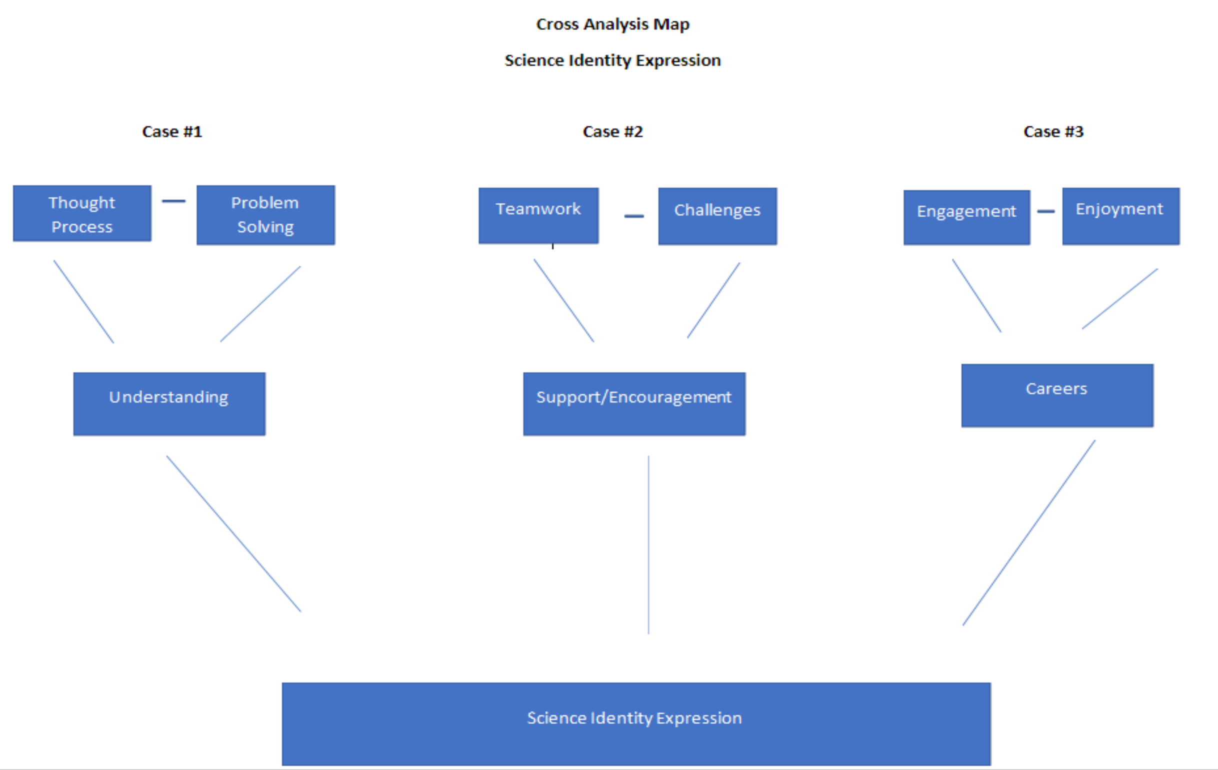
Discussion of Results

This study explored girls' science affinities (interests and attitudes) and science identity formation. The literature suggested that girls, particularly in underrepresented populations, who develop strong identities and attitudes around science are more likely to persist in STEM (Olitsky, 2007; Carlone et. al., 2008; Archer, 2012; Young et al., 2017; Kim et al., 2018). The study sought to examine how science identity was expressed by rural, African American, middle school-aged girls participating in an informal science learning program. The study also sought to describe the actions these African American girls took in support of their developing science identities.

Discussion of the results is presented here in three parts. First, the results of components 1 and 2 from Chapter 4 (science affinities and science identity formation) as they map onto the BBSC program are presented. A map of these themes is shown in Figure 11. Second, implications for the practice, based on the results of this study, are discussed. Third, future directions for the research data results as they apply to the discussion of African American girls and informal science learning are provided.

Figure 11

Cross Analysis Map of Themes



Case 1. Understanding—Thought process and problem solving—BBSC girls' science interests and preferences. Connecting science with their real-life interests helps underrepresented students sustain their science identity (Upadhyay, 2009). When underrepresented students view learning science and solving science problems as connected to their life experiences and future goals, they are more willing to actively engage in science. For many underrepresented students, socialization with science comes from role models and mentors, like supporting family members and scientists in their communities.

This study demonstrates that understanding must be part of the discussion regarding informal science learning programs, particularly as understanding relates to rural, African American middle school-aged girls' science identity. The results indicate that the problem-solving skills and thought process exhibited by the BBSC girls in their understanding of science content and interests are important to the program's overall effectiveness. This study aligns itself with the limited literature on the role of identity in science education efforts to improve rural, African American, middle school-aged girls' persistence in science fields, particularly in the distinctive context of informal science learning environments (Elam et al., 2012).

BBSC, an informal science learning program, was in alignment with the girls' preferences for using their problem-solving skills and their thought process to create a better understanding of science through their engagement with hands-on activities. The BBSC girls expressed a desire for deeper learning and understanding of science. They exhibited a focus on understanding the "nuts and bolts" of processes and tinkering with these processes. The program gave the girls access to scientists and the opportunity for in-depth exploration of activities they enjoyed. However, the activities still created some frustration for the research participants. One of the BBSC girls suggested improving the program by expanding the program design and resources to provide the services to more students and the community.

The data show that some of the BBSC girls entered the program with a higher beginning interest than the others. Their interest in science was higher following their enrollment in the BBSC program. The BBSC program provided access to the kinds of science opportunities for which these African American girls express a preference. However, it remains unclear if the program helped to sustain or increase the research participants' preferences based on their race, ethnicity, and/or gender and exactly what role their rural community plays in their preferences.

Case 2. Support/encouragement—Teamwork and challenges—BBSC girls' science attitudes. Students who have support from the science community and encouragement from family enjoy spaces created for teamwork opportunities with their peers and scientists (Hughes, Nzekwe, & Molyneaux, 2013). The capacity of informal science learning institutions, like science centers and museums, should be leveraged to facilitate meaningful family and peer interactions around science that lend support and encouragement, as well as situations for working together as a team with the scientific and program communities. Their programs can be impactful for students who need this support and encouragement for scientific success through environments for teamwork. This data confirm that creating teamwork opportunities and overcoming challenges are a bridge for the support and encouragement that these BBSC girls need for their science and program achievement.

The analysis suggests that these BBSC girls saw some of the science engagement as challenging and the cause of some frustration. Even though science is challenging, and failure is common for everyone, some of these girls struggled to see this reasoning. Yet, they all desired to be knowledgeable and skilled in science. Some were quite drawn into their own self-determination. However, no one enjoys failure or frustration in understanding and completing science activities. The BBSC program's support and encouragement provided them with context for their frustrations through teamwork with their program community. It is evident in the data that these BBSC girls understood that experiments may not turn out as expected and there is always learning in mistakes. The BBSC program structure and design allowed for the girls to communicate frustration and failure in an environment where they worked together through these challenges with support and encouragement from within their program community.

The data regarding the BBSC girls' attitudes show that most of them had a more positive attitude toward science than they did before enrollment in the program. Examination of these contributions to the girls' science identity suggests that receiving support and encouragement while working together through even tough challenges may have a positive influence (Young et al., 2017).

Case 3. Career aspirations—Engagement and enjoyment—BBSC girls' science identities. Several factors influence science identity formation. For these girls in the BBSC program, the major factors in science identity formation were science engagement and science enjoyment, which appear to inform their science career pathways. Researchers like Merolla and Serpe (2013) advocate the use of informal science programs to provide opportunities, through science engagement, for students to meet STEM career professionals and role models and learn about STEM careers.

Science engagement was a major part of the program data provided by the BBSC girls. Some of the BBSC girls embraced themselves as a future scientist because of their engagement in science. Some other BBSC girls, as evidenced by Egypt, might not have felt experienced and knowledgeable enough in science to accept a science career pathway, yet their interest remained.

The BBSC program fostered interest in opportunities for hands-on activities that increased science engagement, leading to science enjoyment.

Within science engagement resides science enjoyment. In the BBSC program, exploring and tinkering allowed the girls to have ways to engage in science. The BBSC program provided numerous opportunities and ways for the research participants to engage in science by completing science activities, innovating new designs, reflecting on why processes work, and relating them to their real lives. The current research suggests that colleges and universities (e.g., the R1 university facilitating this program) should develop programs like the BBSC program. Such programs would create welcoming environments that provide students, especially African American girls, who are interested in STEM with opportunities to develop meaningful relationships involving engagement and enjoyment centered around their interest in a science career pathway (Merolla & Serpe, 2013; Sasson & Cohen, 2013).

Because the BBSC girls saw themselves as someone interested in science, they had the potential for a science career and a better attitude toward science, leading to a higher level of science identity (Calbrese Barton et al., 2013). By seeing career options and the relevance of science fields to their own lives, they could see possibilities within these fields for themselves. By improving their interest and attitude in science, they improved their science identity. Thus, underrepresented students like the BBSC girls are likely to experience and gain a positive attitude toward science engagement and science enjoyment as a valuable tool for accessing a better science career pathway.

Interpreting the results for the analysis of BBSC girls' science affinities. As discussed in Chapters 1 and 2, middle school is the time when girls tend to begin to lose interest in science (Catsambia, 1995; Young et al., 2017). It is also a major life stage for identity formation. Based on the literature, science affinities are expected to decline over time for girls in the same age group as the BBSC girls (Calbrese Barton et al., 2013). The interaction effects between understanding, support and encouragement, and career aspirations in the program reported for the affinities of science interests, attitudes, and identities imply that the expected relationship was consistent among the BBSC girls. The effects could be due to the higher trajectory of science affinities prior to enrolling in the BBSC program. The science affinities for these girls appeared even higher after enrollment in the BBSC program, an informal science learning program, which is supported by literature (Elam et al., 2012; Sasson & Cohen, 2013; Dou et al., 2019). However, the limitations of the research design and interaction effects make it impossible to determine the true cause of the relationships between understanding, support and encouragement, and science career aspirations in the formation of science identity for these rural, African American, middle school-aged girls. From this perspective, the BBSC program may have had a positive impact on the African American girls; however, more emphasis should probably be placed on connecting science career aspirations and role model interactions with more science identity formation opportunities.

Preparation and affinities are integral to students' science success and identities. In addition to being academically prepared for science fields, African American girls should also have positive interests and attitudes toward science content. Research suggests that STEM affinities vary by race and gender, with Black women having more positive attitudes toward STEM than do other peer groups (Young et. al., 2017). Therefore, considering all the results presented, two questions move to the forefront.

First, if the African American girls participating in the BBSC program preferred to learn science in certain ways, do those ways support the formation of science identities? The science affinities reported in Chapter 4 align with recommended best practices for engaging girls in science. Based upon their research, organizations like the National Science Foundation have published best-practice guidelines for engaging girls in science (National Science Foundation, 2007; Munley & Rossiter, 2013). Some of those best practices include:

1. Girls benefit from collaboration with their peers when they can participate and communicate fairly.
2. Girls are inspired and motivated by projects and opportunities that they find culturally relevant and hold real-life meaning.
3. Girls find excitement in hands-on activities and investigations.
4. Girls enjoy projects and programs that allow them to be independent as well as apply their creativity and preferred learning styles.
5. Girls' confidence and performance improve in response to positive feedback.
6. Girls benefit from relationships and opportunities with mentors, science professionals, and informal science learning environments.

The BBSC program provided the type of science that is consistent with the best-practice recommendations from the National Science Foundation and the type of experiences that girls prefer (e.g., science engagement, teamwork, and problem-solving skills). Therefore, it is reasonable to expect that the affinities these BBSC girls expressed will support the formation of science identities and that programs like BBSC can facilitate this formation.

Second, will the best practices support all of the affinity themes found among BBSC girls? Practitioners in the field would be well served by understanding which guidelines apply best to such girls. The BBSC girls might be very keen on the collaboration in best practice 1, as teamwork was supported in their science attitudes. They reveled in the hands-on activities and investigations that align with best practice 3 and that supported their high science attitude for science engagement. Some of the girls were reliant on their creativity and learning styles, as guided by best practice 4. All these girls needed the support and encouragement from their program community, as represented in best practice 5. This support and encouragement also lead into the positive relationships formed within their program community of facilitators and other science professionals, which are highlighted in best practice 6. However, these girls might need assistance in developing the relationships with mentors, as is also highlighted in best practice 6. In addition, they could have used more support in connecting culturally relevant meanings to their program experiences, as in best practice 2.

Lastly, if BBSC was providing activities and events aligned with theory and best practices, why was there no communicated connection between the girls' science affinities and their race and gender? Maintaining early high levels of science affinities is an improvement over what the literature predicts will happen to most girls, which is a steady decline in interest in science (Calbrese Barton et al., 2013). While it is possible to say the BBSC program was sustaining these African American girls' interest in science, it is impossible to say that their identifiable race and gender were determining factors. The research design may be a predictor of this indifference. However, due to the program structure, something should be happening. There is enough concern to merit further study, even if there are no additional conclusions about the value of the program as it pertains to race and ethnicity. One point to note: many of the leading and national institutions that create best practices for girls in science have only recently, in the last several years, begun to examine culturally relevant programming and opportunities as they pertain to race/ethnicity and their intersection with gender (Tan et. al., 2013; Young et al., 2017).

What BBSC girls' affinities and identities tell us about girls in science, their careers, and the disparities they face. This section will discuss BBSC girls' science affinities in terms of their science interactions and aspirations, as well as the disparities they face in society. In addition, discussed here is how different science affinities are predicted to interact with race and gender expectations in the formal classroom and in the girls' future career planning and preparation.

The BBSC girls noted their strong preference for science engagement (e.g., exploratory hands-on science activities) that created enjoyment for them. This relationship between engagement and enjoyment created positive interest and attitude for a science career goal or aspiration (Case 3). These girls showed evidence that, when faced with frustration and struggles, they responded best with teamwork and the support/encouragement of their peers and supporting adults (Case 2). For the BBSC girls, their thought process and their problem-solving skills were defining elements of what furthered their understanding (Case 1).

The BBSC girls did not demonstrate one monolithic science identity. These girls shared much in their preferences and attitudes toward science, but they also showed evidence of very different styles of science engagement. Often, when addressing the issue of girls in science, educators, researchers, and policy makers approach the issue as though there is one problem, a gender problem. If they could separate out the factors related to how girls, particularly African American girls, lose interest in science, the problem might be solved.

The remainder of this discussion of results will focus on the ways in which BBSC girls' affinities are likely different from or similar to those of boys, particularly African American boys, which might result in different outcomes according to gender. It has already been noted multiple times in this literature that girls are less likely to engage in hands-on science and sustain their interest than are boys (Alexander et. al., 2012). It might be accurate to say that middle school-aged boys, particularly African American boys, articulate many of the same science affinities as those identified by the BBSC girls. It seems likely that boys, particularly African American boys, enjoy science engagement, problem-solving, teamwork, support, and encouragement. Boys, particularly African American boys, might also experience struggles that are exhibited through their frustration and challenges involving science. Despite the similarities, the main difference exists in how science plays out in the classroom and in day-to-day life for boys and girls.

The BBSC girls' science affinities seem to have been influenced by the limited presence of female role models, especially African American females, who are in science. Given the much lower participation of women in sciences, girls have fewer relatable role models and possible mentors than do boys. The lower numbers of role models for girls signal that science careers are not viable options for women (Riegle-Crumb & King, 2013). In contrast, boys have access to a wide range of popular mainstream science role models and are far more likely to have personal ones in their own lives. Any disparity that exists in retaining women in science may be due to the judgement of ability by male peers and the culture created in these spaces. The BBSC girls expressed a desire for careers in science. The culture created in science career spaces that they may to work in should encourage their success in meaningful ways, rather than creating an ability judgement mindset. Regardless of their ultimate careers, the BBSC girls appeared to value the role that science and this program will play in their lives.

These are generalizations presented above. Each girl or boy will take an individual path. Some girls will find amazing mentors and succeed in the male-dominated fields of STEM. Many boys will lose interest in science and move on to something else. However, gender will almost certainly play a part in the experiences and choices these future scientists make. How identity formation emerges with regard to science will be heavily influenced by gender and race. Therefore, some gates are locked for girls in science and female scientists of all types, but especially those representing underrepresented populations. Yet, the keys to success and achievement for them (girls and women in science) exist in spaces like informal science learning environments.

This broader role of science learning is missing from the discussion of race and gender disparities and science. School systems are not providing boys and girls with equitable experiences (Byun et.al., 2012). Informal science learning programs like BBSC address the problem, which might appear to remove the need for schools to address these disparities. Rather than relying on external programs like BBSC, schools can use the research from informal science learning programs as models for identifying and removing systemic barriers to science engagement.

BBSC girls' science affinities and identities point to numerous ways in which schools can properly support African American girls' science development. The BBSC girls cited a preference for hands-on science engagement, teamwork and support/encouragement with peers and others, and use of problem-solving skills. Furthermore, they were attracted to engagement that created opportunities for enjoyment and the use of their thought process. It is important to note that BBSC girls' affinities point to achievable ways that schools can support the development of science identities in girls and remove institutionalized obstacles they face.

Limitations

Limitations of the study include the research design, issues of the sample, and selection bias and homogeneity.

Research design. The goal of this research study was to gain a better understanding of the impacts of the Benjamin Banneker Science Club program on African American girls' science affinities and science identity formation. In order to determine the impact BBSC has on African American girls with any level of certainty, a research design with a control group and random participant assignment with pre- and post- measurements of both groups would be required. Without these components, only informal claims can be made about changes in participants' science affinities.

Neither a comparison group nor a random assignment was available. Therefore, it cannot be stated declaratively that changes in the African American girls' science affinities were due in whole to the Benjamin Banneker Science Club program intervention.

Sample. This research study may present some problems regarding the sample. The sample size is low (*n* = 5), but it is representative of the total population of eligible participants from the research cohort. There is selection bias among the participants, which relates to the research design. In addition to being small and selection biased, the research study could also be seen as demographically homogenous, even though this was the intended design. In addition, the small sample size may limit generalizability of the result findings. However, according to Brown (2008), sampling of people may be purposeful sampling such as typical, unique, maximum variation, convenience, or theoretical, each with its own features. The sampling methods incorporated in this research study seem to better align with Brown (2008).

The sample may present a problem when analyzing the purpose of the BBSC program and this research more critically. The results show that the African American girls in the BBSC program came to the program with high science affinities. These African American girls already enjoyed science and had people in their lives willing and able to support their science interests. Therefore, serving African American girls who were already more likely to persist in STEM may limit the generalization of the research study. The elements and components that demonstrate effectiveness with the group of African American girls studied here may not intersect with African American girls who do not have such high baseline science affinities. African American girls from different backgrounds (geographically, socially, or environmentally) may have different science affinities or may be looking for different elements in engaging science.

There may be limited impact from the BBSC participation because some of the African American girls in the program were already highly inclined toward science. Results from the interviews and observations suggest differently. All the African American girls stated that they did not have these opportunities to engage with science outside of the BBSC program. They expressed a strong appreciation and desire for the hands-on learning and engagement provided by the BBSC program. When discussing formal, school-based science—in particular, after March 2020 (COVID-19 pandemic)—it is important to highlight the exhibited frustration of these African American girls.

Selection bias and homogeneity. The African American girls attending the BBSC program were already interested in science and/or had strong family and community support for science education and learning. Selection bias makes it more challenging to detect changes in preferences for science; it also impacts generalizability of the results to a large population of African American, middle school-aged girls. Under the best circumstances, a research study would include multiple years of data and a control group with a wider range of science engagement.

In terms of race, ethnicity, and socioeconomic status, the composition of the BBSC program was close to the demographics of the state; however, the composition of the research study participants was homogeneous. Even though the research design was for African American girls in a rural setting, some might argue that the homogeneity of the participants limits generalizability of the findings when examining other STEM underrepresented populations in rural settings.

Reflection on limitations. The limitations of this research study largely relate to the research design, sample, selection bias, and homogeneity. Under the best circumstances, the study would have employed a randomized controlled group; however, this design was not possible in this design. The number of participants in the program was not high enough to form a control group, the inclusion of which was dependent on the sample size. One possible solution to the issue of sample size could be repeating the study in future years and collecting longitudinal data.

All the limitations discussed above make absolute declarations about the implications of the study concerning. Results of the qualitative analysis might be due to peculiarities in the sample population that do not apply to African American girls in more general terms. Further study will help highlight if these results are any absolute indication of African American girls' science affinities and identity formation or if the study is specific to the research participants.

Future Implications for Practice

Even though the BBSC program is a specifically targeted program, the BBSC African American girls' science identities have implications for the broader field. Implications and recommendations for other outreach programs and informal science learning environments are discussed here. Future implications for the field and stakeholders are also discussed.

The BBSC African American girls demonstrated various identities and affinities. However, these affinities shared common components that are likely present in the wider population of elementary school- and middle school-aged children. The components of the BBSC program could be adapted to other outreach programs. Though the BBSC program is more general in science content, other outreach programs may focus on a particular discipline or career area, such as engineering or technology. The BBSC has developed a wide range of science material across many disciplines over the years. Other programs can adapt the BBSC program approach to their specific subject content area. The BBSC African American girls' science affinities support the use of hands-on science activities, field trips and events, and relatable role models and peers as important components of science engagement.

Furthermore, these BBSC African American girls' communication and dialogue around their classroom study suggest some improvements for teaching science content in formal classrooms. The African American girls' science engagement in BBSC is relatively high. These girls attribute their science engagement and interest in science learning to the components of the BBSC program, such as hands-on science activities, field trips and events, and relatable role models and peers. Access and engagement are both critical to these components. Some recommendations for potentially increasing engagement in science classrooms could involve inviting diverse science guests and experts, as well as highlighting the accomplishments of underrepresented barrier breakers in the STEM fields. In situations where hands-on activities for all students are not possible, including students in classroom demonstrations can signal trust in their capabilities to conduct scientific experiments.

In rural communities like Modlin County, alternative ways of engaging in science can include: (a) creating dialogue among community stakeholders such as students, teachers, families, community members, and organizations to foster open pipelines to STEM education and careers for the entire community; (b) cultivating relationships and collaborating with organizations to support STEM education; and (c) exploring funding opportunities to provide rural students with STEM experiences (Avery, 2013).

Considering some of the limitations discussed above, this study has pointed out possible ways in which parents, educators, and other science allies can better support African American girls in developing strong science identities.

Recommendations for parents. Of the BBSC African American girls who consider themselves to be scientists, the majority reported having support from their parents. The interviews revealed ways in which parents supported their African American girls. Parents provided their time, participation, and transportation for these participants. Based on this parental support and their science affinities, the following are recommended for parents: (a) allow African American girls to get a little dirty with science at home; (b) encourage African American girls to join in on home repairs and maintenance; (c) converse with these girls about science career options; and (d) look for science opportunities that encourage and support African American girls.

Recommendations for educators. Educators are the first science role models that African American girls experience. Educators (e.g., program facilitators) had a powerful impact on the BBSC African American girls. These are some recommendations for educators: (a) teach with hands-on science activities as often and as much as possible; (b) exhibit enthusiasm with students; (c) invite diverse experts and scientists into the classroom to act as role models for students; (d) allow students to conduct more advanced experiments; (e) support all types of science identities; and (f) seek access to curricular and research support and resources from local universities and community colleges, even in rural areas (Goodpaster, Adedokun & Weaver, 2012).

As early as elementary school and throughout their formal education, African American girls need exposure to science with mentors and role models who share their race and gender

(Young, Young, & Paufler, 2017). These students must be exposed to African American females in science as one strategy to increase and support their interest, attitude, and identity. In addition to science professional exposure, classrooms should include teachers and counselors who advocate for African American girls by consciously amending classroom activities and curriculum with real-world and culturally relevant lesson plans that speak to African American girls and their futures.

Recommendations for other science allies. Other science allies can include scientists, researchers, and informal science program coordinators. The recommendations for these science allies include: (a) seek opportunities to engage African American girls in science; (b) provide opportunities for African American girls to explore, tinker, and investigate on their own; (c) demonstrate that science is fun and enjoyable; (d) create opportunities for African American girls to learn new things; and (e) learn more about youth development in underrepresented populations, including through professional development for informal science education staff (Bevan & Semper, 2006).

Future research. Results of the study suggest that replication in subsequent years with a control group will strengthen the findings. In addition, collecting data from a broader sample of African American, middle school-aged girls to further elaborate on science identities will help determine generalizations to the larger population. Future research could more carefully address how enrollment in informal science learning programs affects the development of a science identity over time. In addition, examining the conceptual framework through the lens of the black feminist theory and intersectionality can strengthen future studies. Collins (1986) argues that black women have made use of their marginality to create a Black feminist thought that shows a unique standpoint on self, family, and society. Crenshaw (2017) developed intersectionality to theorize that women of color face multiple oppressions where social categories and hierarchies intersect without a single, fixed meaning. Through this lens, the participants in this study could convey different data to support these theories. With an examination focus on access to science resources and role models through this type of intervention program with interviews and observations, research data could address these two theories of intersectionality and black feminist thought.

Replication of the study with the expanded cohort of BBSC participants will provide a larger data set with a repeated research design. A longitudinal model with a control group and multiple years of data collection will help to address the limitations mentioned previously. A repetitive research design over several years would also provide the opportunity to track changes in African American girls' science affinities over time.

In addition, it would be interesting to compare these rural, African American, middle school-aged girls' perceptions of learning science in formal education settings (e.g., public middle school) to learning science in informal education settings like science centers or museums. Both types of spaces of learning have notable opportunities to create experiences—for example, providing mentors and guest speakers that are a representation of them—that directly reflect the cultural knowledge and background of these girls. According to Young, Young, and Paufler (2017, p. 31), "By promoting social consciousness through culturally relevant pedagogy, girls of color may reconsider STEM careers." A very important aspect of this promotion of social consciousness should be science activities that also have a community focus, as the rural life of these girls is a critically important tangible piece to remember. It would be remiss to ignore the need for further examination of the various experiences of students like these girls, who have intersectional science identities in different types of science spaces.

APPENDICES

APPENDIX A: BBSC MONTHLY MEETING AGENDAS/ACTIVITIES

November 9, 2019: Football Tackle Day

OVERVIEW

Families learn about the physics behind football tackles, performing both calculations in the classroom and experiments on the field, and then see how tackles can lead to concussions and traumatic brain injury.

OBJECTIVES

Families will:

- See how science is relevant outside of typical STEM careers
- Practice unit conversions and proportions
- Be able to calculate the momentum of a moving object
- Use mathematical calculations to make predictions
- Understand the causes and symptoms of concussions

MATERIALS

iPads
Paper
Pencils
Stopwatches
Scale
Knockerballs
NFL Concussion Assessment Tool

SETUP

- Make sure football field is reserved and Knockerballs are inflated
- Connect iPads to wifi

ACTIVITY

<u>Introduction</u>

"Who here watches football? Who's ever played football? Anyone in a fantasy league right now?"

Spend a few minutes talking about everyone's favorite teams, etc. to get the group excited about the day's theme, then ask if they can think of any connections between football and science. What are some STEM careers that are football-related? Write ideas on the board as you discuss. Examples include:

Physical therapist
Statistician
Athletic Trainer
Biomechanical engineer
Orthopedic surgeon
Architect
Sport psychologist
Nutritionist
Materials scientist
Electrical engineer
Software engineer

The people we just talked about all obviously use science in their jobs, but today I want to talk about the less obvious—how the football players themselves use science. They may

not be actively thinking about anatomy or geometry or physics equations, but every good player has at least a subconscious understanding of things like the laws of motion and how they can use those laws to their advantage.

There's science involved in so many different aspects of the game, but today we're going to focus just on football tackles.

Show the NSF "Science of NFL Football: Newton's Third Law of Motion" video to introduce momentum in tackles, then discuss as a group to reiterate the definition of momentum and its relevance in collisions (tackles).

<u>Part One: Calculations</u>

Before we get out on the field and try some collision experiments ourselves, we need to take some time to practice with our calculations. Explain that we're going to calculate the momentum of various players to predict the outcome of tackle scenarios. Like we said earlier, momentum is mass in motion. The equation we use to calculate momentum is mass (m) multiplied by velocity (v). Make sure everyone understands that velocity is just speed in a certain direction, so the equation is literally mass times motion. Write p = m*v on the board for reference.

This means that to calculate a player's momentum, we need to know their mass and their speed. We can easily look up any pro player's weight and 40-yard dash time and use those stats to get what we need. Walk the group through the following steps with Cam Newton as an example.

1. **Look up and record your player's 40-yard dash time.** The standard unit for distance is meters, so note that 40 yards = 36.40 meters.

Cam Newton: 4.59 seconds

2. **Divide distance by time to get velocity.**

3. **Look up and record your player's weight.**

   Cam Newton: 245 pounds

4. **Convert weight in pounds to Newtons.** Explain that mass and weight are different – mass is the amount of matter in an object while weight is a measure of the downward force that gravity exerts on that mass. To get the player's mass, we first need to convert the pounds into Newtons (a unit of force) and then divide by the acceleration of gravity on Earth (9.81 m/s^2).

5. **Divide the weight in Newtons by the acceleration of gravity on Earth to get the player's mass.**

6. **Multiply mass and velocity to get momentum.**

$\boldsymbol{p = 881.31\ kg * m/s}$ **That means he'll hit with about 790 pounds of force.**

Ask everyone to choose their favorite football player and calculate their momentum at 40-yard dash speed. They are welcome to use either their smartphones or the iPads to look up the player stats and as a calculator.

Now imagine your player is running down the field with the ball. Remember the video said all NFL defenders have a single-minded goal – to stop the ball carrier – so what would it take to stop your player?

Ask everyone to find another player that would have enough momentum to stop or push back their player. Then put a few matchups on the board and ask everyone to predict the outcome.

Part Two: Collisions

Now what if it was you out on the field? Tell the group that we're now going to calculate their own momentum, which means we need to get their own stats. Explain that we'll be going out to the football field so that everyone can run the 40-yard dash. Everyone should pair up, taking turns running and timing the runner with a stopwatch. Remind the group how to get velocity from their 40-yard dash time. There will also be a scale on the field if anyone would like to find their exact weight for calculation purposes. Be sure to emphasize that the scale will be in a private location to be used one at a time and is in no way required! If anyone feels uncomfortable with the scale, they are welcome to estimate their weight or not worry about it at all and just calculate Miss Robbie's momentum instead.

Once you have finished your momentum calculation, find a partner. Imagine that one of you is on offense running with the ball at full speed toward the end zone, and the other is a defender running at full speed straight towards you for the tackle. Based the momentum each of you would have, can you predict the outcome of your collision?

Let's test it out! Each pair will get into Knockerballs and try running at each other from opposite 10-yard lines. What was the result? How accurate are the Knockerballs in modeling real football tackles? Discuss elastic vs. inelastic collisions – the Knockerballs bounce off each other, but football players usually hang on and go down together.

After everyone has had a chance to test out their collisions, allow time for group Knockerball games.

<u>Part Three: Concussions</u>

Bring everyone back to the classroom for this last part. Making tackles is a big part of football, but it can have serious health consequences. What do you think being repeatedly tackled can lead to?

Most of us have probably heard of concussions and maybe even gotten one ourselves, but what exactly is a concussion? A concussion is a type of traumatic brain injury—or TBI—caused by a bump, blow, or jolt to the head or by a hit to the body that causes the head and brain to move rapidly back and forth. This sudden movement can cause the brain to bounce around or twist in the skull, creating chemical changes in the brain and sometimes stretching and damaging brain cells. If anyone has had a concussion, allow them to share their experience if they like.

Concussions are obviously a serious, widespread issue in football, with about 250 diagnosed concussions each year in the NFL. So, what is the NFL doing about it? Discuss advances to equipment and turf. They are also working to more effectively diagnose and respond to concussions when they do occur.

Show video on the NFL concussion protocol.

The video doesn't really show us what happens inside that blue medical tent, so let's talk more about what the medical examiner actually does in there.

Pass out the NFL Concussion Sideline Assessment Tool and walk through the instructions on the sheet. Ask everyone to find a partner to run the assessment on them and then switch so that everyone has a chance to complete it. Hopefully none of you have a concussion at the moment, so you likely all scored well! This is called your baseline score. If you were to be examined for a possible concussion, the medical examiner would have you complete the assessment again and then compare the two scores. That way we could see if you always have memory trouble, for example, or if something is wrong and your memory isn't working as usual.

Bring up how concussions can lead to CTE and further brain injury. Show clips from *A League of Denial* documentary and the film *Concussion* and discuss.

December 14, 2019: Microbes and Makeup ft. Guest Scientists

OVERVIEW

Families will rotate between two sessions led by visiting researchers from two state R1 universities. The visiting scientists will share their personal stories and then lead games and activities on topics relevant to their current research: the microbial world and antibiotic resistance. The families will regroup at the end for a session on wound healing, in which they will explore the body's healing process and use special effects makeup to create their own fake wounds.

OBJECTIVES

Families will:

- Meet and connect with STEM professionals
- Expand their view of what a scientist looks like
- See that microbes can be both harmful and helpful
- Understand how antibiotic resistance develops in bacteria
- Learn about the biological process of wound healing

MATERIALS

Special effects makeup
Fake blood
Makeup remover
Cotton pads
Q-tips
Palette knives
Makeup brushes
Sanitizer
Mirrors
iPads

Note: Guest scientists will bring their own materials.

SETUP

- Load sfx makeup tutorials on iPads

ACTIVITY II

Introduction

"Today we're going to talk about how our bodies heal wounds. Who's gotten a cut or a scrape or even needed stitches before?"

Ask the groups to talk amongst themselves and share what they might already know or have experienced with wound healing. Prompt the discussions with questions like:

- What do you see when you're wounded?
- What do you feel?
- How long does it take a paper cut to disappear? What about a bigger cut?
- How do you know you have a cut?
- What happens?

Keywords like redness, inflammation, swelling pain, throbbing, bruising, scabs, etc. should come up. After the small group discussions, have a few people share back. Invite families to tell any injury horror stories they may have!

Part One: Wound Healing

Explain that we can break the wound healing process down into four basic stages. Show the TED Ed video to walk the group through the stages of wound healing. After the video, pass out a set of phase cards to each group and have them arrange the cards in order. Then pass out the photo card set. Can you put the photo cards in order too? Which photos show which phase of healing? How do you know?

Now think about ways we treat our wounds. Why, for example, should you put pressure on a new, bleeding cut? What do Band-aids do? Neosporin? These products and treatments largely mimic natural parts of the healing process.

Part Two: Special Effects Makeup

Ask the group which kinds of professions need an understanding of the wound healing process. They should think of a variety of medical professionals, from nurses to dermatologists to surgeons. They may also think of materials scientists who work on new band-aid materials or pharmaceutical researchers who develop products like Neosporin. There's another group of people too – special effects makeup artists!

Sfx makeup artists need to understand the stages of wound healing in order to make cuts/bruises/scars on movie characters look realistic. A cut should look very different during the battle scene when the injury occurs than it does in a scene three days later. Once a wound reaches the proliferation and maturation stages, for example, the skin around the wound may pucker as the margins contract. Makeup artists use the product collodion specifically for that skin puckering effect.

It’s your turn to get creative now! Go over the sfx makeup products and tools available and explain that we’re going to try our hand at creating our own fake wounds. You can try creating one on yourself, or you can recruit someone else to be your model. Pass out the iPads with pre-selected tutorials and encourage families to follow along with the videos. Pass out printed guides and photos as well. As the students work, engage them with questions like:

- What phase of the healing process do you think that cut is in?
- Will you be using the bright red fake blood or the darker, more brownish blood? Why? (Discuss how blood oxides in contact with the air.)
- What does the redness around the wound indicate?

January 23, 2020: Where in the World

OVERVIEW

Families will perform experiments and calculations to learn how GPS technology works. They will then put their navigational skills to the test on a GPS scavenger hunt.

OBJECTIVES

Families will:

- Identify the components of the Global positioning system
- Understand how the GPS components work together
- Use linear regression to extrapolate data
- Practice GPS navigation

MATERIALS

Masking tape
Stopwatches
Pencils
Paper
Graph paper
Boxes
Maps
String
Rulers
Battleship pieces
GPS receivers
GPS quick guides
Small prize items

SETUP

- Mark waypoints in the GPS
- Hide items at each waypoint
- Make triangulation boxes

ACTIVITY

<u>Introduction</u>

"Everyone close your eyes for a second. Imagine that your phone is ringing right now. You pull it out of your pocket, answer it, and it's Mr. Richard! You're about to go in on him for not being here today – although maybe he is allowed to take the day off since it's his birthday – but immediately you can sense that something's wrong. It's not Mr. Richard's voice on the other end. It's Dr. Smithers. Dr. Smithers explains that Mr. Richard has been in an accident and you need to get to Hilltop Hospital right away! You have no idea where Hilltop Hospital is, but you rush outside, jump in the car, turn it on, and buckle your seatbelt. Now, what's the first thing you do?"

Right, if you're anything like me you'd open maps on your phone and type in "Hilltop Hospital!" Siri gives me lovely step-by-step directions, and I just follow along without having to think much about where I'm going. Today, we're going to learn how that technology works and then put our navigational skills to the test with a scavenger hunt.

Does anyone already know anything about how the maps on our phones work? Discuss the basics of GPS (Global Positioning System), using the smartboard to show images and the whiteboard to draw as you talk. GPS is a three-part system that consists of satellites, ground stations, and receivers. There is a network of about 30 GPS satellites orbiting the Earth at all times. These satellites continuously transmit faint radio signals, which travel at the speed of light, back to Earth. The five ground stations around the world monitor these signals to keep track of each satellite's exact location and make sure it's working properly. The receiver is the part you hold in your hand – your phone, the GPS you mount in your car, etc. A GPS receiver intercepts radio signals from the satellites and calculates how far away each satellite is based on how long it took for the signal to arrive. Once it has information on how far away at least three satellites are, your GPS receiver can pinpoint your location using a process called trilateration.

We'll go over trilateration in a bit. First, we're going to see exactly how a GPS receiver can calculate how far away a satellite is based on the radio signal.

Part One: Calculating Distance

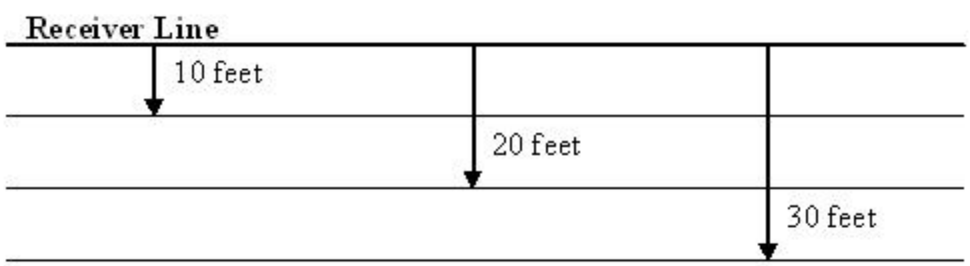
We know that distance is equal to rate multiplied by time. Write d=rt on the board and do a simple problem using r=1 ft/s and t=2 seconds to calculate distance to show that this equation makes sense. We have three variables in this equation: distance (d), rate (r), and time (t). If we know any two of those three things, we can use what we know to calculate the third thing.

With a GPS signal, we always know r, the rate, because the radio signals travel at the speed of light. The speed of light is 3×10^8 m/s, so the radio signal can travel from the satellite down to Earth faster than the blink of an eye! The GPS receiver and the satellite both have internal clocks, so we also know t, time – exactly how long it took that signal to reach the receiver. With both r and t, the GPS can calculate distance.

Now let's experiment! Lead the group out to the football field and ask everyone to pair off. One person in the pair will act as the GPS signal coming from a GPS satellite and the other will be the receiver.

Receiver: When it is your turn to be the receiver, sit facing away from your partner and the signal lines. When ready with the stopwatch, without turning around or looking back, start timing and yell, “GO!” at the same time. When your partner arrives next to you and says, “Here!” – stop timing and record your data on the data sheet. The first three times, your partner will tell you where they are starting, and you can learn their pace. The last four times, your partner will randomly choose a line at which they started. You must try to guess how far away they started!

Signal: When it is your turn to be the signal, start at the 10-foot line and tell your partner you are starting there. When they are ready and yell go, run directly and quickly up to them or past them. Yell “Here!” when you arrive or pass them. Repeat for the 20 and 30-foot lines, again letting the receiver know where you are starting. On the fourth and fifth runs, you may start from any of the three lines. Do not tell the receiver where you are starting, and do not give away your position with noise! When the receiver yells go, run to them at the same pace as you did for the first three times. (Remember the speed of light does not change.) On the sixth and seventh times, drop your pencil flat on the ground half way between your start line and the receiver. This time when the receiver yells go, run quickly to the receiver as before. But this time, you must stop and pick up the pencil on the way. How did this affect the time and the distance estimate?



Discuss possible causes of error in GPS location, namely Earth’s atmosphere and ionosphere delaying the radio signal. 3×10^8 m/s is the speed of light in a vacuum, but the radio signal has to travel through the atmosphere and ionosphere, which are definitely not vacuums! The ionosphere is full of charged particles, and the atmosphere is full of water molecules. This can slow the signal down and cause error. Is it possible for the signal to arrive earlier than expected? Not if the satellite is in the orbit you think it is in: the speed of light is absolute and cannot be exceeded. However, if the satellite’s orbit were closer than you think it is, the signal would seem to arrive early. Hopefully you are locked into enough other satellites’ signals to know that this one has an error.

Have students plot their data with time as the x-axis and distance in feet as the y-axis. The data points may not be perfectly linear – have the students estimate a line of best fit. Can you predict how long it would take the “signal” to travel 15, 50, and 100 feet? Can you determine the distance between the signal and the receiver if it took 5 seconds for the signal to arrive at the receiver? 10 seconds?

Part Two: Triangulation

The activity consists of two parts. First, students in groups of two or three each receive a box, map, ruler and scissors. Each team picks a place on the map where they want their "unknown" location to be; perhaps this location represents where they are, where a little bug is, or even where in Canada Maya is located. Then they measure the distance from that location on the map to the center of three of the sides of the box. Now, their box has a location on it, and three measurements to go along with it.

Second, the groups trade boxes. With the information given with the boxes, students use the measurements to cut the string into each of the three lengths, measure from the center of each of the sides, and find the location of the object. Then they check with the students who made the model to see if they are correct.

We see how GPS is able to determine your exact location from satellite mapping, now how can we identify or describe that location? How could you tell someone else EXACTLY where someone or something is located? Discuss coordinates, latitude and longitude, and the cardinal directions.

Latitude and longitude Battleship

Part Three: Scavenger hunt

Explain that we will be breaking into groups and racing to complete a scavenger hunt. There are five locations around the school campus with a cache of small items. Each location has been marked as a waypoint in your GPS using the location's coordinates. It is your group's job to navigate to each waypoint, collect one item from each cache, and return to BASE. We'll all start at BASE, and I'll stay there the whole time. First group to return to me with one item from each waypoint wins!

Pass out the GPS receivers and quick guides. Go over how to use the GPS receivers as a group and make sure everyone feels comfortable before sending groups off. One parent with each group! Have each group start at a different location and go in a different order.

Optional Extension

GPS can also be used for fun activities and recreational purposes. For example, has anyone ever been to a corn maze? Did you wonder how that corn maze was created? Today farmers can use

GPS to design and plow mazes into fields. Show an aerial photo of a real corn maze, explaining that it was designed using GPS technology and inexpensive software. To design the maze, a GPS engineer made an image of the desired picture using mapping software to produce a set of coordinates that would connect to form a picture—kind of like connecting the dots. Then these coordinates were downloaded into driving instructions on the farmer's tractor-mounted GPS receiver. The farmer plowed the maze—that is, connected the dots—following the GPS instructions.

Can you use the GPS to make your own pictures? Walk the students through using the "Track" feature and waypoints to do this.

February 8, 2020: Mini Golf Geometry

OVERVIEW

Families will practice measuring angles and using the Law of Reflection to determine how to hit a hole-in-one in putt-putt! They will then build their own putt-putt course to test the accuracy of their geometric calculations.

OBJECTIVES

Families will:

- Use geometric tools to measure and draw angles
- Understand the Law of Reflection
- Solve for unknown angles
- Practice drawing to scale

MATERIALS

Angle card deck
Graph paper
Rulers
Tape Measures
Protractors
Pencils
Laser pointer
Mirrors
Golf clubs
Golf balls
Scorecards
Assorted craft supplies
Assorted building supplies

SETUP

- Assemble pre-made mini golf hole #1

ACTIVITY

Introduction

"Who's played mini golf or putt-putt before?"

Put the picture of a putt-putt hole shown in Figure 1 up on the screen and chat about the group's experience for a few minutes, making sure to describe the game and rules if anyone hasn't played before. Draw everyone's attention back to the Figure 1 photo and ask a volunteer to describe how they would make the shot on that hole.

With the rock obstacle in the middle, a straight shot won't work. Instead, you'll need to aim the ball towards the wall, knowing it'll hit the wall and bounce off. That's called a bank shot. But are you guaranteed a hole-in-one as long as you bank the ball off the wall? No, the trick is hitting the ball at the right angle – meaning it's all about geometry! Today, we're going to learn some geometry basics and then apply what we learn to a mini golf course.

Figure 1. Example putt-putt hole.

Part One: Practice with Angles

First, we need to understand angles and how to measure them. Students should have been introduced to these concepts already, but provide a brief refresher covering the points below. Be sure to draw on the white board to illustrate each point as you talk.

- Angles are formed when two lines meet at a single point. That point is the vertex of the angle.
- You can think of an angle as a slice of a circle, and they are commonly drawn as an arc (part of circle).
- Angles are measured in degrees. Degrees are a measure of rotation.
- A full rotation is 360°, so a full circle has 360°.
- Angles that look like one quarter of a circle have approximately one quarter of the degrees of the full circle, so, 360 ÷ 4 = 90°. A 90° angle forms a square corner at the endpoint. It is called a right angle.
- Angles that are smaller than 90° are called acute angles, and angles that are larger than 90° are called obtuse.
- An angle that goes halfway around the circle measures 180° and forms a straight line. In fact, it is called a straight angle.

You can have the group stand for a minute and practice following commands like “turn 90°” or “turn 360°” to reinforce those concepts.

Does anyone know what tools we can use to measure angles? Today we’ll be using protractors. Check to see who has used a protractor before and then walk the group through a quick tutorial. We need to make sure we’ve really got angle measuring down, so we’re going to play a warmup game to practice using our protractors.

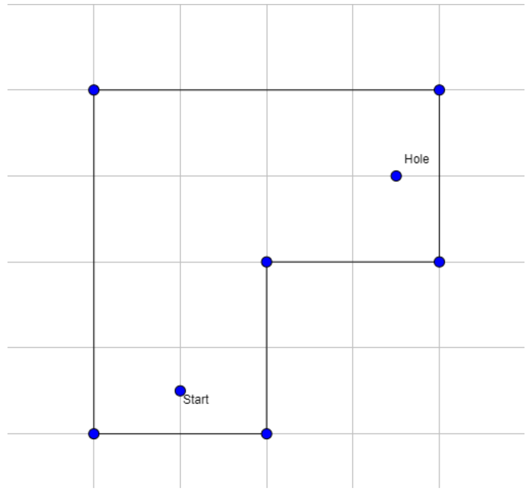
This game is just like the concentration card game you’ve probably played before, but with angles! Each group will get a deck of cards. There are two types of cards in the deck: cards with angle drawings and cards with a degree measurement. Each angle drawing matches with one of the degree measurements (i.e. the drawing of a right angle goes with the card that says 90°). To set up the game, lay all of the cards out face down in a grid on the table. Player One will flip any two cards faceup. If the cards match, Player One removes those two cards and puts them in their own personal pile to the side. Player One then gets to go again, continuing until they flip up two non-matching cards, which ends the turn. If the cards don’t match the first time, Player One immediately turns them facedown again and it becomes Player Two’s turn. The only extra step with this version of the game, is that each time you flip up an angle drawing, you must measure it using the protractor and write the angle measurement down on the card. The player with the most matches at the end wins!

Collect the angle card decks and draw everyone’s attention back up to the front. Explain that there is one more concept to learn. [demonstrate the law of reflection with a laser pointer and mirrors]. This is called the Law of Reflection. The laser beam is reflected off the mirror at the same angle that the laser beam is coming toward the mirror. This law also applies to a ball bouncing off a wall or the floor. Call up another volunteer and ask them to stand at the other side of the room. Pass the ball to the volunteer by bouncing it once (throw the ball so that it hits the floor exactly between the two of you). The ball bounces up to the volunteer at the same angle you threw it. Likewise, if you hit a golf ball at the wall on a putt-putt course, it will bounce off the wall at that same angle you hit it.

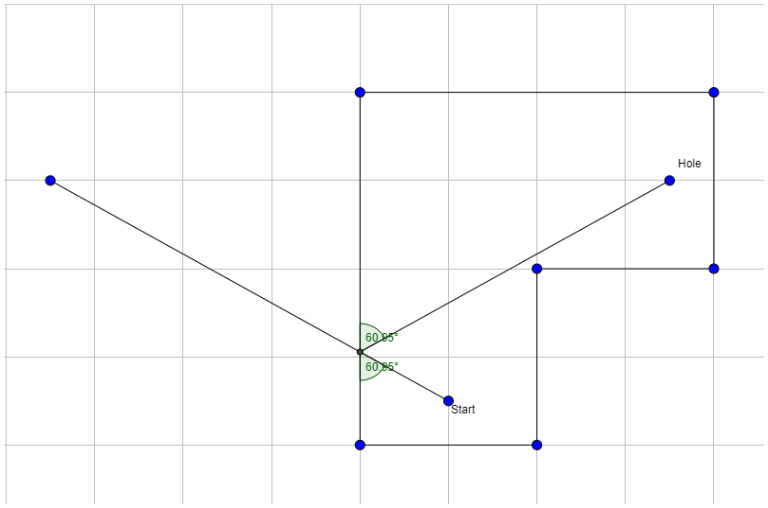
<u>Part Two:</u>

Now we can focus on mini golf. We’re going to use angle measurement and the Law of Reflection to plan out how to score a hole-on-one. We’ll practice some theoretical calculations on paper and then we’ll play to see if our plans actually work! Draw an example putt-putt hole on the white board or on paper with the doc cam. We’ll walk through this example together as a group before you try on your own. Go through the following steps for the example hole:

1. Locate the hole and the starting position of the ball.



2. Choose which wall you want to bank off of.
3. Reflect the hole over that wall and label the reflected hole. Reflecting the hole over the wall is like flipping it over the wall, so the real hole is on the right side of the wall and we'll draw the reflected one on the left side of the wall. To do that, count the number of spaces between the wall and the hole. Now count out that same number of spaces in the other direction and draw a dot for the reflected hole.
4. Use a ruler to *carefully* draw a dotted line connecting the ball and the reflected hole.
5. Go over the section of the dotted line from the ball to the wall, making it solid. That solid line shows the path you want the ball to take.
6. Using the ruler, draw another solid line connecting the spot on the wall to the hole to get the ball in and score that hole-in-one!
7. Pause and take a look at the lines you've drawn. Do they make sense? Do you notice that the angle of incidence equals the angle of reflection?
8. Measure the angle of incidence (the angle between the wall itself and the line from the ball to the wall).
9. Measure the angle of reflection (the angle between the wall itself and the line from the wall to the hole).



10. Solve for the remaining angle between the two lines. The wall is a straight line, or straight angle, with a measure of 180°. Therefore, the measurements of the angle of incidence, angle of reflection, and that remaining angle must add up to 180°.

Unknown remaining angle = 180 – (angle of incidence + angle of reflection)

Your turn to try! Pass out the scale drawing of Hole #1, pencils, rulers, and calculators. Show the group the real Hole #1 and explain how the scale drawing was made. Once you have finished your calculations, you'll come up and test it out on the real hole. Remind the group that the goal is to score a hole-in-one with a bank shot. They should go through the same steps as in the example.

As everyone finishes, they can come up one by one to play the real hole and see if their theoretical paper solutions work. For students who finish early, challenge them to go back to their paper and come up with a solution to score a hole-in-one by banking off of *two* walls. They can test out those solutions as well. Regroup for a discussion after everyone has had a turn. How accurate were our solutions? Can anyone think of some reasons the ball may not have followed the predicted path perfectly? Talk about spin on the ball, friction, imperfections in the wood or floor, force of the hit, etc.

<u>Part Three: Course Construction</u>

To play a good game of mini golf, we definitely need more than one hole. You all are going to build the other holes yourselves!

1. Get into groups of two, three, or four.
2. Take stock of the building and craft supplies that are available to you.
3. Plan your concept on paper.

4. Build and decorate!
5. Make a scale drawing of your finished hole.
6. On paper, determine how to score a hole-in-one.
7. Try it out!

When all of the holes are finished, gather up the group and pass out scorecards. Allow everyone to play through the entire course.

August 2020: Chromebooks and Chemistry – Meeting #1

OVERVIEW

Students will familiarize themselves with their new Chromebooks and complete a design project with Tinkercad in preparation for next month. They will also explore the science of polymers by experimenting with diapers.

OBJECTIVES

Families will:

- Become more familiar with the features of their new Chromebooks
- Begin working with computer aided design (CAD) software
- Define the term *polymer*
- Explore some common polymers
- Investigate how diapers work

MATERIALS

Chromebooks
Example vinyl sticker and metal etching
August activity kits

SETUP

- Assemble and deliver activity kits

ACTIVITY

Introduction

Take some time to check in with the families; see how everyone is holding up and how they feel about the new school year starting. Does anyone have any life updates? Anyone cook or read or make or learn something new recently?

We'll be exploring the Chromebooks for the first half of the meeting, and then diving into the activity kits for the second half.

Part One: Chromebook Basics

Many of the students have probably already played around with their Chromebooks and familiarized themselves with the basics, but we'll begin with a quick Chromebook tutorial to make sure everyone is on the same page. Using screen share, walk students through the features and functions listed below. Be sure to ask the students questions throughout the tutorial, letting them engage and share their knowledge as well.

- Login with google account (google.com/accounts)
- Desktop Layout
    - Shelf on the bottom left: pin and access apps
    - Status tray on the bottom right: settings
    - App launcher circle icon on the shelf to launch all apps
    - Pin apps to the shelf with a two finger click
    - Download android apps from the Playstore
- Trackpad and Keyboard
    - Scroll with two fingers
    - Right click with two fingers
    - Ctrl + Alt + ? For keyboard shortcuts
- Split Screen
- Using Google Drive

Ask the students if they've discovered any cool Chromebook functions, shortcuts, or apps that we haven't seen yet that they would like to share with the rest of the group. Also check to see if anyone has had any problems or if there are any questions.

Have the students practice by going through the following steps on their own:

1. Launch all apps and use the two finger click to pin Google Maps to the shelf.
2. Open your Google Drive and create a new document.
3. Split screen the document and Google Maps.
4. Use Google Maps to find the distance between your house and any city in the U.S., then record the distance in your Google doc.
5. Close Google Maps.
6. Launch all apps and pin Google Translate to the shelf.
7. Open Google Translate and split screen with the Google doc.
8. Translate "good morning" from English into any other language and copy and paste the translation into the Google doc.
9. Share the Google doc with me.

Part Two: Tinkercad

Now it's time to get a little fancier with our Chromebooks. Tell the students that you'll be introducing them to Tinkercad, a computer aided design system that is used to make 3D prototypes and models. Share your screen to show what Tinkercad looks like and some example projects. What do you think computer aided design (CAD) systems are used for? Who do you think uses them? Discuss prototyping and modeling in engineering, architecture, etc.

Explain the metal etching project we'll be working on next month and how we'll be using Tinkercad to create the sticker template for the etching. Show the example to help students visualize what they will be creating. Have them open Tinkercad and log in to the SSS class, then return to the Zoom meeting.

Screen share and run through a tutorial of the following steps on Tinkercad to create the sticker template.

1. Add a box shape to the work plane.
2. Set the box to (--dimensions--).
3. Add letters, numbers, or shapes on top of the box to create your design.
4. Set all design letters/numbers/shapes to "Hole."
5. Select the entire thing and click "Group."

Now it's your turn! Let the students work on their designs. If they don't finish during the meeting, they can finish on their own time. Explain that you will print the stickers and deliver them in the September kits. Now let's see what's in the August kit! This kit contains multiple activities – we'll do one together today, then you'll have a couple to try at home, and then we'll do the last one together at our next August meeting.

Part Three: Polymers (from SIS 2020)

Introduction to Polymers

This activity is all about experimenting with a kind of molecule called a polymer. Before we get started, let's remind ourselves of some chemistry basics. All matter is made up of tiny particles called atoms. So far, 118 different types of atoms have been discovered (and organized on the periodic table), and they all have different properties. These atoms are way too small to see, but they combine into countless different molecules to make up all of the substances in our everyday lives. Can anyone name some atoms and molecules? If students can't think of any on their own, bring up water and carbon dioxide.

If we take a bunch of molecules and connect them in a long chain, we get a special kind of molecule called a polymer! The word polymer means “many” (poly-) “parts” (-mer), because polymers are made from chains of many identical, microscopic parts.

Polymers are everywhere. Remember the stickers you just designed? Those will be made of vinyl polymers (chains of vinyl acetate)! Sports equipment like rubber balls and plastic helmets are made of polymers, as are household items like Ziploc bags and shampoo bottles. Even your hair, DNA, and some foods are made of polymers! Starch, which is found in potatoes and foods like pasta, is a polymer made by plants to store extra energy.

Instant Snow

Instruct students to take out their container of sodium polyacrylate A (instant snow), explaining that they have a polymer called sodium polyacrylate in their activity kits. This polymer doesn’t look very exciting right now, but the magic happens when you add water.

Have the students measure out --- of the sodium polyacrylate A into a cup and --- of water into another cup, and then pour the water into the sodium polyacrylate. What happened? Students should notice that the polymer expanded and got really fluffy! There is also no water left in the cup; it was all absorbed by the polymer. Invite them to dump the cup out into a pie plate and play around with it.

Can anyone think of what you might use a polymer like this for? Does it remind you of anything? This polymer is called instant snow. Movie producers use it all the time when filming snowy winter scenes. Many movies are filmed in California, where it rarely snows for real, so producers use this stuff to get the snowy look instead.

[[igloo or snowman building?]]

Diaper Gel

Now ask the students to take out their container of sodium polyacrylate B (diaper gel). Have them measure out the sodium polyacrylate and water as before, and again add the water to the sodium polyacrylate. What happens this time? Instead of getting fluffy, it absorbed all the water and turned into a squishy gel! Invite the students to dump the gel out onto a pie plate to examine it more closely. Explain that both of the powders are sodium polyacrylate, but their molecules were arranged slightly differently, so they absorb water differently. The first type of sodium polyacrylate is more coiled up on itself, so it makes individual grains of gel. The second isn’t, so the gel all sticks together.

This polymer can hold so much water because of the way its molecules are arranged. It has special areas that water really likes attaching to, so the water then becomes part of the molecule. This is very different from how towels work, since water just “hides” in the crevices between the threads—if you squeeze, you can force the water out. Since the water actually bonds to the sodium polyacrylate polymer, no amount of squeezing will get it out.

Diaper Comparison

Can anyone think of what the sodium polyacrylate B polymer might be used for? Here's a hint: you probably used it every day for about two years of your life. There are actually many different uses for this polymer, but one of the most common uses is in diapers to absorb all the liquids a baby makes. Everyone should have two different brands of diapers in their activity kits. We'll be using chemistry to see which of the two diapers is more effective.

Instruct students to take out the two diapers and label them "1" and "2." They should also take out two cups and two pie plates, labeling a "1" and "2" of each. Ask everyone to make a few minutes to make some observations about the diapers.

- Are they patterned the same? (Do they have the same prints on them?)
- Do they smell the same?
- How do they fasten/close?
- How bulky are they?
- Is one softer than the other?
- Which one seems more comfortable?

Based on those observations, can you predict which diaper will hold more liquid? Discuss the predictions as a group.

It's the sodium polyacrylate crystals inside the diaper that absorb the liquid, so we need to cut the diaper open to get the crystals out. Have the students follow along as you demonstrate cutting the top and sides off diaper 1 and then peeling apart the layers. This should be done over a pie plate. Once the polymer layer has been located, have students scrape the polymer from the diaper into the pie plate. Remind them that we only want the polymer crystals, not the cotton fluff. Repeat with diaper 2.

Does one of the diapers seem to have more crystals than the other? Try using your spoon to measure how many spoonfuls of polymer you got from each diaper and record your measurements.

Now it's time to see how much water each diaper can absorb! Instruct the students to carefully scoop one spoonful of the polymer from diaper 1 into cup 1. Explain how to add one spoonful of water at a time into cup 1, giving the polymer time to absorb the liquid in between spoonfuls and keeping count. Show the students how to see if the polymer has reached maximum absorption by tilting the cup and looking for water running up the side. Continue adding water until the polymer has reach maximum absorption and then record how many spoonfuls of water you added. To calculate the total amount of water that diaper 1 can hold, multiply the amount of water one spoonful of crystals can hold by the previously recorded amount of crystals. Repeat with diaper 2.

Compare the end results for the two diapers – which diaper held more liquid? Thinking about which diaper is the most absorbent, which seems the sturdiest, and which seems more comfortable, which diaper would you choose? Review the definition of a polymer and how diaper polymer absorbs urine, turning it into a gel to keep babies' bottoms dry.

Note: Ask students to throw the gel into the trash when cleaning up, rather than wash it down the sink, because it can clog pipes.

To complete at home:

- Leakproof bag
- Polymer Gummies

To complete during second August meeting:

- Bouncy Ball (SIS 2020)
- Oil Spill (SIS 2020)?

October 24, 2020: Let's Get Colorful!

October Meeting Agenda

October 24, 2020
9:00 AM – 12:00 PM
Modlin Pond State Park
"Let's Get Colorful!"

9:00 AM Welcome and COVID Safety Protocol Review

9:10 AM Modlin County Partnership Chromebook Reveal

9:25 AM Announcements and Overview of the Day

9:30 AM Exploding Paint Rockets

10:30 AM Tie Dye Time!

11:20 AM Snack Break

11:30 AM Rotation:

- Surveys
- Light Experiments (HNM testing)

11:50 AM Closing Announcements

October Meeting Agenda

October 24, 2020
1:00 PM – 4:00 PM
Modlin Pond State Park
"Let's Get Colorful!"

1:00 PM Welcome and COVID Safety Protocol Review

1:10 PM Announcements and Overview of the Day

1:20 PM Exploding Paint Rockets

2:20 PM Tie Dye Time!

3:20 PM Snack Break

3:30 PM Rotation:

- Surveys
- Light Experiments (HNM testing)

3:50 PM Closing Announcements

OCTOBER 2020 ACTIVITY WRITE-UP

SETUP

- Cover tables with drop cloths
- Add water to fabric dye bottles

ACTIVITY

Introduction

Welcome families to the Benjamin Banneker Science Club program and let them know how excited we are to have them all here. Explain that we are celebrating the 2020 program kickoff by getting colorful! We'll be experimenting with color in a couple ways today – starting with exploding paint rockets!

Part One: Exploding Paint Rockets

To start, ask if anyone can name a rocket part. Talk through the three parts below and their functions.

- Fuselage: main body of the rocket that holds the control systems
- Fins: provide stability so that the rocket flies straight
- Nosecone: makes the rocket more aerodynamic and reduces drag

Add that rockets also need some kind of propulsion system, or engine, to provide thrust and get it off the ground. Our rockets will be propelled by a chemical reaction between water and Alka-Seltzer tablets. To demonstrate the propulsion system, fill a film canister one third of the way up with water from the pitcher. Break an Alka-Seltzer tablet into thirds and drop one third into the film canister. Quickly put the cap on the film canister (making sure it snaps into place), give it a shake, and set it cap-side-down on the ground a safe distance away from the families. Back away and watch! If your rocket engine fails to launch, the lid is likely loose and leaking. Try again, making sure you hear a snap when putting the lid on.

Explain, "When Alka-Seltzer dissolves in water, a chemical reaction occurs that releases carbon dioxide gas. Gasses like to expand to fill their containers, but the film canister containing the gas is too small. The gas keeps pushing and pushing until the pressure is finally released and launches the canister into the air. This release of pressure provides thrust to make our rocket soar upwards. Gravity quickly pulls our rockets back down to Earth, but real rockets have enough thrust to keep travelling upwards until they leave Earth's gravitational pull. For a fun twist today, we'll be adding paint into the engine canister along with the water. These rockets will release the paint as they launch, creating a splatter paint masterpiece!"

Reiterate to the group, "We already have a propulsion system for our rockets with the Alka-Seltzer and film canister, but we'll need to engineer the other parts—the fuselage, fins, and nosecone—ourselves. We'll design and build those parts out of construction paper and add them onto the film canister."

Inform everyone that their goal today is to make a rocket that flies as high as possible. In order to do that, they can experiment with the length of the fuselage, the number of fins, and the shape of the nosecone as they engineer their rockets. Show example completed rockets and let families know that they have an instruction sheet at their tables to guide them through each step. When they are finished creating the construction paper rocket parts, they can take their rockets over to a poster board launch zone. The paint explosions will create a unique piece of art on the poster board.

Walk around to offer assistance as families build their rockets. Encourage them to give thought to their designs and make predictions about the launch. For example, will a rocket with a longer fuselage or a shorter fuselage fly higher? Why?

As families finish building, remind them to bring their rockets, paint, and Alka-Seltzer over to a poster board. The poster boards have been spread around the area to make sure launches are done at a safe distance and pitchers of water have been placed at each poster board spot. It may be helpful to walk each group through their first launch. The key is to make sure the film canister lid is fully snapped on!

Encourage everyone to make modifications to improve their launch until they reach their desired height. They can modify the water : paint : Alka-Seltzer ratio in the rocket engine and/or the physical rocket parts.

When everyone has had a chance to do several launches, bring the group back together and lead a debrief discussion. What went well? What was challenging? Which kinds of rockets went the highest? Did anyone notice any patterns? Any other observations?

<u>Part Two: Tie Dye</u>

Congratulate everyone on their rocket launches and let them know we'll be moving on to our next colorful activity – tie dying hoodies! Show the Benjamin Banneker Science Club branded hoodies to get everyone excited. We'll be using fabric dye, rather than paint, in this activity. When we apply the dye to our hoodies, a chemical reaction takes place between the dye molecules and the fabric molecules. The dye bonds with the cotton and actually becomes a part of the fabric. That makes the dye permanent, and your hoodies should stay vibrant even after washing.

Before passing out the hoodies, give the group an overview of the tie dye process:

- First, you'll need to get your hoodie wet; this makes it easier for the dye to saturate the fabric. We'll send one group at a time to the dunking station where a Morehead staff member will dunk your hoodie in a bucket of water for you. You'll then need to wring it out so that it's damp but not soaking wet.
- Next, you'll bring your hoodie back to your table and twist/fold it in any pattern you like. Use rubber bands to secure. You can create your own pattern or pick one from the instruction guides on each table.
- Place the rubber banded hoodie on top of the baking rack and set the baking rack on top of the disposable baking pan. This apparatus will allow the dye to drip off the hoodie and collect in the disposable pan for less mess. Put on gloves.
- Now you're ready to apply the dye! Use the squeeze bottle to apply the dye directly onto your hoodie, making sure to saturate the fabric. You'll probably want to apply the dye to one side and then flip over and dye the other.

Pass out hoodies and tie dye kits but do not put the actual dye on the tables until they have completed the folding and rubber banding. Guide the group through each step of the tie dye process.

Tell families that once they have finished dying their hoodies, they can seal them inside the giant Ziploc bags from the tie dye kit to take home. The hoodies should sit in the bag for at least 8 hours, or even overnight. After 8 hours – overnight, take the hoodies out and wash them in the washing machine. After washing, your one-of-a-kind hoodie is ready to wear!

Part Three: Surveys and HNM Testing

Explain to the students that this program also involves a research component. As part of that research, we'll need them to complete surveys periodically. Pass out the surveys and pens and emphasize the need for honest answers. Make sure that students know they won't be graded and that there are no right or wrong answers.

As students work on the surveys, invite a few families at a time to check out the activities at the HNM testing station. Make sure every family gets a chance to try the HNM activities.

Part Four: Closing

Pass out and review thermochromic slime take-home activity and ask families to complete the post-meeting survey before leaving. Make sure to thank everyone for coming and remind them to mark their calendars for next month!

THERMOCHROMIC SLIME

This slime is made with thermochromic pigment. Thermochromic pigments change color when their temperature changes. For example, when the red pigment is cold, it absorbs all wavelengths of visible light except red. When it warms up, the molecular structure shifts and it absorbs all wavelengths except yellow.

Procedure:

1. Split the bottle of glue between the two bowls, pouring an equal amount into each one. Try to get all the glue out!

2. Add 4 tablespoons of water to your bowl, using the tablespoon measure and water bottle.

3. Pour a bag of thermochromic pigment into your bowl, and use the popsicle stick to stir until everything is mixed really well. It will take a long time to stir! Be patient and keep going!

4. Measure 4 tablespoons of water into your cup.

5. Pour a bag of borax into your cup and use a clean popsicle stick to stir until the borax dissolves.

6. Pour the borax solution into your bowl and stir everything together until well mixed.

7. Your slime will be wet and gooey at this point. Pick it up and knead it in your hands until you have a smooth, beautiful, color-changing slime!

EXPLODING PAINT ROCKETS

When Alka-Seltzer dissolves in water or water-based paint, an acid-base reaction occurs that releases carbon dioxide gas. Gasses like to expand to fill their containers, but the film canister containing the gas is too small. The gas keeps pushing and pushing until the pressure is finally released and launches the canister into the air!

Procedure:

1. Use the construction paper, scissors, and tape to build your rocket around a film cannister. Turn the film canister upside down so that the cap is on the bottom of the rocket.
   - For the fuselage/body: Cut construction paper to desired height. Tape the paper to the film canister and roll into a tube around the canister. Tape to secure the tube.
   - For the fins: Cut out desired shape and number of fins from construction paper and tape onto fuselage. Simple triangles work well.
   - For the nosecone: Start by cutting out a circle of construction paper. Then, cut a slit from the edge of the circle to the center point. Take the edges of the slit and overlap them to create a cone shape. Tape to secure. The more you overlap the edges, the taller and narrower the nosecone will be.

2. Bring your rocket and paint over to the poster board.

3. Flip the rocket upside down and remove the cap. Pour some water and some paint into the film canister. You can choose how much water and how much paint – or choose to leave out the water and use only paint!

4. Break up an Alka-Seltzer tablet. Drop a piece into the film canister and then quickly snap the lid on, shake it once, and set it on the poster board with the lid on the bottom (so your nosecone points up). Step back and watch it launch!

5. Experiment with the amount of paint, water, and Alka-Seltzer to get the perfect, artful launch.

November 14, 2020: Build-A-Zoo Day

November Meeting Agenda

November 14, 2020
9:00 AM – 12:00 PM
Modlin County Middle School
"Build-A-Zoo"

9:00 AM Welcome and COVID Safety Protocol Review

9:15 AM Begin Zoo Project

10:15 AM Snack Break

10:35 AM Finish Zoo Project

11:00 AM Parents Arrive and COVID Safety Protocol Review

11:05 AM Biodiversity Jenga

11:50 AM Surveys and Closing Announcements

<u>November Meeting Agenda</u>

November 14, 2020
1:00 PM – 4:00 PM
Modlin County Middle School
"Build-A-Zoo"

1:00 PM Welcome and COVID Safety Protocol Review

1:15 PM Begin Zoo Project

2:15 PM Snack Break

2:35 PM Finish Zoo Project

3:15 PM Biodiversity Introduction

3:30 PM Parents Arrive and COVID Safety Protocol Review

3:35 PM Biodiversity Jenga

3:50 PM

NOVEMBER 2020 ACTIVITY WRITE-UP

SETUP

- Place a sheet of giant graph paper at each seat
- Lay out the plastic animals at the front of the room

ACTIVITY

Introduction

"Has anyone ever been to a zoo before? What do you remember about it? What was your favorite and/or least favorite part?"

Give everyone some time to talk about their zoo experiences. Explain that we will be designing our own zoos today, which is a big project! For a little more inspiration before we start (and in case anyone hasn't been to a zoo before), let's take a look at an example zoo map from the Taronga Zoo in Sydney, Australia. Students who brought their Chromebooks can take a Google Earth tour of the Taronga Zoo for an even closer look! Ask students to share their observations about the zoo map.

Ask, "Who do you think normally designs zoos? What kinds of professionals?" Discuss how architects, habitat designers, zoologists/biologists/animal scientists, veterinarians, marketing managers, educators etc. can all be involved in zoos.

Tell the students that they will get to try out all those roles today as they design a zoo of their very own. We'll be drawing our own zoo maps on the graph paper, but there are several steps to go through first.

Part One: Animals

Our first step is going to be choosing which animals we want in our zoos. Tell students that they will have a budget of $500,000 to spend on the animals. They will get additional funding to build enclosures later on.

Pass out the ANIMALS sheet from the zoo catalogue and show students that the cost of each animal is listed in the first column of the table ("Cost Per Animal"). Then draw their attention to the "Minimum Family Group Size" column. Explain that some animals are solitary, so you can buy just one for your zoo, but some animals need to be in family groups, so you'll be required to buy more than one. If you want anteaters, for example, you're allowed to have only one. But if you want elephants, you'll have to buy at least two. To get the total price of your two elephants, you'll have to multiply the number in the first column ("Cost Per Animal") by two. You can always have more than the minimum, so buying five elephants is allowed! If you buy five elephants, you'll need to multiply the cost per animal by five for the total cost of the elephants.

For each animal the students choose, encourage them to record the animal name, number, and total cost on their blank sheet of paper. Remind them to check that they stay within the $500,000 budget.

You can also encourage students to use their Chromebooks or the iPads to look up photos and habitat information for any animals they aren't familiar with.

Part Two: Space Needed

Once everyone has selected the animals for their zoos, we need to figure out how much space each type of animal needs.

Draw students' attention to the Space Required for First Animal (ft.^{2}) column on the ANIMALS sheet. Explain that if you only have one of that type of animal, this column shows you exactly how much space you'll need for it. If you have one crocodile, for example, you just find the crocodile row, slide your finger over to that column, and it says you need 15,000 ft.^{2}

If you have more than one of that animal, you'll need to add extra space. The last column on the sheet (Space Required for Each Additional Animal) tells you how much extra space to add for each extra animal. If you have two crocodiles, for example, you'll need to do 15,000 ft.^{2} (for the first crocodile) plus 7,500 ft.^{2} (for the second crocodile), giving you a total of 22,500 ft.^{2} for your crocodiles. For three crocodiles, you'd do 15,000 + 7,500 + 7,500 = 30,000 ft.^{2}

Walk around and assist as needed. Students are welcome to use calculators. Encourage students to record the space needed for each animal type on their blank paper.

Part Three: Enclosure Areas

Now that we know how much space we need for each animal exhibit, it's time to buy enclosures. Clarify that all the animals of one type will be housed together in one enclosure. All three crocodiles will go together in one enclosure, the elephants will be together in a separate enclosure, and the anteater will go in another enclosure on its own.

Pass out the ENCLOSURES sheet from the zoo catalogue and explain that these are the enclosures available to purchase for their zoo. No boring rectangles in our zoos!

Ask students to notice that the cost and dimensions, or side lengths, of the enclosures are shown but not the area. We need to calculate the area of each enclosure before we can choose which ones to buy for our animals. Challenge students to use the area formulas sheet to calculate the areas on their own or working with the person next to them. This may be very difficult for some students, so you can also work through the calculations as a group. Students should write down the area of each enclosure on their ENCLOSURES sheet.

Part Four: Put it on the Map

Now that we know how much space is inside each enclosure, we can choose the right enclosure for each animal type.

Our three crocodiles, for example, need 30,00 ft.^{2} That means the semicircle and triangle enclosures are too small, but they would fit inside the pentagon because the area of the pentagon is over 30,00 ft.^{2} Once you've selected the enclosure, you can draw it on the map! The graph paper will be the zoo map. If none of the enclosures are big enough for the space you need, you can combine them. You can put two of the triangles together for a total area of 50,000 $ft.^2$ (25,000 + 25,000 = 50,000) for example.

As you draw your enclosures on the map, think about which enclosures you'd want next to each other and leave room for walkways. You may also want to add additional features like restrooms, cafes, a ticket booth, etc.

Once students have the enclosures drawn, invite them to add the plastic animals to their zoo! They can grab one of each animal type and put it in the enclosure; i.e. use one elephant to make the elephant enclosure.

TWO OPTIONAL EXTENSIONS: You may choose to have the students stay under a $2 million budget when buying their enclosures and/or have them draw the enclosures to scale on the graph paper with each square representing 100 $ft.^2$ (10 ft. X 10 ft.).

Part Five: Biodiversity Jenga

Point out to the students that some of the animals they have chosen for their zoos are ***endangered species***. Ask if anyone can describe what the endangered species designation means (a species at high risk of extinction, very likely to disappear completely in the near future). Does anyone know why we are so worried about endangered species? What might happen if one of these animals went extinct? Tell students that we are going to play a little game to help answer these questions.

We're going to play a game of Jenga with a twist. In our Jenga game, each block represents one species of animal or plant. Pass out the rainforest ecosystem labels and have students stick one label on each block. When the students have labeled each block, ask them to stack all the blocks into a Jenga tower. The whole tower represents an ***ecosystem***, all the living and nonliving things in an area. This Jenga is a rainforest ecosystem. The plants and animals in an ecosystem interact with each other and depend on each other to survive. For example, the Jaguar in a rainforest needs smaller animals to eat and the birds in the rainforest need trees to nest in. Each time you pull out a block during the game, imagine that you are removing that species from the ecosystem. As you play, notice what happens to the ecosystem tower.

Explain the classic Jenga rules and invite everyone to start playing! Parents vs. students!

After everyone has played a game or two, regroup and ask everyone to share their observations. Discuss how a healthy ecosystem needs to be balanced just like a Jenga tower. As they played/removed species, the tower/ecosystem became more and more unsteady until it eventually fell. Just like pulling out that last Jenga block, removing one species from an ecosystem can make the whole thing collapse. Each species has its own important job, so extinction of one species affects all the others and can lead to total ecosystem collapse.

Ask participants if they can think of any reasons a species might go extinct – like habitat loss from deforestation. The trees of the Amazon Rainforest are constantly being cut down by logging companies or to make room to graze cows, grow crops, or mine for metals. Climate change is also causing extinction, as temperatures rise and plants and animals can no longer survive in their natural habitats. Other factors include human overhunting, pollution, etc.

Discuss how zoos can play an important role in conservation with breeding and reintroduction programs, as well as public education. However, we need these animals in the wild, not just in zoos!

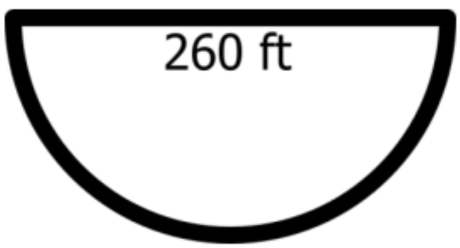
Part Six: Closing

Tell students that they can take home their Biodiversity Jenga sets and encourage them to play with siblings and friends to share what they've learned. Ask families to complete the post-meeting survey before leaving. Make sure to thank everyone for coming and remind them to mark their calendars for next month!

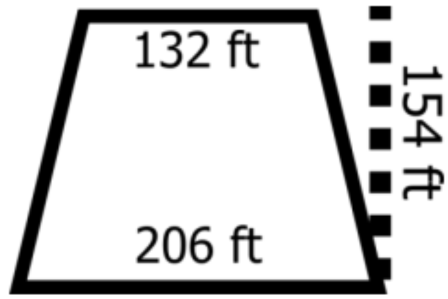
ANIMALS

Animal	Cost Per Animal	Minimum Family Group Size	Space Required for First Animal ($ft.^2$)	Space Required for Each Additional Animal ($ft.^2$)
Anteater	$2,500	1	32,500	2,500
Black Bear	$15,000	1	40,000	10,000
Brown Bear	$15,000	1	40,000	10,000
Camel	$1,250	1	35,000	5,000
Crocodile	$3,000	1	15,000	7,500
Deer	$7,500	2	35,000	10,000
Egret	$2,000	1	21,500	2,500
Elephant	$20,000	2	42,500	10,000
Flying Squirrel	$2,000	2	25,000	5,000
Fox	$7,500	2	35,000	10,000
Frog	$1,500	1	2,500	500
Galapagos Tortoise	$3,500	1	15,000	7,500
Gazelle	$10,000	2	25,000	5,000
Giraffe	$24,000	2	35,000	5,000
Gorilla	$20,000	4	35,000	5,000
Hedgehog	$2,000	1	5,000	1,000
Hippopotamus	$7,500	1	32,500	5,000
Kangaroo	$3,000	6	35,000	2,500
Koala	$7,500	1	15,000	2,500
Leopard	$7,500	2	45,000	15,000
Lion	$7,500	4	25,000	7,500
Lizard	$1,500	1	7,500	1,000
Meerkat	$750	12	15,000	5,000
Monkey	$3,500	4	25,000	2,500
Moose	$1,250	4	28,125	5,000
Panda	$40,000	2	40,000	10,000
Pangolin	$10,000	1	15,000	5,000
Penguin	$2,000	8	17,500	2,500
Platypus	$2,000	1	7,500	5,000
Polar Bear	$10,000	4	40,000	10,000
Rhinoceros	$18,000	1	40,000	12,500
King Cobra	$5,000	1	5,000	1,000
Tapir	$7,500	2	32,500	2,500
Tiger	$15,000	2	37,500	10,000
Yak	$1,250	2	20,000	5,000
Zebra	$3,000	4	25,000	2,500

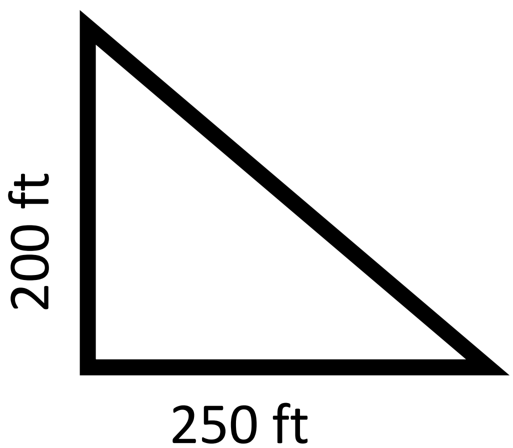
ANIMAL ENCLOSURES



Cost: $120,000

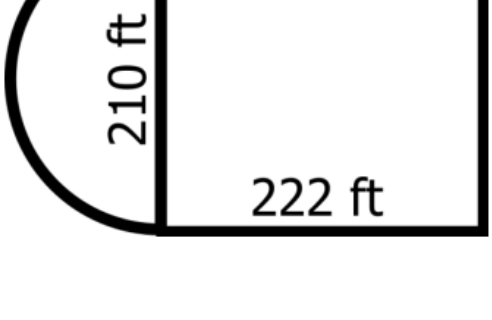


Cost: $100,000

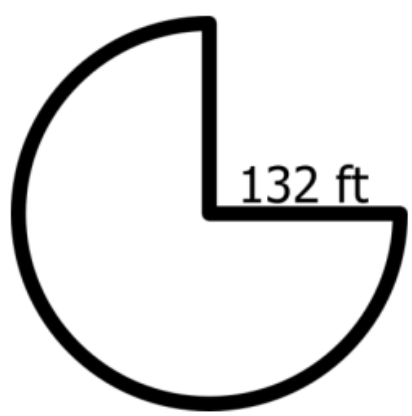


Cost: $95,000

Cost: $105,000



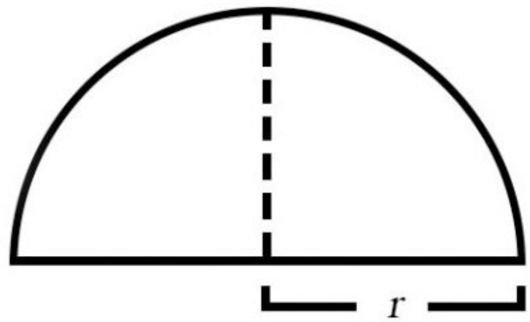
Cost:$145,000



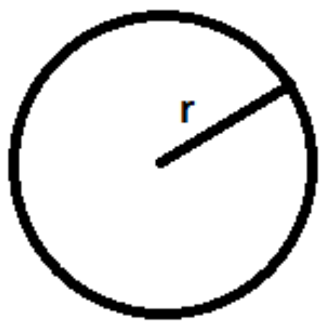
Cost:$130,000

Area of a Semicircle:

$$A = \frac{\pi r^2}{2}$$

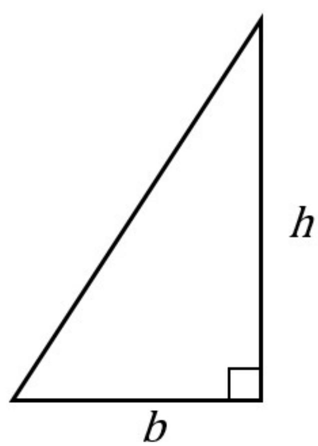


Area of a Circle:



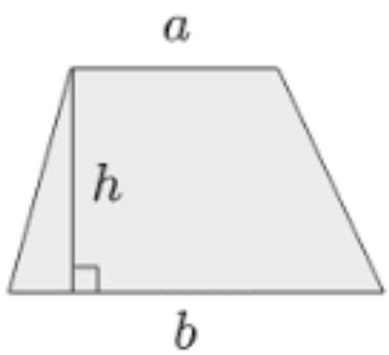
$$A = \pi r^2$$

Area of a Right Triangle:



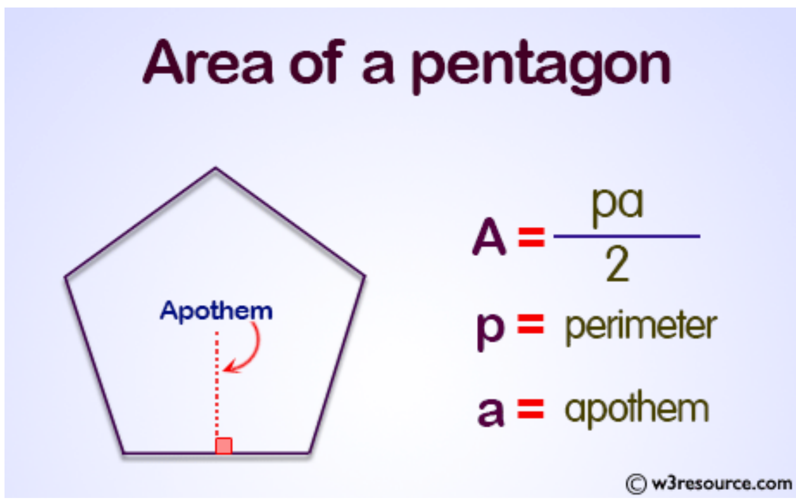
$$A = \frac{1}{2}bh$$

Area of Trapezoid:



$$A = \frac{(a+b)h}{2}$$

Area of a Pentagon:



APPENDIX B: INDIVIDUAL INTERVIEW GUIDE

Welcome and ground rules (3 minutes)

Hello! Thank you all for participating in this discussion. My name is Crystal Harden and I am a graduate student at the University of North Carolina at Chapel Hill.

As you know, you were invited to join this discussion because you are a participant in the Saunders Science Scholars Program. The purpose of these interviews is to gain a better understanding of the effectiveness of the Saunders Science Scholars Program and the program's impact on how you view science in general.

In case you have not been in a structured individual interview before, a structured individual interview is a structured discussion where I will ask you a series of questions to encourage sharing of ideas and opinions. I really want you to express yourself openly and honestly. There are no right or wrong answers. I just want to know what you think.

I am going to record this session to ensure this report accurately reflects your comments. However, your responses will not be linked with your name in any way. Everything you say will be kept strictly confidential. Because we are videotaping and recording, I may need to remind you occasionally to speak up or talk one at a time so that I can hear you clearly when we review the session recording tapes.

I am your guide through the questions. Each time I ask a question, your perspective is important to hear. Bear in mind, I am looking to hear a variety of opinions and experiences.

Introductions (1 minutes)

1. Let's begin by saying your name, how old you are, and what is your favorite scientific topic is.

Introductory questions (10 minutes)

1. Now, I would like to ask you about why you decided to join the Saunders Science Scholars Program? (probe for a) academic achievement, b) parental or familial influence, or c) interest in science)

2. What topics do you remember in the Saunders Science Scholars Program?

3. As a Saunders Science Scholar, what is your favorite part of the program to participate in?

4. What words would you use to describe science?

Transition questions (10 minutes)

1. When you think of someone who is a scientist, what comes to mind? What do you think of? (list) (fun, creative, curious, smart, physical characteristics)

2. What do you think makes someone a good scientist or just good at science? (interests, (tv, clubs, hobbies), gender, or science person and sporty person)

3. What words would you use to describe yourself in science?

Key questions (20 - 30 minutes)

1. How have your views of science and scientists changed since your participation in the program? Better or worse? Not at all?

2. Has your view of yourself changed (specifically your view as science person) since before you were in the Saunders Science Scholars Program? Since starting the Saunders Science Scholars Program? (more or less interested, more or less involved, change in interests, future directions)

3. What were some of the most memorable activities/events of the program? Did these contribute to your view of yourself as a science person? If so, how?

4. Did the program (activities, events, coordinators) change your thinking? Do you think like a scientist now? What are some examples?

5. Do you think that some people have an easier time with science? If so, who?

Ending questions and summary (10 minutes)

1. Is there anything that we missed during our discussion?

2. Can you think of any ways to improve the Saunders Science Scholars program?

3. Is there anything else you would like to share about the program that we have not discussed already?

This concludes our discussion. I have enjoyed talking with you. Thank you again for your time. I will be using the results of this and other interviews to help improve the Saunders Science Scholars Program.

APPENDIX C: FIELD NOTE PROTOCOL

1. How are students engaged in the activity of the day/science design?
2. What science knowledge/practices matter today? How?
3. What tools (human, material, digital, other) matter in how they bring different knowledge and practices together towards the design?
4. Did the adult facilitator use a STEM mini lesson?
5. What pictures or other artifacts did the adult facilitator get today? And what is notable about the picture? Describe the interaction in detail that the picture capture.

APPENDIX D: ARTIFACT ANALYSIS/INTERVIEW PROTOCOL

1. What is the name of your innovation or product? How did you come up with that name?
2. What was the problem you were trying to solve?
3. How did you come up with the idea for your invention?
4. What are some other things you need to figure about your invention?
5. What are some changes you would make to your invention? Could you draw them out and label them on a picture?
6. What other new ideas do you have to add to your invention?
7. What materials are you planning to use to make your changes to your invention?
8. Where did you get the information to come up with the idea for your invention?

APPENDIX E: PARTICIPANT OBSERVATION FIELD GUIDE

Participant observation

What is participant observation?

Participation observation is a qualitative method whose objective is to help researchers learn the perspectives held by study populations. Researchers are interested both in knowing what those diverse perspectives are and in understanding the interplay among them. Qualitative researchers accomplish this through observation alone or by both observing and participating, to some degree, in the study community's daily activities.

Participant observation takes place in the study community settings and locations that have some relevance to the research questions. This method is distinctive because the researcher observes participants in their own environment. The researcher tries to learn what life is like for the participant while remaining an "outsider".

The researcher will make careful, objective notes about what they see, recording all accounts and observations as field notes in a field notebook. Informal conversation and interaction with members of the study population are also components of this method and should be recorded in the field notes with as much detail as possible.

Ethical guidelines

How is confidentiality maintained during participant observation?

Researchers involved in participant observation must make a personal commitment to protect the identities of the people they observe or with whom they interact. Maintaining confidentiality means ensuring that particular individuals can never be linked to the data they provide. This means that researchers cannot record identifying information such as names and addresses of people that they meet during participant observation. It may be reasonable to record the names and locations of establishments in the field notes but they should be coded and eliminated upon entry of the field notes into the computer with the code list kept in on a separate, secured computer file with limited access.

Researchers should make sure that no personal information that is given by a participant is ever included in the actual participant observation. Protecting participants' confidentiality also requires that researchers do not disclose personal characteristics that could allow others to guess the identities of participants who played a role in the research. Therefore, researchers must take great care not only in entering participant observation data into field notes. A researcher's refusal to divulge confidences will reassure participants that they will protect their confidentiality. Participant confidentiality must also be respected during eventual presentation of the data in public dissemination events as well as in printed publications.

How should informed consent be handled for participant observation?

When talking to people about the research and the researcher's role, it is important to emphasize that people are not required to talk to the researcher and there will be no repercussions if they do not. If the researcher's involvement with an individual appears to be progressing beyond participant observations to a formal interview, it is necessary to obtain informed consent before beginning an in-depth interview.

Logistics of participant observation

What are the responsibilities as a participant observer?

Researchers conducting participant observation need to be prepared and willing to adapt to a variety of uncontrolled situations and settings. The amount of participation in activities versus observation of the participants by the researcher depends on the objectives and design of the project, on the circumstances, and the ability to blend in with the study population.

Specific responsibilities include:

- Observing people as they engage in activities that would probably occur in much the same way if the researcher was not present
- Engaging to some extent in the activities taking place, either in order to better understand the local perspective or so as not to call attention to the researcher
- Identifying and developing relationships with key informants, stakeholders, and gatekeepers

Where should participant observation take place?

Where the researcher should go to do participant observation depends on the research goals. The researcher should try to go where people in the study population often go in their daily lives, and if appropriate, engage in the activity of interest.

When should participant observation take place?

Participant observation is often done at the beginning of the data collection phase, but the method is also sometimes revisited later to address questions suggested by data collected using other methods. The best time to schedule participant observation sessions depends on what, whom, and where observation is needed. The researcher may need to set up specific times based on when the particular activity takes place such as on the day a weekly meeting is scheduled. There might be specific times of day when an activity usually occurs. It may also be important to observe the same population in several different locations and at different times.

How long does participant observation take?

The specific duration of participant observation depends on the setting, activity, and population of interest. For example, the researcher might spend an hour, an afternoon, or a series of afternoons in a particular setting.

What should the researcher observe during participant observation?

Category	Includes	Researchers should note
Appearance	Clothing, age, gender, physical appearance	Anything that might indicate membership in groups or in sub-populations of interest to the study, such as social status, socioeconomic class, religion, or ethnicity
Verbal behavior and interactions	Who speaks to whom and for how long; who initiates interaction; languages or dialects spoken; tone of voice	Gender, age, ethnicity, and social status of participants; dynamics of interaction
Physical behavior and gestures	What people do, who does what, who interacts with whom, who is not interacting	How people use their bodies and voices to communicate different emotions; what individuals' behaviors indicate about their feelings toward one another or their social rank
Personal space	How close people stand to one another	What individuals' preferences concerning personal space suggest about their relationships
Human traffic	People who enter, leave, and spend time at the observation site	Where people enter and exit; how long they stay; who they are (ethnicity, age, gender); whether they are alone or accompanied; number of people
People who stand out	Identification of people who receive a lot of attention from others	The characteristics of these individuals; what differentiates them from others; whether people consult them or they approach other people; whether they seem to be strangers or well known by others present

How does the researcher document what was learned during participant observation?

Documentation of participant observation data consists of field notes recorded in field notebooks. These data are records of what was experienced, what was learned through interaction with other people, and what was observed. Field notes should include an account of events, how people behaved and reacted, what was said in conversation, where people were positioned in relationship to one another, their movements, physical gestures, researcher subjective responses to observations, and all other details and observations necessary to make the story of the participant observation experience complete. Field notes may be written either discreetly during participant observation or following the activity. Notes should be expanded as soon as possible before memories of the details fade.

The researcher might also sketch a map of the observation site indicating important establishments and locations, mark where certain activities were taking place, and places where follow-up observation is needed.

What should the researcher do with the field notes?

As soon as possible after collecting participant observation data, the researcher should expand whatever notes into a descriptive narrative. Include as many details as possible. Once the notes are expanded, the researcher will need to type the field notes into a computer file. The notebook and any hard copies of the typed data should be stored in a secure location along with any other products of participant observation.

<u>Participant observation preparation</u>

How does the researcher prepare for participant observation?

The researcher needs to know what the research is about. A thorough understanding of the study will help the researcher stay focused during participation observation. The researcher should determine specific objectives for the participation observation activity. Also, it is important to be aware of scenarios that one had not expected to encounter which may suggest new directions for the research.

In preparing for the participant observation activity, it is useful to find out as much information as possible about the site for participating and observing as well as activities that participants will engage. If necessary, visit the site and make initial observations before setting up the official data collection time.

Similarly, establish the shorthand conventions that will be used to indicate and abbreviate the words and concepts going to be used in notetaking. Establish how to separate objective observations from interpretations and how gender and age will be indicated.

How should the researcher behave during participant observation?

The most important behavioral principle in participant observation is to be discreet. The researcher should not stand out or affect the natural flow of activity. It also helps to be aware of local meanings for particular body language (positions and gestures) and tones of voice, as well as what types of physical and eye contact are locally appropriate in different situations. The researcher should use good judgement in determining whether to participate in certain types of activities.

What should the researcher document?

Document what was observe and make sure to distinguish it from both the expectations and interpretation of what is observed. It is important to document what is actually taking place rather than what is expected to be seen. It is critical to not let expectations affect observations. The purpose of participant observation is partly to confirm what is known or thought but is mostly to discover unanticipated truths as an exercise of discovery.

The researcher should avoid reporting interpretation rather than an objective account of what is observe. For a researcher to interpret is to impose judgement on what is seen. The danger of not separating interpretation from observation is that interpretations can turn out to be wrong. This can lead to invalid study results which can ultimately be damaging for the study population.

How does the researcher take field notes?

Handwritten notes that are later converted into computer files are often the only way to document certain participant observation activities. Notes from participant observation are called field notes and they are written directly into field notebooks.

How does the researcher expand the notes?

Following each participant observation event, the researcher needs to expand the field notes into rich descriptions of what was observed. This involves transforming researcher notes into a narrative and elaborating on initial observations on a computer (if not available then by hand). Eventually, all expanded notes should be typed into computer files using a specific format. Expanding the field notes involves the following:

- The researcher schedules time to expand the field notes preferably within 24 hours from the time field notes are made. This makes it less likely to forget what an abbreviation stands for or less likely to forget what was meant. The sooner that the researcher can review the notes, the greater the chance for forgetting things not written down. Good note-taking often triggers the memory, but with the passage of time, this opportunity fades.
- The researcher expands the shorthand into sentences so that anyone can read and understand the notes. Use a separate page in the field notebook if necessary. Depending

on circumstances, the researcher might be able to expand and type notes into a computer file at the same time.

- The researcher composing a descriptive narrative from the shorthand and key words is critical. A good technique for expanding the notes is to write a narrative describing what happened and what was learned about the study population and setting. This narrative may be the actual document produced as expanded notes. It is important to create separate, clearly labeled sections to report objective observations versus interpretations and personal comments.
- The researcher reviewing expanded notes and adding any final comments is important. If the researcher has not typed the expanded notes directly into a computer file, add any additional comments on the same page or on a separate page. If using additional pages then be sure to clearly cross-reference new notes with the original pages.

Summary Participation Observation Steps

- Determine the purpose of the participant observation activity as related to the overall research objectives.
- Determine the population(s) to be observed.
- Consider the accessibility of the population(s) and the venues in which the researcher would like to observe them.
- Investigate possible sites for participant observation.
- Select the site(s), time(s) of day, and date(s), and anticipate how long the researcher will collect participant observation data on each occasion.
- Consider how the researcher will present themselves, both in terms of appearance and how the researcher will explain the purpose to others if necessary.

- Plan how and if the researcher will take notes during the participant observation activity.
- Remember to take the field notebook and a writing instrument.
- Schedule time soon after participant observation to expand the notes.
- Type the notes into computer files using the standard format set for the study.

Tips for Taking Field Notes

- Begin each notebook entry with the date, time, place, and type of data collection event.
- Leave space on the page for expanding the notes, or plan to expand them on a separate page.
- Take notes strategically as it is usually practical to make only brief notes during data collection. Direct quotes can be especially hard to write down accurately. Rather than try to document every detail or quote, write down key words and phrases that will trigger memories when notes are expanded.
- The researcher should use shorthand. They will expand and type the notes soon after writing them. Use abbreviations and acronyms to quickly note what is happening and being said.
- The researcher should cover a range of observations. In addition to documenting events and informal conversations, note people's body language, moods, or attitudes; the general environment; interactions among participants, setting, and other information that could be relevant.

Observation Worksheet: Gates to Greats

Location:	Date:	Start Time:	Stop Time:
Area of Observation	**Interests**	**Attitudes**	**Feedback**
Behavior (what, by whom, where)			
Conversation (what, by whom, where)			
Context (what else is going on?, what is the weather?, is it a special day?)			
General mood (what, how conveyed, by whom)			
Other areas of observation:			

Observation Memo/Field Note Questions

1. How are students engaged in the activity of the day/science design?
2. What science knowledge/practices matter today?
3. What tools (human, material, digital, other) matter in how they bring different knowledge and practices together towards the design?
4. What pictures or other artifacts of practice do you get today? And what is notable about the picture? Describe the interaction in detail that the picture captures.

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