VARIED STEM PATHS:

AN ANALYSIS OF THE POST-SECONDARY CAREER INTERESTS OF THE PARTICIPANTS OF AN INFORMAL SCIENCE PROGRAM

A Dissertation

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ABSTRACT

For many years, policy makers and science education researchers in the United States (Rozek, Svoboda, Harackiewicz, Hulleman, & Hyde, 2017) and internationally (DeWitt et al., 2010) have expressed concern over a decline in the number of students who are prepared for and/or interested in careers in science, technology, engineering, and mathematics (STEM). Of special concern is the underrepresentation of women and racial/ethnic minorities in STEM careers (Blickenstaff 2005; Chang, Eagan, Lin, & Hurtado, 2011; Estrada et al. 2016). Out-of-school science programs have been shown to be effective spaces to spark and foster science interest (Dabney et al., 2012; Price et al., 2019), and are important tools to narrow opportunity gaps (Deutsch, 2019).

More longitudinal studies are needed to show how the STEM career interests of young adults change as they leave high school and participate in college and careers. Likewise, more longitudinal studies are needed to understand the effects of participation in out-of-school science programs on career interests. This study fills both needs through the investigation of the STEM career interests and science aspirations of a group of 228 participants, 63 of whom participated in the Science Minors and Achievers Program housed in the Museum of Science and Industry, Chicago, over five years. Chi-square analysis, Sankey diagrams, and mixed effect modeling were used to answer the following four research questions:

1. Was there an association between condition (Science Minors and Achievers Program participation), gender, socioeconomic class, or race/ethnicity and the STEM career interests of participants in the five years after secondary school?
2. How stable was STEM career interest over three, four, and five year periods after secondary school? Did this stability vary by condition or gender?
3. How did field of STEM career interest vary by condition, gender, or race/ethnicity?
4. Did STEM career aspiration vary by year, condition, gender, race/ethnicity, socioeconomic class, or the interactions between these variables in the five years after post-secondary school?

Consistently across analyses, there was a significant association between participation in the Science Minors and Achievers (SMA) program (condition) and STEM career interest and science aspirations. Sankey diagrams uncovered considerable movement through STEM career interest categories over time, even amongst participants who began and ended time intervals in the same category. The year after high school was an important decision-making period, especially for participants interested in STEM careers and those identifying as female. Chi-square analysis showed condition and gender patterns in reported field of STEM career interest. The gender patterns reflect underrepresentation patterns of women in STEM fields. However, post-hoc analyses elucidated significant differences within the comparison group but not the SMA group, which may be indicative of a mediating effect of participation in the SMA program on gender representation disparities in STEM fields.

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APPROVAL OF THE DISSERTATION

This dissertation, “Varied STEM Paths: An Analysis of the Post-Secondary Career Interests of the Participants of an Informal Science Program”, has been approved by the Graduate Faculty of the School of Education and Human Development in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

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DEDICATION

This work is dedicated to my late father, James Charles Skeeles, whom we lost too soon while I was pursuing this degree. From a young age he inspired me to follow my dreams and pursue a career that I loved rather than endured, to strive for excellence, and to persist through difficulty. He and my mother Marty Skeeles worked tirelessly to support my sisters and I in a multitude of ways as we worked toward our personal, educational, and professional goals.

Dad, you modeled a deep respect and value for family, science, nature, and education, which is echoed in my own life. Your unconditional and selfless love and support was unparalleled and unbounded. Thank you.

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CHAPTER 1

INTRODUCTION

For many years, policy makers and science education researchers in the United States (Rozek et al., 2017) and internationally (DeWitt et al., 2010) have expressed concern over a decline in the number of students who are prepared for and/or interested in careers in science, technology, engineering, and mathematics (STEM). The decline in interest is paralleled by an increase in available STEM jobs (Rozek et al., 2017). The phenomenon of more and more students losing STEM interest and/or STEM career interest as they increase in age and progress in their educational trajectories and careers is traditionally described using the metaphor of a leaky STEM pipeline (Engineering Infrastructure Diagramming and Modeling, 1986; Lykkegaard & Ulriksen, 2019; Tytler, 2014).

Women and certain racial/ethnic minority groups are underrepresented in STEM careers, especially upper-level STEM careers (Blickenstaff 2005; Chang et al., 2011; Estrada et al., 2016). Studies show that although women and racial/ethnic minorities often show high aptitude for and interest in participating in STEM careers early in their educational trajectories, they encounter considerable barriers and discrimination along their educational and career paths, resulting in pronounced and persistent underrepresentation in STEM careers (Blickenstaff, 2005; van den Hurk, Meelissen, & van Langen, 2019). Examples of barriers include unequal access to financial resources to fund education across racial/ethnic groups (Estrada et al., 2016) and hostile school and work climates (Blickenstaff, 2005). The representation gap for women is especially evident in the fields of computer science, engineering, economics, statistics, and mathematics (Hazari, Sadler, & Sonnert, 2013; Steinke, 2017.

The underrepresentation of women of color, men of color, and White women in science and STEM fields is often framed by politicians and researchers as a national economic problem (Rozek et al., 2017). However, equitable access to science and STEM careers is more importantly an issue of social justice, as access to jobs affects not only financial security, but also personal fulfillment and happiness (Archer, DeWitt, & Willis, 2014). Furthermore, a diverse scientific workforce enhances creativity and the quality of scientific work (Phillips, 2014).

The use of the leaky STEM pipeline metaphor to describe the phenomenon of more and more students losing interest in STEM careers as they move through their educational and career pathways has come under criticism. First, the pipeline is characterized as a linear and unidirectional flow of students moving through STEM courses and into STEM careers, with increasing numbers of students dropping out along the way. Leakiness is typically measured by "headcounts" or numbers of students interested in STEM or enrolled in STEM courses/majors, and eventually moving into STEM careers at particular benchmarks. The visualization of a linear pathway with uniform steps to entering a STEM career does not account for individuals who move in and out of STEM career interest and/or participation, take a different path to a STEM career (Miller & Wai, 2015), or participate in STEM careers in different ways (Cannady, Greenwalk, & Harris, 2014; Lykkegaard & Ulriksen, 2019).

In fact, some argue that the view of a singular path to a STEM career can be damaging to underrepresented groups such as women and racial/ethnic minorities who may be more likely to take a less common route to a STEM career (Cannady et al., 2014). Similarly, DeWitt, Archer, and Osborne (2014) argued that highlighting a multiplicity of pathways to science careers and types of available science careers will allow a more diverse group of people to feel that science is "for them." A pipeline metaphor suggests there is one path to take to enter a STEM career and does not account for the underlying complexity along the path to career choice. In addition, some authors show results that indicate the leaky pipeline metaphor no longer accurately depicts gender differences in U.S. STEM majors and careers over varying disciplines and time career points. Thus, a more nuanced view is necessary for policy makers to find appropriate measures to increase gender diversity in STEM fields (Miller & Wai, 2015).

Furthermore, looking only at participant counts does not consider the societal, sociocultural and contextual factors that interact with participation in STEM studies and careers, especially gender and racial/ethnic identity. A body of science identity formation research demonstrates that it is often more difficult for women and underserved racial/ethnic minority individuals to identify with the dominantly White male culture, practices, and paradigm of science (Archer et al., 2013; Brickhouse, 2001; Calabrese Barton, 1998; Calabrese Barton, Tan, & Rivet, 2008; Carlone & Johnson, 2007; DeWitt et al., 2010). Therefore, it is important to consider gender, race/ethnicity, and other aspects of identity when investigating STEM career decisions.

Out-of-school science programs have been identified as an important way to spark and/or support STEM career interest (Dabney et al., 2012), but there is a need for additional rigorous studies, including longitudinal quasi-experimental studies such as this one, to illuminate the effects of programs (Falk, Koke, Price, & Pattison, 2018). The focal youth development program in this study is particularly interesting from an equity standpoint, as the program is specifically designed to serve youth from underserved racial/ethnic groups. Out-of-school programs have been shown to be an important way to reduce opportunity gaps (Deutsch, 2019). A better understanding of the career aspirations and experiences of youth during and after participation in a STEM-focused out-of-school program could help inform policies to narrow representation gaps in STEM fields.

In this study, I will investigate the STEM career interests and aspirations of individuals as they transition from high school to college or careers. The participants comprising the treatment group took part in a youth development program in a science museum throughout high school. They are referred to as the Science Minors and Achievers (SMA) group. The participants in the comparison group did not participate in the museum youth development program. The inclusion of a comparison group in the study will allow for analyses that will shed light on the potential impacts of long-term participation in a science-themed out-of-school program. Throughout the study, I will investigate how participants' racial/ethnic and gender identities may interact with their STEM career decisions and aspirations. This study is longitudinal and spans five years after high school; thus it is well suited to investigate how career decisions and aspirations change over these critical years. This approach addresses many critiques of the traditional linear STEM pipeline metaphor expressed by Lykkegaard and Ulriksen (2019), and indeed many of the methodological techniques employed are inspired by their work.

CHAPTER 2

REVIEW OF LITERATURE

There is widespread concern about the decreased number of students entering STEM majors and careers, as well as the lack of equal representation of women and underserved racial/ethnic minorities in STEM careers. To understand patterns of STEM career participation, we must understand the path that individuals take to a STEM career. The first step in understanding this process is to investigate how individuals move in and out of STEM career interest. In assessing the literature, it is clear that career decisions are dynamic, complex, and context-dependent (Cannady et al., 2014; Lykkegaard & Ulriksen, 2019).

STEM Career Representation

Based on the National Survey of College Graduates (NSCG) data, the National Science Foundation (2018) reports that while women make up half of the college-educated workforce, they represent only 28% of the science and engineering workforce. Women are less represented in some STEM subfields, comprising only 15% of engineers and 26% of computer and mathematical science workers.

Based on the same data, many racial/ethnic groups are underrepresented in STEM fields. In 2015, at 67%, White science and engineering professionals were represented in science and engineering professions at a level similar to their representation in the working age U.S. population. However, Latinx, Black, and American Indian science and engineering professionals were underrepresented at only 11% of the workforce compared to 27% of the U.S. working age population. Asian science and engineering professionals were overrepresented at 21% of science and engineering professionals compared to 6% of the working age U.S. population.

Thus, when simply comparing national representation to representation in science and engineering careers, we consider White women, Black men, Black women, Hispanic men, Hispanic women, American Indian men, and American Indian women to be underrepresented in the sciences. It should be noted that although many STEM education studies group White and Asian students and scientists together based on broad representation trends, and by virtue of being equally or overly represented in STEM, it is clear that the experiences of Asian and White students are unique (Aschbacher, Li, & Roth, 2010). The heterogeneity within the "Asian" racial category in particular (as well as other race/ethnicity categories), is often grossly underestimated (Yoshikawa, Mistry & Wang, 2016).

STEM Pipeline Studies

For many years, researchers and policy makers used the metaphor of a STEM pipeline as the dominant frame to investigate STEM participation throughout educational pathways and careers (Cannady et al., 2014; Miller & Wai, 2015). However, in the last 10 years many researchers have been critical of the approach of counting numbers of individuals participating or interested in STEM at different benchmarks (i.e., STEM majors in their freshman year in college) to assess STEM career interest over time. They are critical of the visualization of the pipeline as people moving along a singular pathway towards a STEM career going through the same gateways to get there (e.g., calculus, STEM major). Some researchers also question the notion that an ever-increasing group of people leak out as they progress along the pipeline.

Cannady et al. (2014) conducted an analysis of the National Educational Longitudinal Study of 1988 (NELS:88) and concluded that almost half of the individuals who eventually become scientists or engineers do not follow the traditional path implied by the STEM pipeline metaphor. For instance, although taking high school calculus is highly predictive of eventually entering a STEM career, in their study 48% of eventual scientists and engineers did not take calculus in high school. Furthermore, Cannady et al. (2014) believe that the metaphor masks important underlying differences in science and engineering subfields. They suggest taking a pathway approach that allows for varied journeys to a STEM career and avoid using value-laden language such as "leaking," which implies that those who "leak" from the STEM pipeline have failed, rather than choosing a different but equally valuable endeavor, or participating in STEM in a different way.

Miller and Wai (2015) critique other authors' use of the leaky STEM pipeline metaphor to describe the fact that more women than men leak out of the STEM pipeline throughout their trajectory. They used retrospective longitudinal methods to investigate the accuracy of the metaphor using data from the NSCG and the Survey of Doctoral Recipients (SDR). In these two surveys, Ph.D. earners were questioned retrospectively about their educational histories (e.g., year they earned their bachelor's degree). Miller and Wai found a nuanced picture: Women with STEM bachelor degrees were less likely than men with STEM bachelor degrees to earn STEM Ph.D.s in in the 1970s and 1980s, but increases in the relative number of women earning STEM Ph.D.s led to the closure of this gap by the1990s. At the time of their 2015 study, however, there was a decline in women earning bachelor's degrees and Ph.D.s in computer science, engineering, and physical science for the first time in 40 years. They emphasized that entering STEM fields without STEM bachelor's degrees is an important pathway that is not recognized in the traditional view of the pipeline, and that this pathway can result in more well-trained STEM graduates. Miller and Wai also suggest that the term leaky pipeline is not helpful to women, and suggest using more positive language when discussing individuals who pursue another type of career.

Lykkegaard and Ulriksen (2019) performed a longitudinal, mixed methods study that investigated both the different ways that students move in and out of STEM career pipeline, as well as the underlying experiences that led to their career decisions. Using these methods, they were able to uncover the more nuanced underpinnings of movement through the STEM pipeline. They followed 240 students who participated in a university STEM outreach program for three years starting 18 months prior to secondary school completion. The participant pool was purposefully chosen to be predominantly composed of individuals with existing STEM interest and without a family history of university attendance. The students' educational and career plans were assessed at three time points: before the project began, after the project began, and 18 months after graduating secondary school. Then, more in-depth educational reflections were collected from 15 focal students based on their educational and career goals (and to allow for maximum variation amongst participants) to gain a more detailed view of their motivation for pursing specific educational trajectories.

Lykkegaard and Ulriksen (2019) not only categorized students as having STEM career interest, but also health, arts, and business career interests. The authors used Sankey diagrams in addition to percentages to illustrate the flow of students in and out of the career interest groups at the three time points. Then, Lykkegaard and Ulriksen carried out a qualitative analysis of the experiences of five focal case participants linked to the students' career choices and trajectories. Their results indicated that participants move in *and* out of STEM career paths; in fact, they found more participants moving into STEM than out of STEM. This supports the critique of the STEM pipeline as linear, closed, and ever-narrowing, and highlights the need for longitudinal studies which capture movement in and out of fields of study. In some cases, although it seemed students moved out of STEM career interest, from the point of view of the student they moved into a career path based on similarities, such as a foundation in mathematics. This illustrates the limitations of studies relying solely on the rigid classifications of STEM fields; there is no allowance for nuanced views of what can be considered STEM, or underlying similarities between disparate fields of study.

Science Aspiration and STEM Interest

Definition and measurement. Science aspiration refers to a student's "future expectations or visions about working in science" (Du & Wong, 2019). Multiple Likert-style survey items can be used to measure science aspiration as a construct. Chemers, Zurbriggen, Syed, Goza, and Bearman (2011) used seven survey items to measure the construct of science aspiration. Cundiff, Vescio, Loken, and Lo (2013) used three items to measure the science aspirations of college students: "how likely it will be for them to major in science," "how likely it will be for them to pursue graduate work in science," and "how likely it will be for their eventual career to directly pertain to science." Together, the survey items can account for a broader view of what counts as a science career, and how individuals may choose to participate in science or STEM careers. For instance, note the language differences, "a job that uses science" is different from "becoming a scientist" or working in "scientific research." The first item is inclusive of applied science careers, while the second two are not.

In other cases, the direct expression of desiring to hold a STEM or science career may be referred to as science aspiration. For example, a student may respond “scientist” to a question about what career they hope to have in the future. Findings involving both STEM career interest as indicated by a direct expressed desire, and science aspiration measured as a construct, are relevant to this study and are included in this literature review. However, based on the work of Dewitt et al. (2010, 2014) there is not always a direct correlation between having high science aspirations as measured by a construct and aspiring to have a career in science. Thus, in this study *science aspiration* indicates a construct measured by survey items, while *STEM career interest* indicates express desire to hold a STEM career; and the concepts are treated distinctly.

Trends. Wong's (2015) work indicates that underrepresented racial/ethnic minority students may aspire to applied science careers rather than research science careers at higher rates due to the stereotype that scientists are typically White men. This is congruent with other studies that indicate while some students enjoy science, they may be less likely to envision themselves as a scientist in the future (DeWitt et al., 2010).

It has been shown that students as young as 10 display positive attitudes toward science and science careers, but these attitudes become more negative over time, with marked declines in middle school, and during the transition from high school to college (DeWitt & Archer, 2015). Additionally, Aschbacher et al. (2010) found that only 45% of their 33 participants retained their initial science, engineering, or medical career interest from tenth to twelfth grade.

Large-scale longitudinal studies have shown that students' career aspirations in the early high school years have a strong association with later participation in the indicated career (Croll, 2008; Tai, Liu, Maltese, & Fan, 2006). Considering the underrepresentation of racial/ethnic minorities and women when compared to White males in science/STEM careers (Blickenstaff, 2006; Estrada et al., 2016), it is especially important to understand science career intentions and aspirations over time for different gender and racial/ethnic groups.

Logically, if students are to attain a STEM or science career they must first aspire at some level to a STEM or science career. Previous research shows that student science aspirations are connected to structural factors such as gender (Turner & Lapan, 2005), race/ethnicity (Strand & Winston, 2008), and class (Archer et al., 2014; St. Clair & Benjamin, 2011), as well as familial attitudes toward science (Archer et al., 2012) and school science experiences (Aschbacher et al., 2010). Ellis, Fosdick, and Rasmussen (2016) cite many of these same factors, including demographics, school science experiences and quality, as well as some additional factors such as early STEM interest, identity, and student support in college, as being specifically linked to STEM college and career persistence. However, upon examination of more recent studies, these trends are not always straightforward. For instance, attitudes toward school science and parental attitudes toward science don't necessarily translate to science career aspiration (DeWitt & Archer, 2015). Further, White males, although well-represented in STEM careers, often don't report higher science aspirations when compared to other gender and racial groups (DeWitt & Archer, 2015; St. Clair & Benjamin, 2011). Thus, although it is evident that the investigation of student science aspirations is important, the trends elucidated by previous research require further investigation and clarification.

Gender trends. Most studies, including a number of large-scale studies, some of which are longitudinal (Archer & DeWitt, 2016; Mann, Legewie, & DiPrete, 2015; Schoon, Ross, & Martin, 2007; Webb, Lubinski, & Benbow, 2002), report that a greater percentage of males than females aspire to a science career. In one study, slightly more males than females moved away from their science, engineering, or math career aspirations during high school, but this was based on a small sample size of students (Aschbacher et al., 2010).

Race/ethnicity trends. Trends when regarding race and ethnicity aren't as clear across studies, especially when considering the unique experience that results from the intersectionality of race, gender, and class. For instance, DeWitt and Archer (2015) found Asian students, Black students, and students identifying as "other" races have higher science aspirations than their White counterparts. Aschbacher et al. (2010) found that amongst the racial/ethnic designations Asian students reported the highest aspirations, but when considering race and gender together, African American girls were particularly likely to retain their science aspirations. Riegle-Crumb, Moore, and Ramos-Wada (2010) found eighth-grade Black and Hispanic males have equal levels of science aspiration when compared to White males. However, White females, Black females, and Hispanic females all reported lower science aspirations than White males.

Factors Associated with High Aspiration/Interest

Attitudes toward science and educational experiences. Archer and DeWitt (2016) found that positive student attitudes toward science are related to high science aspirations. Engaging school science experiences, which are closely related to student attitudes toward school science, are also identified in studies as related to science aspirations (Schoon et al., 2007). In fact, one set of researchers found that enjoyment of science was particularly impactful on the science aspirations of White and Hispanic female students (Riegle-Crumb et al., 2010). Other factors associated with positive educational experiences, such as support and mentoring from teachers and professors, as well as access to quality high-school level science instruction, are important to the development and maintenance of student science aspirations (Chemers et al., 2011; Sahin, Gulacar, & Stuessy, 2015; Webb et al., 2002).

Science and academic identification. Science identity and academic identity are clearly linked to the development and maintenance of science aspirations, particularly for women and underrepresented minority students (Chang et al., 2011; Chemers et al., 2011). Science identity is how students see themselves, and how they believe others perceive them as they participate in scientific endeavors (Aschbacher et al., 2010). Student academic identity is "the appropriation of academic values and practices within a sense of self, reflecting the willingness and commitment to the practices of the academic community" (White & Lowenthal, 2011). Science self-efficacy, or confidence in one's ability to do science, which is closely related to science identity, has also been shown to be related to science aspirations (Chemers et al., 2011). Achievement, which can be considered related to, albeit not equivalent, to the performance, competence and recognition components of Carlone and Johnson's (2007) science identity framework, was found to be particularly important to science aspirations in the work of Riegle-Crumb et al. (2010).

Participation in out-of-school science/STEM experiences. Out-of-school (OST) science/STEM programs have the potential to provide engaging and in-depth science experiences for youth participants, which may in turn spark early interest in science (National Research Council, 2015). Children who are engaged in science at a young age have a much greater chance of ultimately entering a science career, especially in engineering and the physical sciences (Dabney et al., 2012; Maltese & Tai, 2010; Tai et al., 2006). OST programs provide spaces for children to explore and actualize career aspirations, and many are important in narrowing opportunity gaps as some provide enriching and unique experiences to youth of all socio-economic backgrounds (Deutsch, 2019). Research evidence shows that over 60% of OST programs positively impact youth in areas such as attendance, math and science achievement, and graduation and promotion rates, as based on the most rigorous standards set by the Every Student Succeeds Act (Deutsch, 2019; Neild, Wilson, & McClanahan, 2019). OST programs which include a science component present an avenue to engage a population of girls who may not seek-out science activities specifically, as girls attend OST programs at the same rate as boys (Afterschool Alliance, 2015).

There is a body of literature supporting the long-term impacts of science OST programs on girls' engagement with science and eventual participation in science careers.

In fact, Dabney et al. (2012) found participation in STEM OST activities, as well as middle school interest and gender, was related to interest in STEM careers at the university level. Krishnamurthi, Ballard, and Noam (2014) conducted a meta-analysis of the outcomes of 11 STEM out-of-school programs that intentionally recruit and serve underserved youth in high need communities and have a reputation for excellence. Overall, Krishnamurthi et al. (2014) found the programs help youth: “(a) develop an interest in STEM and related activities, (b) develop a capacity to productively engage in STEM learning activities, and (c) come to value the goals of STEM and STEM learning activities" (p. 11).

McCreedy and Dierking (2013) used qualitative data to examine the long-term impacts of four STEM OST programs designed specifically for girls in a retrospective study using interviews, questionnaires, and personal stories of adult alumnae. Although McCreedy and Dierking did identify long-term impacts of STEM OST programs, including the importance of STEM experiences in personal life narratives, and that informal STEM experiences led to some participants to developing positive relationships with science, they also reported a continued tension in girls’ identification with science.

Although there is clear evidence that links OST science programs with positive student outcomes, there is a great diversity of programs and implementation practices throughout the country, and our understanding of science OST programs and impacts remains incomplete. The National Research Council’s (NRC) 2015 report, *Identifying and Supporting Productive STEM Programs in Out-of-School Settings,* highlighted the incompleteness of evidence about out-of-school program outcomes and impacts. The gaps in the literature are due at least in part to the particular challenges of studying out-of-school programs. These challenges include the following: (1) implementers rarely, by design, give their participants tests; (2) many experiences are short term, making it difficult to isolate program effects; and (3) much of the existing data are collected at the program level rather than the individual level. As a result, few studies follow students over time to demonstrate potential long-term effects, and therefore more longitudinal and long-term studies are needed. Despite these challenges, a number of studies have linked participation in OST activities with long-term engagement with science (NRC, 2015).

Overall, although there is evidence of the positive impacts of OST science programs, there are additional challenges to carrying out long-term studies that evaluate the impacts of the programs after students graduate high school. Thus, there is a need for more longitudinal studies that employ a comparison group and track participants after high school. This study helps to fill that need.

Science capital. Finally, in their longitudinal large-scale study of the science aspirations of youth in the UK, Archer and DeWitt (2016) identify science capital as the most important factor predicting science aspirations. According to Archer and DeWitt, science capital is more important than the often identified factors of negative views of school science and scientists. The authors identify science capital as the "cultural, social, symbolic resources a person has at their disposal…notably the resources that enhance attainment, engagement, and participation in science" (p. 12). Science capital includes social (e.g., science social networks, knowing science professionals), cultural (e.g. scientific knowledge and skills, science literacy), and economic (e.g. funds to purchase STEM materials and experiences) resources. It should be noted this concept of science capital overlaps with many other previously identified factors that are important to science aspirations.

In their study, DeWitt and Archer (2015) also found that science interest and aspirations are high across gender, class, and race/ethnicity amongst the many youth in their study. The barrier for most youth is not aspiring to a science career, but rather being able to identify with science to the point of believing that science is for them, and that a science career is open to them (DeWitt et al., 2014). Thus, policies aimed at "raising aspirations" of youth, especially those from lower socioeconomic classes or particular racial/ethnic groups, is based on a deficit viewpoint and misguided.

Factors that Inhibit Aspiration/Interest

Most of the factors identified in the body of science aspiration research as inhibitive to maintaining and carrying out science career aspirations are related to the White male image, paradigm, and culture of science, which serves to exclude people who are not White males. For instance, Chang et al. (2011) found that racialized experiences in college negatively impacted the science aspirations of underrepresented minority students. Archer and DeWitt (2016) posited that the brainy image of science and scientists turns many students off from science, especially girls, working class students, and Black students. Cundiff et al. (2013) discovered that female undergraduate students who reported higher gender science stereotypes (male superiority in science) reported lower science aspirations. The opposite effect was reported for males who held higher stereotypical beliefs, especially highly gender-identified males, who reported higher science aspirations. In their cross-national study, Mann et al. (2015) found a negative impact of a national culture of gender stereotyping and STEM aspirations. Finally, Wong

(2015) attributes the low aspirations for science research careers of underrepresented minority youth to the perception of science as a White male middle class pursuit.

Theoretical Framework

Science identity theory informs this study. Science identity theory is under the larger umbrella of identity theory. The process of identity development is closely connected with the process of choosing a career path, and more specifically, developing a science identity is connected to developing science career aspirations. A body of work on *critical moments* and *critical turnings* connects identity work with career decisions (Lykkegaard & Ulricksen, 2019). Increasingly, research on science/STEM career decisions has been based on science identity theory, as students' career choices and expectations are intertwined with the process of identity development (Holmegaard, Madsen, & Ulriksen, 2014).

Science identity has been connected to science persistence, engagement, interest, learning, motivation, and commitment (Aschbacher et al., 2010; Calabrese Barton & Yang, 2000; Carlone & Johnson, 2007; Chang et al., 2011; Chemers et al., 2011; Hazari et al., 2013; Osborne & Walker, 2006; Steinke, 2017; Syed, Azmitia, & Cooper, 2011). Furthermore, in their qualitative analysis, Lykkegaard and Ulriksen (2019) found evidence of links between identity formation and career decisions.

Identity theory provides a lens through which to critique the existing dominant culture and norms of science (Calabrese Barton, 1998), and strive for more equitable science education and workplace environments (Carlone & Johnson, 2007). An identity lens is well suited for the examination of the representation gap that affects women and historically underserved racial/ethnic minorities (Herrera, Hurtado, Garcia, & Gasiewski, 2012).

Definitions of science identity. Aschbacher et al. (2010) draw upon the work of Brickhouse (2001) and describe science identity as a teacher's sense of who the students are, what they are capable of, and who they aim to become in regards to science. Aschbacher et al. (2010) further describe science identity as how the students see themselves and how they believe others perceive them as they participate in scientific endeavors. This is very similar to Trujillo and Tanner (2014), who describe science identity as "the extent to which a person is recognized or recognizes himself or herself as a 'science person'" (p. 13). Hazari et al. (2013) take their science identity definition, "how students think science is related to who they think they are," from the work of Brickhouse et al. (2000, p. 443), and also describe science identity as perceptions of one's self as a scientist. Together, these definitions of science identity highlight how a person perceives themselves, and how others perceive them, in relation to science.

Theoretical foundation of science identity. Science identity development has been a focal area in science education research for over 20 years, with Brickhouse, Lowery, and Schultz calling for more science identity research in 2000. Attention to science identity development is particularly important when striving for equitable representation of people who are underrepresented and/or historically underserved and excluded in the sciences (Brickhouse et al. 2000; Brickhouse & Potter, 2001; Carlone & Johnson, 2007; Chang et al., 2011; Tan, Calabrese Barton, Kang, & O'Neill, 2013; Young, Feille, & Young, 2017).

Identity. Science identity is a concept that is embedded within the broader theory of identity. Many researchers draw their understanding of science identity from the work on identity of Lave and Wenger (1991), Wenger (1998), and Gee (2000). The work of Lave and Wenger (1991) connects the process of identity formation to the process of learning, and situates the process in the context of learning communities which have their own practices, values, language and norms (Aschbacher et al., 2010). As students engage in the practices of a learning community, they form identities-in-practice, which are related to who they are, who they can be, and who they want to be; and are mediated by the norms of the learning community (Tan et al., 2013). Wenger's (1998) work highlights the notion that although identity formation is a process of coming to be that it is individual, it is influenced by and constrained by societal structures. The work of Gee (2000) also informs several important science identity studies (Carlone & Johnson 2007; Hazari et al., 2013), and describes identity as being "recognized as a certain 'kind of person' in a given context" (p.99). Gee (2000) notes that a person's identity is in fact composed of multiple identities which are based both on social performances, as well as a person's unique being; and are changeable, context-dependent, and connected to "historical, institutional, and sociocultural forces" (p. 100).

Overall, these frameworks of identity situate science identity as being fluid and malleable, multidimensional, context-specific, and formed by internal, external, social, societal, and institutional forces. People may have more than one science identity, and these may be particular to different social and science contexts. For instance, science identities can be particular to school science (or even the particular science class or discipline) or out-of-school science contexts. Science identity is influenced both by how the student views themselves and how others see them in relation to science. As science is a human endeavor and subject to social forces and biases, science identity is connected to an individual's social identities such as gender, socioeconomic class, and race/ethnicity; as well as related power structures (Aschbacher et al., 2010; Brickhouse et al. 2000; Brickhouse & Potter 2001; Calabrese Barton & Yang, 2000). The science identity lens allows us to "ask questions about the kinds of people promoted and marginalized by science teaching and learning practices…" and "aids in the quest for a more equitable science education" (Carlone & Johnson, 2007, p. 1189).

Models of science identity. Carlone and Johnson (2007) described a model of science identity that has informed countless science identity studies (e.g., Kane, 2011; Young et al., 2017). This model identifies three dimensions of science identity—competence, performance, and recognition. According to Carlone and Johnson (2007), someone with a strong science identity would rate themselves and be rated by others highly in these three dimensions. *Competence* includes knowledge and understanding of science content, *performance* includes social performances of relevant scientific practices such as communication and using tools, and *recognition* includes recognizing oneself and getting recognized by others as a "science person."

Herrera et al. (2012) expanded this model in their work. In their study, they confirmed the importance of the recognition from others, but included self-recognition, or agency, in the definition of recognition. They also identified multiple contexts in which STEM identity is developed (e.g., societal, non-STEM, and STEM), stressed the intersectionality of STEM and racial/ethnic identities, and acknowledged that specific disciplines within STEM have their own norms and practices, that in turn affect the identity development process.

Critical moments or turnings. The idea of critical moments is useful in investigating the underlying experiences that lead to career decisions and connects the process of identity formation to the outcome of career decisions. Lykkegaard and Ulriksen (2019) use the concept of critical turnings as "a productive lens for understanding students' reflections concerning their educational trajectories and the identity work included in these reflections", and they recognize transition and choice processes as complex and a "process of identity formation and maintenance" (p. 1603). These choices, such as career choices, involve much more than arriving at a decision point (e.g., choosing a college major) and making a decision. They define critical moments as "an event described in an interview that either the researcher or the interviewee sees as having important consequences for their lives and identities" (Thomson et al., 2002, p. 339).

The theory of critical moments highlights the tie between the process of identity formation and career decision-making, as well as the individual and varied nature of the experiences that lead to identity formation. This highlights the need to consider the overlapping and interacting identities of individuals, such as gender, race/ethnicity, and science identity when examining the career decision making. The connection between critical moments and identity formation guided the design of this study; and will also inform future work focused on understanding the individual experiences of participants at the time of career decisions/transitions through analysis of linked participant interviews.

Science aspiration and identity. Science aspiration refers to a student's "future expectations or visions about working in science" (Du & Wong, 2019). The concept can also be called STEM aspiration and be applied to the broader area of STEM. Science aspiration is a multifaceted and complex concept. Indeed, DeWitt and Archer (2015) describe the development of science aspirations as a complex process involving a "tangled interweaving of identities and inequalities of gender, ethnicity and social class" that shape both the possibility and desirability of science in children's lives (p. 151). This complexity must certainly affect observed trends, especially around structural factors such as gender, socioeconomic class, and race/ethnicity.

For example, in their large-scale survey study of underrepresented minority (URM) students majoring in biomedical or behavioral science fields, Chang et al. (2011) found that negative racial experiences hinder the rate of undergraduate major persistence, whereas domain identification (e.g., science identity) enhances persistence. Similarly, in their survey study of undergraduate and graduate students, Chemers et al. (2011) reported a significant relationship between identity as a scientist and commitment to science careers.

Researchers have recognized a being/doing divide, which means that students may enjoy doing science, but don't see themselves as having the resources or ability to pursue a science career, or as the type of person who engages in science (DeWitt et al., 2014). For instance, one study found that while science aspirations of 12- and 13-year-olds were high regardless of gender and race/ethnicity, students with lower socioeconomic status were less likely to believe that they would obtain their desired career (St. Clair & Benjamin, 2011). Another study found that the most common reason for students to opt out of post-compulsory science courses in high school was that they were unable to picture themselves as scientists (Lyons & Quinn, 2010). Thus, the items used to measure science aspiration, as well as the wording of the items, will affect the observed trends of student science aspiration. This is especially true when examining trends based on structural variables such as race/ethnicity, class, and gender, with known associated structured inequities.

Science aspirations have been shown to be affected by one's ability to imagine themselves as a scientist or working in a science field, which highlights the inherent connection between science aspirations and science identity. Appropriately, many science aspiration studies are rooted firmly in science identity theory (Aschbacher et al., 2010; DeWitt & Archer, 2015; Wong, 2015). Science identity development is both an individual and social process; these processes are impacted by societal norms and perceptions of others, and thus it is expected that science aspirations will interact with, but not be predicted by social identities such as gender, race/ethnicity, and class.

Studies show that students who leave the sciences are not less talented or competent than those who stay but are less likely to identify with the culture of science (Tobias, 1990; Trujillo & Tanner, 2014), or to be recognized by peers and mentors (Carlone & Johnson, 2007). The culture of science includes the use of specific language and procedures (Lemke, 1990), “values, beliefs, and genres of discourse” (Brown, 2004), and curriculum. The culture of science is enacted in K-12 and higher education classrooms, as well as professional STEM environments. Many studies have shown that it can be a more difficult process for students and professionals who are underrepresented in the sciences to recognize and balance both their personal and scientific academic identity (Brickhouse, 1994, 2001; Brown, 2004; Calabrese Barton et al., 2008).

Osborne and Walker (2006) found in their sample of high school students that students of color who are more invested in school and more highly academically identified are at greater risk of withdrawal from school, while this coupled effect was not observed for their White peers. The authors posit that highly academically invested students of color are more affected by bias and stereotype threat (Osborne & Walker, 2006). Overall, research clearly indicates that eventual science career outcomes of underrepresented gender and racial/ethnic groups are impeded *not* by low aspirations, achievement, academic investment, or familial expectations, but by systemic racial bias and the exclusionary dominant culture of science (Dewitt et al., 2010; DeWitt & Archer, 2015; National Science Foundation, 2014).

Exclusionary science environments affect the participation of non-White male student participation during K-12, undergraduate, and graduate educational experiences, and then also in professional environments. Science is a discipline and tradition centered around a White male paradigm (Brickhouse, 2001; Calabrese Barton, 1998; Carlone & Johnson, 2007; DeWitt et al., 2010); when compounded with low concentrations of female and racial/ethnic minority role-models and other systematic societal factors, this can create significant barriers for aspiring scientists who are not White males in terms of aligning their social identities with a science identity recognized and validated by others in the science community (Archer et al., 2013; Calabrese Barton et al., 2008; Carlone & Johnson, 2007). Additionally, the dominant culture and norms of science may make non-

White male students less likely to *want* to be part of a science community of practice (Brickhouse & Potter, 2001).

In their large-scale longitudinal mixed-methods study, Archer and DeWitt (2016) found that girls must do more identity work to reconcile their identities with the masculine nature of science. Even when girls and especially girls of color demonstrate high science achievement on benchmarks such as tests, science identity development can be difficult (Tan et al., 2013). Although women and girls of color identify with and engage with science in diverse meaningful ways, their science identities are often less likely to be legitimized in a formal school science environment (Brickhouse et al., 2000; Brickhouse & Potter, 2001; Calabrese Barton et al., 2008).

The underrepresentation of women and certain racial/ethnic groups in STEM fields is a complex issue with no simple explanations or remedies, but the importance of science and STEM identity development have received increasing attention in recent years as a lens through which to better understand the problem. In fact, some researchers consider science or STEM identity the most promising and comprehensive lens through which to investigate students' movement and persistence through the K-12 and higher education science/STEM pipeline (Brickhouse et al., 2000; Carlone & Johnson, 2007; Herrera et al., 2012).

Summary. In this study, I investigate how post-secondary students' STEM career interests and science career aspirations change over time, and what factors they may be related to. Previous identity and science identity research supports the notion that student career choices and expectations are intertwined with the process of identity development (Holmegaard et al., 2014). The two studies that have most strongly informed this study were also grounded in identity theory (DeWitt et al., 2010; Lykkegaard & Ulriksen, 2019). The work of Lykkegaard and Ulriksen (2019) was also informed by critical moments/turnings research, which connects the process of identity formation to the outcome of career decisions.

Identity theory posits that identity is a complex and context-dependent process. Individuals can develop a science identity in part through participating in communities of practice. The culture and practice of science is based on a White male paradigm, and research supports the idea that the development of a positive science identity is at least partially dependent on participation and recognition within the science community. In the science community, there are certain norms and practices, including whether or not a young person is recognized in the science community, which impact whether he or she is likely to see themselves as having a future career in science. These processes of identity-formation and recognition are interwoven with racial/ethnic and gender identity. With these considerations in mind, throughout the study I will investigate the connection between race/ethnicity and gender with STEM career interest and science aspirations. This focus is consistent with science identity research that connects recognition and participation in science communities of practice to science identity formation. Science identity theory connects racial/ethnic and gender identity to STEM career interest and science aspirations, and allows us to examine the representation gap of women and racial/ethnic minorities within the existing culture and structural inequities of science and science education.

The following research questions guide this study:

Research Questions

1. Was there an association between condition (SMA program completion), gender, socioeconomic class, or race/ethnicity, and the STEM career interests of participants in the five years after secondary school?
2. How stable was STEM career interest over three, four, and five year periods after secondary school? Did this stability vary by condition or gender?
3. How did field of STEM career interest vary by condition, gender, or race/ethnicity?
4. Did STEM career aspiration vary by year, condition, gender, race/ethnicity, socioeconomic class, or the interactions between these variables in the five years after post-secondary school?

CHAPTER 3

METHODOLOGY

Overall Study

This study is part of the larger National Science Foundation (NSF)-funded Developing Youth Project (DYP) five-year quasi-experimental sequential (Prinzie & Onghena, 2005) longitudinal mixed-methods study examining the effects of the Science Minors and Achievers (SMA) Program. The study has been reviewed by the Museum of Science and Industry, Chicago Institutional Review Board.

Study Design

Research question 1. In order to address the question "Was there an association between SMA program completion, gender, or race/ethnicity and the STEM career interests of participants in the five years after secondary school?", Chi-square and Fisher's exact test analyses were used to determine whether there is a statistically significant relationship between condition (SMA participants versus comparison group participants), gender, gender within condition, race/ethnicity, socioeconomic class, and STEM career interest.

Research question 2. Sankey diagrams were used to visualize how students move through three STEM career interest categories during three, four, and five year post-secondary intervals. Only data from participants with a complete set of responses for the time interval in question were included in the Sankey diagrams. The diagrams were constructed for overall participants, as well as by gender and condition (program participation), and helped to visualize how participant career interest changed (or not) over time, and how this was related to gender and condition. Percentages of how many times participants changed categories of STEM career interest, when participants changed career interest category, and which trajectories were most common by condition, gender, and gender within condition, were also used to elucidate movement between career categories over time.

Research question 3. In order to answer the question “How did field of STEM career interest vary by condition, gender, or race/ethnicity?” participant distribution in STEM career categories, pie charts, and Chi-square/Fisher’s exact test analysis were used to compare condition, gender and race/ethnicity groups.

Research question 4. Mixed-effect modeling was used to assess whether “STEM career aspirations varied by year, condition, gender, race/ethnicity, or the interactions between these variables in the five years after post-secondary school?” The model included condition, gender, race/ethnicity, and socioeconomic class as independent variables, and STEM career aspiration (a composite variable based on four Likert-style survey items), as the dependent variable.

Science Minors and Achievers Program

The Museum of Science Industry (MSI), Chicago, houses a youth development program called the Science Minors and Achievers (SMA) program. Most interested youth applicants are accepted into the Science Minors program. The cost of the program is free to youth. Participants are eligible for the program starting at 14 years of age, but can begin at a later age. The participants who have consistent attendance and complete service hours at the museum progress through tiered stages of the program. About 30 to

40 youth begin the program as a cohort, and there are usually three 10-week sessions (consisting of 10 full Saturdays) a year. Thus, roughly 140 youth enter the program in a given calendar year. Once they complete the 10-week Science Minors youth development program, they then move on to the "In-betweeners" stage during which they complete 10 additional service hours, which renders them eligible for the Science Achievers program. The staff have found these required 10 service hours to be instrumental for confidence building before moving on to the Achievers program, which requires more initiative, responsibility, and leadership. There is no time limit during which the youth must complete their service hours, so Minors progress into the Achievers program at different points, resulting in varying sizes of Achievers' cohorts. The average program participant is active in the program for 2.6 years.

When participants move on to the Achievers program, they begin to wear lab coats just as other museum staff do, and are given museum I.D. badges; thus, they are indistinguishable from other museum staff. These intentional outward changes in the youth's appearance are designed to mirror changes in their agency, responsibility, ownership and independence as they progress through the program. Most Science Minors (85% to 90%) move on to the Science Achievers program. Thus, I refer to both the Science Minors and Science Achievers programs as the Science Minors and Achievers (SMA) program. Participants graduate from the program upon their high school graduation. The youth celebrate their graduation from the program with a party and a gift of a laptop. Many of the youth return as paid summer interns after completing the program.

SMA Program Features

Positive youth development framework. The SMA program is based on a positive youth development (PYD) framework. PYD focuses on youth assets rather than deficits, and is based on an understanding that human development is elastic, and that the different levels of ecological settings that individuals inhabit (e.g., home, school and community) should be considered when studying development (Lerner, Phelps, Forman, & Bowers, 2009). PYD programs honor the connections between the different spaces and contexts the youth are moving through, with a focus on building relationships and a sense of community within the program, and connecting the world of the program with other parts of the participant's life (Catalano, Berglund, Ryan, Lonczak, & Hawkins, 2004; Lerner et al., 2009). Furthermore, a PYD program focuses on developing the youth themselves across a range of developmental skills and competencies, rather than following a novice-to-expert advancement model within a single discipline. In other words, the focus is on developing important life skills and competencies that will benefit the youth regardless of eventual career choice.

Staff and youth relationships. The Science Minors and Achievers (SMA) program has many unique characteristics. First, strong relationships between staff and youth are privileged. The youth are supported in their college and/or career searches, and in some cases the relationships between youth and staff continue beyond the duration of the program. Price, Kares, Segovia, and Brittian Loyd (2019) analyzed SMA participant interviews and found that relationships between youth and staff were particularly important for those identifying as young women, and were connected to an increase in STEM career interest during the program. A later analysis of SMA participant interviews also found relationships between the youth and staff emerged as one of the five features of the program that youth identified as important and impactful (Mroczkowski, Price, Harris, & Skeeles-Worley, 2021). The other four features of the SMA program which emerged as impactful for youth were: (1) the scaffolded program structure with increasing autonomy over time, (2) a positive peer culture, (3) meaningful opportunities and experiences, and (4) a sense of belonging (Mroczkowski et al., 2021).

Horizontal design. Also based on a tenet of the PYD framework, the project is designed horizontally rather than vertically, meaning that the aim is to support the youth in their intellectual, social, and emotional development, across a range of contexts (e.g., home, society, the classroom, identity and discourse), ultimately supporting not just science knowledge and skills, but life and career skills. Horizontal design has been shown to be particularly effective in STEM programs for girls due to the importance that girls place on being part of the scientific learning community (Calabrese Barton et al., 2008). To this end, leadership and communication skills are privileged in the programming. This focus of the program aligns well with the highly interactive work at MSI, as employees with improvisation and performance backgrounds are purposely recruited, and the youth perform for and educate guests as Achievers.

Connection to science identity. Although the SMA program is first and foremost a youth development program, it is also a science program designed to support the development of a positive science identity. Racial, ethnic, and gender identities, and the intersectionality between and among these identities, are important factors in identity development (Brickhouse, 2001; Calabrese Barton et al., 2008; McCreedy & Dierking, 2013; Williams & Deutsch, 2016). This is especially true when considering science identity development, as both females and underserved minorities are likely to experience barriers to forming a strong science identity. Possible barriers include historical exclusion, stereotype threat, lack of role models, lack of meaningful recognition by others, and outright discrimination (Brickhouse, 2001; Calabrese Barton et al., 2008; Carlone & Johnson, 2007; McCreedy & Dierking, 2013). Science identity development matters when considering engagement with and participation and persistence in science (Herrera et al., 2012).

The MSI SMA program staff aim to create connections across varied contexts such as home, school, and out-of-school contexts. This connection is especially important for the science identity development of girls and young women, and even more so for girls and young women in urban underserved schools who may experience more dissonance between their school or program identities and their home or community identities (Calabrese Barton et al., 2008). For many students, learning science is as much about being a participant and feeling accepted in a science learning community as it is about mastery of the content (Calabrese Barton et al., 2008; Carlone & Johnson, 2007; Strayhorn, 2015). Based on sociocultural theory and Bronfenbrenner's ecology theory of development (1979), if students can connect their knowledge from multiple contexts, such as their home life, their school life, and out-of-school environments, then this will potentially support their engagement with a science learning community and support science identity development (Calabrese Barton et al., 2008, Krishnamurthi et al., 2014).

The program is designed to support youth development, and more specifically career aspirations, competencies, and identity development. However, as it is a program covering STEM content that is housed in a science museum, the program would be expected to not only attract youth who are interested in science, but also support science identity development and science career aspirations. Thus, this study aims to examine the participants' relationship with science (including school science experiences, science self-concept, and views of scientists), as well as science aspirations.

Participants

Recruitment. The study is quasi-experimental, as participants are divided into SMA program participants and comparison group participants from the same age group who did not participate in the SMA program. The comparison group allows for important comparisons, and there is a need for more studies investigating the outcomes of STEM OST programs using comparison groups (Krishnamurthi et al., 2014). The youth participants were not assigned to the SMA participant group and the comparison group randomly. It was decided upon discussion with the program and museum staff that random selection was not in line with the values and goals of the program, as students from underserved racial/ethnic groups and students with established family connections were specifically recruited for the program. One of the unique and impactful features of the SMA program are the strong relationships that are built between the staff and the youth participants as well as their families (Price et al., 2019). These relationships are often strengthened through sibling participation and long-term family involvement and investment in the program.

All participants voluntarily consented to take part in this study. The youth are from diverse racial/ethnic backgrounds, schools, and a variety of Chicago-area neighborhoods. Both SMA and comparison group participants were reimbursed for participation in the study. All participants in the SMA program were invited to take part in the study. Comparison group participants were recruited from local parks (cohort one) and the museum floor (cohorts two and three). Criteria for participant group recruitment included having finished their high school education, having not yet started a post-secondary educational program, and having visited a science museum within the prior year. Prior museum visitors would be more likely to enter the study with STEM interest, making them more similar to program participants.

The SMA program draws from the wider Chicago area, as some students opted to drive up to an hour to the museum for the program. Based on provided zipcodes, a small number of the comparison group participants are from other areas in the United States. After the first year of the project (cohort one), researchers noted that the comparison group was composed of a much higher percentage of participants identifying as White, and a corresponding lower percentage of participants identifying as non-White. Therefore, in the second year of the study, participants with non-White racial/ethnic identities were purposefully recruited to the comparison group so that future comparisons between the two groups would be more meaningful.

In total, there were 63 SMA group participants and 165 comparison group participants, for a total of 228 participants. A small number of participants provided only their names and emails but did not respond to any survey questions, so their data was not included.

School. Most participants attended public school in the Chicago area, but a variety of types of school backgrounds, including home-schooling, were represented in the participant pool. Although students who were at least partially home-schooled made-up a small portion of the total participants (6%), there was a higher percentage of students who were at least partially home-schooled in the SMA group compared to the comparison group (12% of SMA group, 4% of comparison group).

Age. The participants in the SMA program range in age from 14 to 18 years old. The survey data analyzed in this study were collected from the participants starting in their last year of high school upon completion of the program; thus, the mean age of the participants is 18 in year one, 19 in year two, 20 in year three, 21 in year four, and 22 in year five.

Gender. The participants identified as 56% female, 43% male and 1% non-binary or transgender (Table 3-1). One participant (<1%) opted not to report their gender identity. Males and females were represented nearly equally in the SMA group (48% males; 51% females), with a comparatively higher percentage of females (59%) to males (41%) in the comparison group (Table 3-1), which matches the demographics of visitors at this museum. A similar percentage of individuals identify as non-binary or transgender in the SMA and comparison groups (2% and 1% respectfully).

Table 3-1
Gender of Participants (n=227)

Gender	% of Total Sample	% of SMA Group	% of Comparison Group
Male	43	48	41
Female	56	51	59
Nonbinary	1	2	1

Race/Ethnicity. Participants were asked to select as many racial/ethnic identities as apply to them. When all chosen categories were reported separately, which results in a cumulative percentage of 116, 47% of the participants reported as identifying as White, 32% as Hispanic/Latinx, 21% as Black/African American, 11% Asian, 1% Middle Eastern, 3% American Indian/Alaskan Native, and 1% as a race/ethnicity that was not listed (Table 3-2). About 16% of participants indicated more than one racial/ethnic category, resulting in an additional 11 unique racial/ethnic identities represented in the sample (Figure 3-1 & Figure 3-2). Of these, the most common was a Latinx/Hispanic and White identity, representing six percent of the total sample (Figure 3-2).

The SMA group has a smaller proportion of Hispanic/Latinx participants (25% compared to 35%) but a larger proportion of Black/African American participants (34% compared to 17%) compared to the comparison group (Table 3-2 & Figure 3-3).

Table 3-2
Race/Ethnicity of Participants with All Participant Choices Counted

Race/Ethnicity	% of Sample	% of SMA	% of Comparison
White	47	53	46
Hispanic/Latinx	32	25	35
Black/African American	21	34	17
Asian	11	13	11
Middle Eastern	1	4	1
American Indian/Alaskan Native	3	4	3
Hawaiian/Pacific Islander	0	0	0
Race/Ethnicity not Listed	1	0	2

Note. Participants were able to choose more than one category, so the sum of the percentages is over 100%

Figure 3-1. Racial/Ethnic Composition of Sample

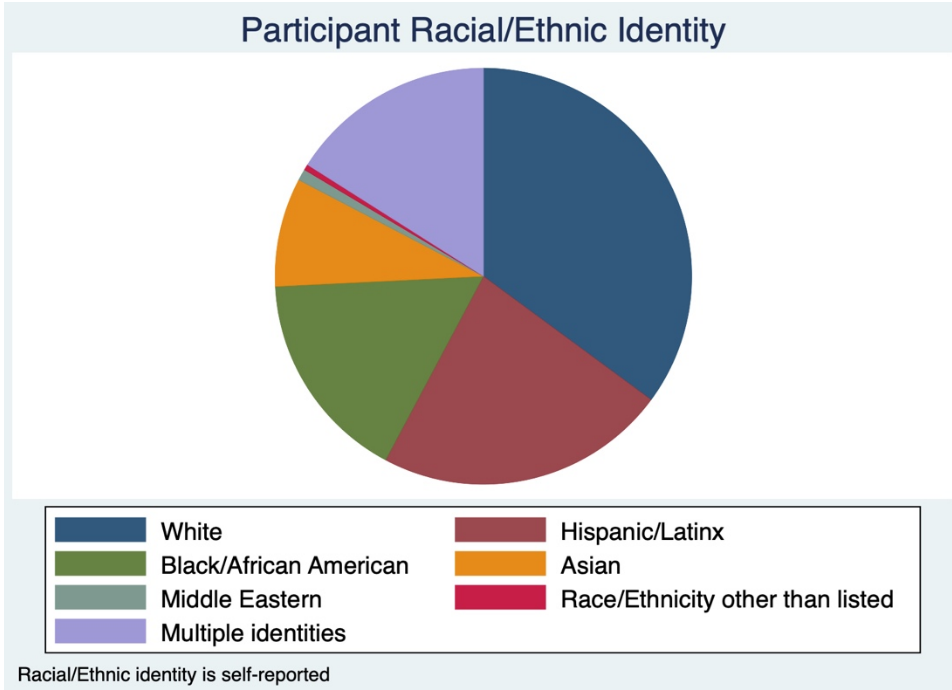


Figure 3-2. Racial/Ethnic Composition of Sample Including Combined Identities

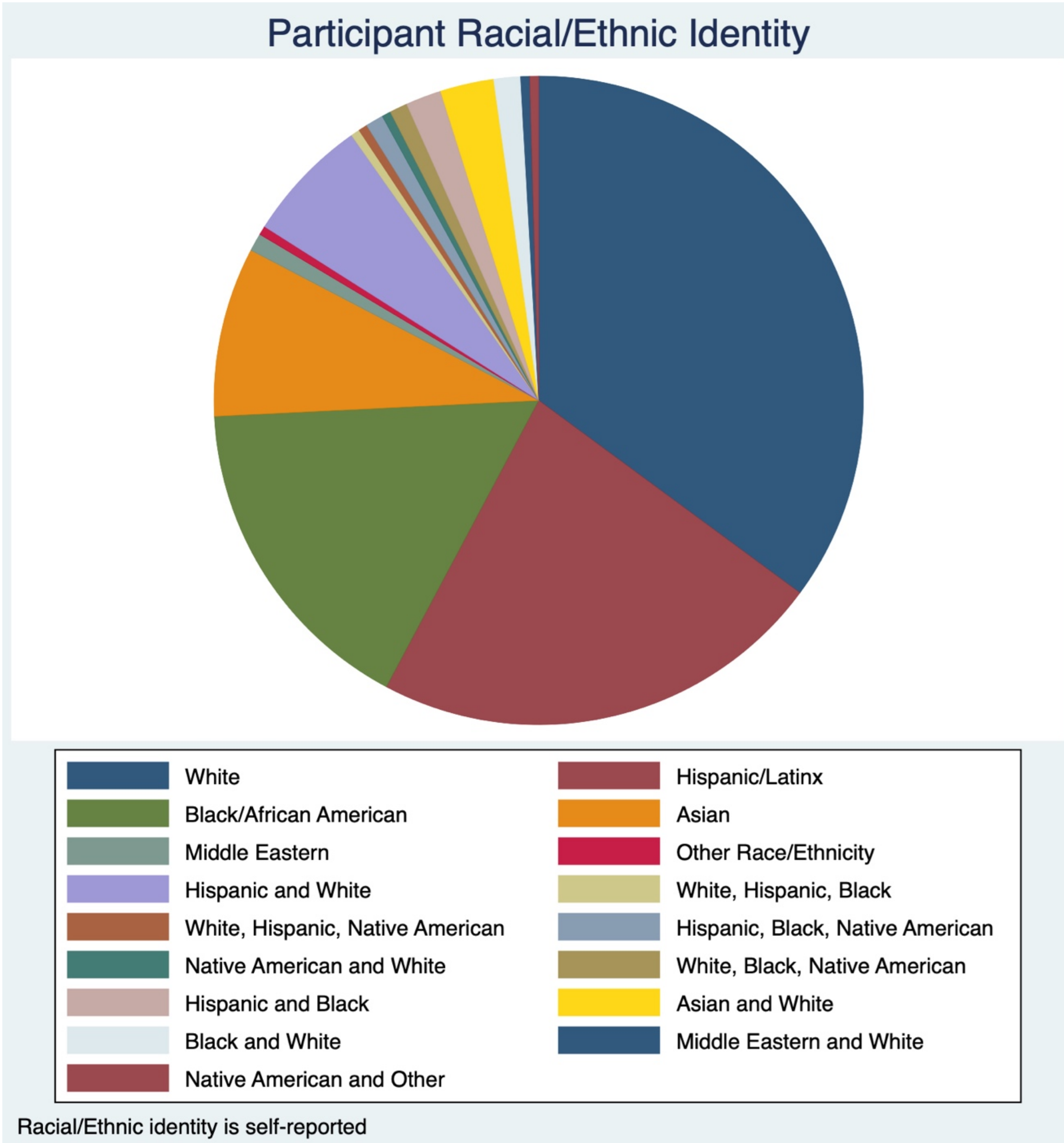
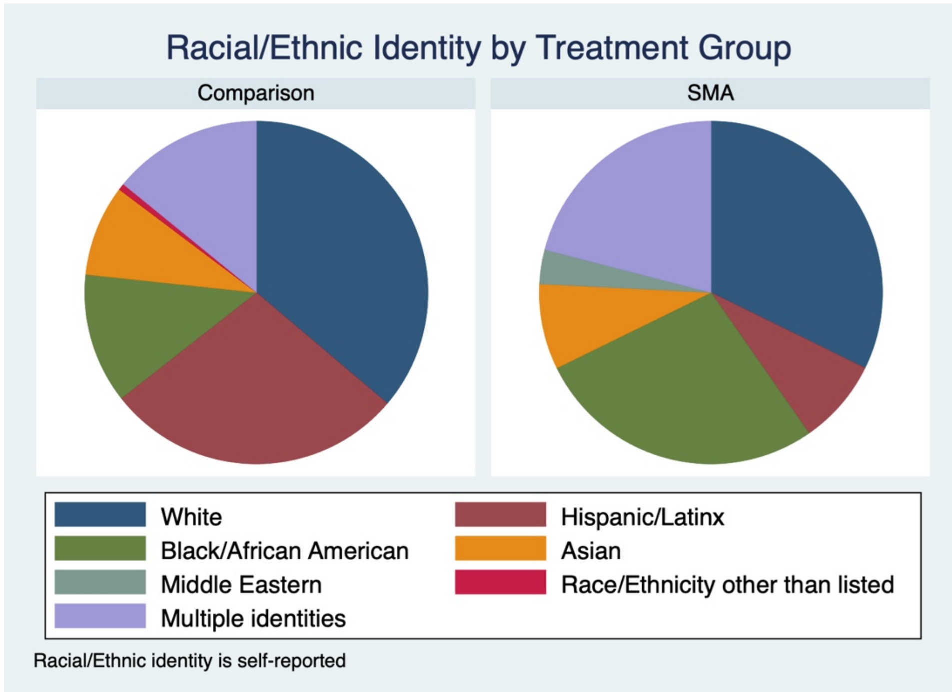


Figure 3-3. Racial/Ethnic Composition of SMA and Comparison Groups



Socioeconomic class. Overall, 71% of the participants were identified as having at least one indicator of socioeconomic disadvantage (Table 3-3). Possible indicators were based on parent/guardian education level, median income level and healthcare worker shortage level within their zipcode, and rurality of home zipcode. Income levels and rurality were based on provided zipcodes the Health and Resources and Services Administration (HRSA).

Although the comparison group had a slightly higher percentage of participants with indication of a background of socioeconomic disadvantage (73% compared to 67% in the SMA group), the proportions across the two groups were quite similar (Table 3-3).

Table 3-3.
Percentage of participants with indicators of a background of socioeconomic disadvantage

Socioeconomic Disadvantage	Total Sample %	SMA %	Comparison %
Yes	71	67	73
No	29	33	27

High School Course Grades. The majority of both SMA and comparison group participants earned an A or B in their highest-level science, math, and English high school courses. However, the SMA group did have higher course marks overall with 100% of participants earning an A or B in science, 91% in math, and 98% in English compared to 89% (science), 80% (math), and 92% (English) in the comparison group (Table 3-4; Figure 3-4). While there is certainly some difference between the two groups in high school grades (ranging from 11 to 6 percent difference earning As or Bs), the majority of participants in both groups earned high grades during high school.

Overall, the SMA and Comparison groups were not assigned randomly and there are some observable demographic differences between the two groups. However, an examination of the type of school attended, age, gender, race/ethnicity, socioeconomic disadvantage indicators, and high school grades of the participants did not elucidate any stark differences between the two groups. Therefore, while observed differences between the two groups cannot be directly attributed to participation in the SMA program, they can provide evidence of program impacts.

Table 3-4.
Percentage of participants in SMA and Comparison groups earning each letter grade in their most advanced high school science, math, and English courses.

	Science		Math		English	
Grade	SMA	Comparison	SMA	Comparison	SMA	Comparison
A	76	54	59	39	75	57
B	24	35	32	41	23	36
C		9	7	15	2	6
D		2	2	4		1

Note. 3% of participants did not report a science grade, 4% did not report a math grade, and 6% did not report an English grade.

Figure 3-4. Participant Science, Math, and English High School Grades

Figure 3-4. Percentage of each letter grade earned in highest level (a) science, (b) math, and (c) English high school courses by participants in comparison and SMA groups.

Data Collection

Surveys. Survey data was collected by the Museum of Science and Industry, Chicago, research and evaluation team. SMA program participants and comparison group participants were surveyed annually in three cohorts over five waves starting in the late Spring/Summer of 2016. Survey development was led by the Museum of Science and Industry, Chicago, research and evaluation team with input from Dr. Robert Tai, myself, and their project advisory board. It is composed of both original questions and items adapted from existing instruments, and covers topics such as attitudes toward science, experience learning science in high school and college classrooms, self-concept in science, aspirations in science, interest in science outside of school, positive and negative images of scientists, and career interest/choice.

The participants completed the survey for the first time after they graduated from their senior year of high school and before they began their post-secondary education or career, and then each consecutive spring/summer during the study. Survey data collection started for cohort one in 2016, for cohort two in 2017, and for cohort three in 2018 (Table 3-5). The study has thus far spanned five years, and therefore there have been five waves of data collection. Therefore, there are five years of data for cohort one, four years of data for cohort two, and three years of data for cohort three (Table 3-5). Data collection for the overall project is ongoing.

For this study, the data from each cohort will be collapsed into year one, year two, year three, year four, and year five data. Thus, the year refers to the same age or developmental stage for the participants, but not the same calendar year. For example, year one data were collected in 2016 for cohort one and in 2017 for cohort two, but directly after high school graduation for both cohorts (Table 3-5). Actual calendar years are referred to as waves; e.g., wave two data were collected in 2017 for cohorts one and two, but yield year one data for cohort two and year two data for cohort three (Table 3-5). This way, yearly sample sizes are bolstered, and longitudinal analyses can elucidate trends as young adults move from high school into college and careers at the same developmental stages.

Table 3-5
Survey Data Collection Timeline by Cohort and Data Collection Wave

Year	2016	2017	2018	2019	2020
Wave	1	2	3	4	5
Cohort 1	Year 1	Year 2	Year 3	Year 4	Year 5
Cohort 2		Year 1	Year 2	Year 3	Year 4
Cohort 3			Year 1	Year 2	Year 3

The survey is composed of a variety of open- and close-ended questions, as well as background questions. There are about 100 questions total on the survey, with small necessary modifications made for the comparison versus SMA surveys and the year one, year two, year three, year four, and year five surveys. Some questions were added and dropped in later years of the survey after preliminary analysis of the survey data. Participants varied quite a bit in the time they took to complete the survey, but the average duration is about 30 minutes. SMA group participants were compensated with a $45 Amazon gift card and comparison group participants were compensated with a $90 Amazon gift card (the rate was higher to reflect that traditionally comparison groups have higher attrition rates in longitudinal studies).

In consecutive years, participants were contacted using a variety of methods including email, text, and social media (Staus, et al., 2021). Across cohorts, annual retention rates varied between 76% and 100% (Table 3-6). Year to year participant retention rates were high for both the SMA and comparison groups (Table 3-6). Across treatment groups over the course of the entire study, cohort one had a retention rate of 77% from year one to year five, cohort two a rate of 80% from year one to year four, and cohort three a rate of 80% from year one to year three (Table 3-6). The exact number of participant survey responses collected by year, Cohort, and treatment group are found in Table 3-7.

Table 3-6
Retention rates by Cohort, Treatment Group, and Year

	Year 1 to 2	Year 2 to 3	Year 3 to 4	Year 4 to 5	Total
SMA Group					
Cohort 1	117%[a]	95%	90%	94%	*94%*
Cohort 2	89%	88%	93%		*74%*
Cohort 3	91%	90%			*82%*
Average	*93%* [a]	*91%*	*92%*		
Comparison Group					
Cohort 1	76%	100%	94%	87%	*62%*
Cohort 2	90%	98%	93%		*82%*
Cohort 3	90%	88%			*79%*
Average	*85%*	*95%*	*94%*		
Overall					
Cohort 1	95%	97%	92%	91%	*77%*
Cohort 2	90%	96%	93%		*80%*
Cohort 3	91%	88%			*80%*
Average	*92%*	*94%*	*93%*		

Note. Number of Participants from the SMA group who took the survey in Cohort 1 actually increased from year one to year two

[a] Used a percentage of 100% for Cohort 1 rather than 117% to calculate the year 1-2 average retention across cohorts

Table 3-7

Number of Completed Surveys by Cohort, Treatment Group, and Year

SMA Group	Year 1	Year 2	Year 3	Year 4	Year 5
Cohort 1	18	21	20	18	17
Cohort 2	19	17	15	14	
Cohort 3	22	20	18		
Total	*59*	*58*	*53*	*32*	*17*
Comparison Group					
Cohort 1	21	16	16	15	13
Cohort 2	68	61	60	56	
Cohort 3	73	66	58		
Total	*162*	*143*	*134*	*71*	*13*

Measures

Dependent variables. In this study three outcome variables were examined. STEM career interest is a three-level categorical variable and was the object of research questions one and two. STEM career type is also a categorical variable originally composed of 12 levels but collapsed to five for some analyses in research question two. Science aspiration is a mean composite variable constructed using four Likert-style survey items.

STEM career interest. One way to assess science/STEM career interest is to have respondents report their desired career, and then categorize the career into various categories (Mann et al., 2015; Schoon et al., 2007). This method was followed in this study. The item "What career(s) are you most interested in having?" was used to code each participant's response as a STEM career, a non-STEM career, unsure/undecided, or not enough information to categorize. During analysis the latter two categories (unsure/undecided and not enough information) were collapsed into a single “undecided” category. I initially coded each career, but then reviewed the designations with other research team members.

STEM career type. The open-ended responses of participants who indicated STEM career interest in the survey question "What career(s) are you most interested in having?" were classified as one of 12 categories: (1) computer science/technology, (2) engineering, (3) health, (4) social sciences/psychology, (5) research scientist, (6) natural resources/agriculture/environmental education, (7) architecture/planning/design, (8) financial analysis/accounting/economics, (9) math or science teacher, (10) mathematician, (11) electrician, and (12) not enough information.

Categories were established through open-coding and examination of participant responses, but were also informed by literature, especially studies addressing STEM field gender and race/ethnicity trends (Sadler, Sonnert, Hazari, & Tai, 2012). During certain analyses, such as Sankey diagrams and Chi-square tests, the four most prevalent categories were retained and the other seven were collapsed into an "other" category. This resulted in a variable with five levels: (1) computer science, (2) engineering, (3) health, (4) research scientist, and (5) other. Computer science, engineering, health, and research scientist accounted for 84%, 88%, 85%, and 86% of reported STEM careers in years one, two, three, and four respectively (Table 3-8). All other career categories accounted for five percent or less of reported careers (Table 3-8). When those who reported STEM-career interest were further subdivided into subcategories sample size was quite low. Sample sizes were too low in year five for meaningful analysis. In fact, most analyses for research question three focused on years one to three due to higher sample sizes of subgroups.

The decision to collapse the less commonly reported STEM careers was due to sample size and meaningfulness of interpretations. For instance, the Sankey diagram constructed to show movement in and out of types of STEM careers showed movement in and out of seven categories (including non-STEM interest and undecided). If all STEM career types were included there would be 14 categories which would result in a Sankey diagram too noisy for meaningful interpretation. The Chi-square test is sensitive to sample size, and when too many subcategories are included there is not adequate expected cell sample size for meaningful interpretation of results.

Table 3-8
Percentage of Reported STEM Career Categories

	Year 1	Year 2	Year 3	Year 4
Computer Science	16.3	13.8	19.8	17.2
Engineering	25.6	24.8	23.4	19
Health	33.3	39.5	33.3	36.2
Research Scientist	8.5	10.1	8.1	13.8
Social Sciences	2.3	1.8	3.6	1.7
Natural Resources	2.3	3.7	4.5	3.5
Architecture/Planning	1.6		1	
Financial Analysis	3.9	2.8	3.6	
Data Science			2.7	5.2
Math/Science Teacher	1.6	1.9		
Mathematician	3.1	1.9		
Electrician	1			1.7
Not Enough Information	1			1.7

Science aspiration. The science aspirations construct was developed by DeWitt et al. (2010) through the use of theory, literature, and the modification of existing instruments. DeWitt et al. (2010) established the reliability and validity of the construct through discussion groups with students, piloting, principal components analysis (PCA), and measures of Cronbach's alpha (DeWitt et al., 2010). The science aspiration variable is mean composite score using four Likert-style items (Table 3-9). The Cronbach's alpha value of the science aspiration construct amongst our study sample was quite high, ranging from 0.90 to 0.92 across the five years of responses.

It is important to check the reliability of constructs in sample subgroups such as gender and race/ethnicity (Weinburgh & Steele, 2000). The reliability of the construct in our sample was also high across the five years for subgroups within condition, gender, race/ethnicity, and socioeconomic class, with the majority of values 0.90 or above, and a total range from 0.74 to 0.99. An exception was the Asian group in year four (0.57). Researchers have pointed out that the "Asian" racial/ethnic category masks considerable within group heterogeneity (Yoshikawa et al., 2016), and indeed researchers have shown how science aspirations vary for specific Asian groups (Wong, 2015). While this reliability score was not low enough to be cause for concern in this study, especially when considering the scores as a whole, it does point to potential for further inquiry into the categorization and exploration of racial/ethnic categories in regards to science aspirations, particularly in the Asian category.

Table 3-9.
Items included in science aspiration construct

Construct	**Survey items**
Aspirations in Science	*I would like to study science in the future* *I would like to have a job that uses science in the future* *I would like to become a scientist* *I think I could be a good scientist one day*

Note. From DeWitt et al. (2010)

Independent and background variables. The association of condition and gender with the outcome variables was investigated in all research questions, racial/ethnic identity was included in research questions one, three, and four, and socioeconomic class was included in the analyses for research questions one and four.

Condition. Participants either participated in the SMA program and were thus part of the treatment, or SMA group, or were recruited as part of the comparison group. Condition is a binary variable and is composed of two mutually exclusive categories.

Gender. Reflecting that gender is certainly not binary, or restricted to male and female, we asked participants to report their gender using an open-ended item ("What is your gender?"). We then coded their responses into three categories, male, female, and non-binary or transgender. There were not enough individuals reporting as non-binary or transgender to analyze their career aspirations as a group. Gender identity is fluid and changeable, and thus the most recently reported gender identity was used in the analysis. For example, if a participant reports as "male" in year 1 but "non-binary" in year four, they are recorded as "non-binary" in the analysis.

Race/Ethnicity. Participants chose all racial/ethnic categories that applied from the following categories: (1) White, (2) Hispanic/Latinx, (3) Black/African American, (4) Asian, (5) American Indian/Native American, (6) Middle Eastern, (7) Hawaiian/Pacific Islander, (8) Other race ethnicity, and (9) Prefer not to answer. The American Indian/Native American, Middle Eastern, Hawaiian/Pacific Islander, and combined racial/ethnic identity categories were not included in the mixed effects model analysis due to small sample sizes.

Socioeconomic class. Socioeconomic status has been shown to be correlated with educational outcomes such as the likelihood of receiving a bachelor's degree and choosing a STEM major (Lauer, 2019; Niu, 2017). Furthermore, a low socioeconomic background has been shown to present barriers to success even amongst full-time professors (Lauer, 2019; Nature, 2016).

The National Institute of Health (NIH) recently expanded their definition of socioeconomic disadvantage beyond income level with the aim to be more inclusive and diversify the field of biomedical science (Lauer, 2019). The NIH found that their previous guideline of a household income of $25,750 or less was "extraordinarily narrow" and only captured 1% of investigators on diversity supplement applications (Lauer, 2019). Thus, they proposed using seven indicators (Table 3-10; those who meet two criteria qualify as SES disadvantaged) to better capture scientists with a background of SES disadvantage and diversify the biomedical research workforce (Lauer, 2019).

Of the NIH's seven new indicators, three were available in this study: (1) have/had no parents or guardians who have completed a bachelor's degree, (2) are from a rural area as designated by the HRSA, and (3) are from an area designated as a low-income and health professional shortage area by HRSA (Table 3-10). Since only three indicators were available, and two of those indicators came from the same indirect measure (zip code), a background of socioeconomic disadvantage was indicated when one criterion was met. This resulted in a binary SES variable indicating evidence of socioeconomic disadvantage or no socioeconomic disadvantage. Participants reported their parent/guardians' highest level of education in the survey. Reported zip codes were used to determine if participants were from an area designated as a low-income/health worker shortage or rural area using HRSA data.

Table 3-10.
Updated NIH Socioeconomic Disadvantage Indicators

	Used in Study	Updated NIH SES Disadvantage Indicators
1		Were or currently are homeless
2		Were or currently are in the foster care system
3		Were eligible for the federal free and reduced lunch program
4	Yes	Have/had no parents or legal guardians who completed a bachelor's degree
5		Were or currently are eligible for Federal Pell grants
6	Yes	Received support from the Special Supplemental Nutrition Program for Women, Infants, and Children as a parent or a child
7	Yes	Grew up in one of the following areas: a) a U.S. rural area, or b) a Centers for Medicare and Medicaid Services-designated Low-Income and Health Professional Shortage Areas

Note. From Lauer (2019)

Analysis

STEM career interest coding. The open-ended survey question asking participants "What is your most desired career?" was used to create a STEM career interest variable for each year of the survey (years one to five). The careers listed by participants could be coded as non-STEM (0), STEM (1), unsure or undecided (2), or not enough information to determine (3).

To determine whether to code a career as “STEM” or “non-STEM”, I began with the NSF list of approved STEM careers (Appendix A). We noted that medical/healthcare careers and game design were not included in this list. We discussed this as a research team and reached consensus that medical and health careers should be coded as STEM careers, especially considering they are likely excluded from the NSF list due to research study funding purposes (according to statute, research funding in medical fields is the domain of the NIH rather than NSF). Some would use the classification of STEMM (science, technology, engineering, mathematics, and medicine) to indicate that health and medicine careers are included, but for simplicity STEM will be used throughout. We also decided as a team that digital game design should be included as a segment of computer science.

In addition, the research team decided to include applied STEM careers in the STEM career category. Including applied careers makes logical sense as technology and engineering are applied fields and included in STEM. The decision was also based on the belief that multiple types of knowledge and paths to knowledge, for example, lived experience, formal learning/education, and practical knowledge, have equal credibility and value. Some examples of applied careers from this study are electrician, accountant, science/math teacher, and agricultural technology.

I initially coded the career responses and then provided a list of the coded careers to the rest of the research team to review. I highlighted the careers I struggled to categorize for special attention. The other research team members, which included multiple established science education researchers, reviewed the coded careers. The team then discussed any disagreements and reached consensus on how to code the careers in question. I checked for consistency in coding across the five waves of data, as the responses were coded at different times. Appendix B contains examples of careers the research team had trouble coding as STEM or non-STEM, and the conclusions they reached as a team. It should be noted that some participant responses included additional information that helped the research team determine which category to place them in. For example, one participant responded "game development, focus in art". Although we would normally code game development or design as "STEM (1)" we coded this particular response as "non-STEM (0)" since the participant provided the additional information that they planned to focus on the artistic element of game design.

When initial efforts yielded some inconsistencies across coders, we realized that the inconsistencies were largely due to how responses listing multiple careers were coded. We decided that those who listed multiple careers, all of which were STEM careers, would be coded as having STEM career interest (1). Those who listed multiple careers, all of which were non-STEM careers, were coded as not having STEM career interest (0). Those who listed a mix of STEM and non-STEM careers would be coded as unsure (2). For instance, a participant response listing both doctor and engineer would be coded as STEM career interest (1), while a combined response of artist and business owner would be coded as non-STEM career interest (0). However, a response of both artist and engineer from the same participant would be designated as unsure (2). Participants who listed very general careers without enough information to place their desired career into a category were coded as not giving enough information (3). An example of a response coded as “not enough information” is “something with animals and kids.”

During the fifth wave of data collection (year five for cohort one, year four for cohort two, and year three for cohort one), the question “do you consider this (your desired career) a STEM career?” was added to the survey. I checked my coded responses against participant responses and found 15% disagreement. The most common areas of disagreement were participants interested in healthcare/medicine marking their careers as "non-STEM" and conversely other participants marking business careers as "STEM." While these responses added clarity to a small number of participant responses, I did not use them to modify the coding method overall since this information was not available for all responses.

The lines between "STEM" and "non-STEM" careers are not concrete and are subject to interpretation. Therefore, the process of categorizing careers utilized in this study has inherent limitations, and is subject to researcher background and biases. However, the same group of researchers completed the coding across the five waves of data using the same process, so this method is consistent and robust enough to examine how participants move within and to and from categories over time in this study.

Sankey diagrams. Sankey diagrams, which are commonly used in the field of thermodynamics to show energy flow, have also been found to be useful to visualize student pathways over time (Askinadze, Liebeck, & Conrad, 2019; Heileman, Babbitt, & Abdallah, 2015; Lykkegaard & Ulriksen, 2019; Morse, 2014; Sadler et al., 2012). The Sankey diagrams in this study contain the categories "STEM Career Interest", "Non-STEM Interest" and "Undecided" in blue, red, and gray respectively. At each time point and between time points bars of varying widths indicate the relative percentage of participants in a particular category or moving to another category. Stata and Microsoft Excel were used to calculate percentages of participants in each category at each time point and moving between categories between time points. The Sankey diagrams were constructed by hand in Microsoft Word.

Only participants with complete data (i.e., year one, year two, and year three responses for year one to year three diagrams) for a year range were used to construct Sankey diagrams, meaning they reflect a complete longitudinal view of how group members move between groups over a range of years. For instance, if a participant reported their desired career in year one and three, but not in year two, their data would not be included in the year one to year three Sankey diagram. This does mean that sample sizes used to construct the Sankey diagrams were lower, especially for year one to year five diagrams (Table 3-11). Further, note that the total number of participants with continuous survey data from year one to five at this point is only 24 (Table 3-11). This small sample size was considered during analysis and interpretation. For instance, Sankey diagrams in which participants were broken into much smaller subgroups, such as gender within treatment groups (research question 1) and STEM career type, were only constructed with year one to three data. Although based on lower sample sizes, the year one to five diagrams are important to include as they provide a longer-term picture of how career interests change during the critical transition period from adolescence into adulthood. As the larger study progresses the number of participants for whom year one to five data is available will continue to increase.

Table 3-11
Number of Participants with Complete Time Point Data for Years 1-3, Years 1-4, and Years 1-5

	SMA	Comparison	Total
Years 1-3	48	127	175
Years 1-4	27	65	92
Years 1-5	13	11	24

Note. Individuals can be in more than one category. For instance, an individual from Cohort 1 who has consecutive data for years 1-5 will also be listed as having complete data for Years 1-3 and 1-4

Chi-square/Fisher's exact test. The Chi-square test of independence, also known as the Pearson Chi-square test (McHugh, 2013), was used to determine whether there were statistically significant relationships between STEM career interest and condition (participation in the SMA program versus the comparison group), gender, gender within condition, socioeconomic background, and race/ethnicity groups (research question one). Chi-square analysis was also used to determine if there were relationships between condition, gender, and race/ethnicity and STEM career type (research question three).

The Chi-square null hypothesis is that groups are independent of one another, thus a significant result indicates that the null hypothesis was violated, and the groups, or two variables, are associated. The Chi-square test is a non-parametric test of significance that is flexible in terms data distribution and variable type/structure (McHugh, 2013). Chi-square analysis is based on the distribution of frequency data across groups, and thus aligns well with the Sankey diagrams used in this study that provide visualizations of the same patterns. Chi-square analysis allows for more than two-level groups, thus it was possible to consider three levels of the STEM career interest variable (yes, no, undecided) rather than two (yes, no). Although the Chi-square test is optimally used with randomly assigned data, it is also used frequently with non-randomly assigned samples, as is the case with the SMA and comparison group participants (McHugh, 2013).

The first main assumption of the Chi-square test is that all groups are independent of one another, or mutually exclusive, which was true for our data. Each participant is assigned only one condition group, one gender group, one SES designation, and one race/ethnicity group. This assumption, however, did result in some limitations to the Chi-square analysis. Since participants marked all racial/ethnic categories that pertained to them in the survey, participants who marked more than one racial/ethnic category were not considered using Chi-square analysis. Each combination of racial/ethnic identities results in a unique life experience, but sample size did not allow for them to be analyzed uniquely with this method at this time. In future research, subgroup sample sizes will be bolstered, and statistical tests which allow for membership in more than one category will be explored. The assumption of independence also means that Chi-square analysis cannot be used for a longitudinal analysis (McHugh, 2013), as repeated measures are related to one another.

The other main assumption of the Chi-square test is that at least 80% of cells have an expected value of five or more (Jeong & Lee, 2017; Kim, 2017; McHugh, 2013). Although the sample size assumption was met in nearly all cases, I opted to be conservative and run both the Chi-square test and Fisher's exact test due to the Chi-square test's sensitivity to sample size (Berge, 2015). Fisher's exact test is more accurate than the Chi-square test when the sample size assumption is not met, but is valid for any sample size (Kim, 2017), and some researchers recommend using Fisher's exact test any time sample size is less than 1,000 participants (McDonald, 2014). Since there is some disagreement about the guidelines of when to use the Chi-square test and when to use Fisher's exact test (Jeong & Lee, 2017; McDonald, 2014), the results of both tests were reported. Interpretation of the Chi-square and Fisher's exact test results aligned in all cases, in other words there were no cases in which the results of the Chi-square test indicated significance, but the results of the Fisher's exact test did not, or vice versa. This alignment adds confidence to the results.

Cramer's V is the most commonly used strength statistic with Chi-square analysis, and thus was used to interpret results (McHugh, 2013). I followed Kim's (2017) method to interpret Cramer's V values based on guidelines from Cohen (1988). It should be noted that the Cramer's V strength statistic sometimes yields low correlation values regardless of statistical significance, and that even weak correlation values can be meaningful if we do not expect the independent variable in question to be responsible for all variation in the dependent variable (McHugh, 2013).

Post-hoc pairwise comparisons should be carried out in cases where contingency tables are larger than 2x2, or in other words, at least one of the variables has more than two levels resulting in more than four cells (McDonald, 2014). The Fisher's exact approach for post-hoc analysis using the Bonferroni's and Holm-Bonferroni's correction was employed using the website developed by Shan and Gerstenberger (2017). Adjusted residuals were also examined to determine which pairwise comparisons held meaningful differences. Chi-square analyses, Fisher's exact tests, and post-hoc examination of adjusted residuals were done in Stata version 14.2 for Mac.

Mixed effect model. A mixed effect model was used to assess whether condition, gender, race/ethnicity, socioeconomic background, the interaction of condition and gender, and the interaction of gender and race, or year, predicted science aspirations. A mixed-effects model describes relationships between a response variable and covariates that are grouped according to classification factors, such as repeated measures on students (West, Welch, and Galecki, 2015). Mixed models are a flexible technique well-suited to use with repeated or longitudinal measures, as they allow for both fixed and random effects of variance (Seltman, 2009). Also, mixed models handle missing data well (Seltman, 2009). This was ideal given the sequential design resulting in differing numbers of repeated measures of science aspiration. Studentized residuals were examined to assure that the assumptions of normality, constant variance, and lack of outliers were met (West, Welch, and Galecki, 2006). The analysis was carried out in R.

CHAPTER 4

RESULTS

Research Question 1

Was there an association between condition, gender, race/ethnicity, or socioeconomic class and the STEM career interests of participants in the five years after secondary school?

Condition. Overall, between year one and year five there was a 13.4% percent decline in comparison participants who reported their most desired career to be a STEM career, while there was a 7.5% percent decline amongst SMA program participants (Table 4-1).

Results of the Chi-square and Fisher's exact analyses elucidated a statistically significant difference in SMA and comparison group participants' STEM career interests at an alpha level of 0.05 in year one (X^2 (2, N = 221) = 16.07, p =<0.001; Fisher's exact = <0.001, Cramer's V=0.30), year two (X^2 (2, N = 201) = 8.15, p =0.02; Fisher's exact = 0.01, Cramer's V=0.20), and year three (X^2 (2, N = 187) = 7.22, p =<0.03; Fisher's exact = <0.02, Cramer's V=0.20; Table 4-2). The effect sizes indicated a medium-large effect in year one, and medium effects in years two and three (Table 4-2; Table 4-3). SMA participants reported higher levels of STEM career interest and lower levels of non-STEM career interest compared to comparison participants (Table 4-1). Results did not show statistically significant differences between condition groups in years four and five.

Post hoc follow-up tests and examination of standardized residuals indicated specific areas of important group differences within these overall effects. In year one and year three comparison group participants were more likely to indicate non-STEM career interests and less likely to indicate STEM interests than expected. Conversely, SMA participants were less likely to indicate non-STEM career interests and more likely to indicate STEM career interests than expected. In year two comparison group participants were more likely to report non-STEM career interests; whilst SMA participants were less likely.

Table 4-1

Total Percentage of Participants with a STEM Career Interest at Each Study Time Point

	Year 1	Year 2	Year 3	Year 4	Year 5	Change Y1-Y5
SMA	Y-76.3% N-5.1% Un-18.6% (*n*=59)	Y-63.8% N-15.5% Un-20.7% (*n*=58)	Y-73.6% N-17.0% Un-9.4% (*n*=53)	Y-63.3% N-30.0% Un-6.7% (*n*=30)	Y-68.8% N-31.3% Un-0% (*n*=16)	ΔY = -7.5%
Comparison	Y-51.9% N-30.3% Un-17.9% (*n*=162)	Y-50.4% N-35.7% Un-14.0% (*n*=143)	Y-53.7% N-36.6% Un-9.7% (*n*=134)	Y-57.1% N-37.1% Un-5.7% (*n*=70)	Y-38.5% N-61.5% Un-0% (*n*=13)	ΔY = -13.4%

Note. Y = (YES) STEM Career Goal; N = (NO) No-STEM Career Goal; Un = Unsure, Undecided, or Unclear. Includes all available data.

Table 4-2.
STEM Career Interest Chi-square and Fisher's exact significant test results

Year 1	*df*	*N*	X^2	X^2 *p*-value	Fisher's *p*-value	Cramer's *V*
Condition	2	221	16.07	<0.001***	<0.001***	0.30[d]
Gender	2	219	8.61	0.01**	0.01**	0.20[c]
Gender within SMA	2	58	5.02	0.08	0.07	0.29[d]
Year 2						
Condition	2	201	8.15	0.02*	0.01**	0.20[c]
Race	8	198	14.00	0.08	0.08	0.19[d]
SES	2	198	5.08	0.08	0.08	0.16[b]
Year 3						
Condition	2	187	7.22	0.03*	0.02*	0.20[c]
Year 4						
Race	8	98	17.22	0.03*	0.01***	0.30[e]

Note. Only statistically significant or nearly statistically significant results are shown.
$^{*}p<0.05$, $^{**}p<0.01$, $^{***}p<0.001$
[a]small [b]small-medium [c]medium [d]medium-large [e]large

Table 4-3.
Guidelines for Interpreting Cramer's V Effect Size for Chi-Square and Fisher's Exact Test

Degrees of freedom	small	medium	large
1	0.10	0.30	0.50
2	0.07	0.21	0.35
3	0.06	0.17	0.29
4	0.05	0.15	0.25
5	0.04	0.13	0.22

Note. Adapted from Kim, H-Y. (2017). Statistical notes for clinical researchers: Chi-squared test and Fisher's exact test. *Restorative Dentistry and Endodontics, 42*(2), 152-155 and Cohen J. (1988). *Statistical power and analysis for the behavioral sciences.* 2nd ed. Hillsdale, NJ: Lawrence Erlbaum Associates.

Gender. Taken as a whole, there were 7% fewer males reporting STEM career interest in year five compared to year one, and 1% more females (Table 4-4). The two gender categories ended up at similar levels of STEM career interest in year five (males 60%; females 54%; Table 4-4). However, these figures are based on cross-sectional views of the participants with much fewer reports in year five due to the study design, and thus require further analysis.

There were significant differences in the STEM career interest responses of males and females in year one (X^2 (2, N = 219) = 8.61, p =<0.01; Fisher's exact = <0.01, Cramer's V=0.20; Table 4-2). Differences between males and females within the SMA condition group were nearly significant in the same year (X^2 (2, N = 58) = 5.02, p =0.08; Fisher's exact = 0.07, Cramer's V=0.29; Table 4-2; Table 4-5). Effect sizes indicated a medium effect of overall gender in year one and a medium-large effect of gender within the SMA group (Table 4-2; Table 4-3).

Post hoc tests indicated that in year one both overall and within the SMA program male participants were less likely to be undecided and females were more likely to be undecided, and that males were more likely to indicate STEM career interest and females were less likely to indicate STEM career interest than expected.

Table 4-4
STEM Career Interest by Female and Male Gender

	STEM Career Goal					
Gender	Year 1	Year 2	Year 3	Year 4	Year 5	Change Y1-Y5
Female	Y-52.9% N-25.2% Un-22.0% (*n*=123)	Y-53.8% N-28.6% Un-17.7% (*n*=119)	Y-58.7% N-33.0% Un-8.3% (*n*=109)	Y-63.3% N-30.0% Un-6.7% (*n*=60)	Y-53.9% N-46.2% Un-0% (*n*=13)	ΔY = +1%
Male	Y-66.7% N-24.0% Un-9.4% (*n*=96)	Y-55.0% N-30.0% Un-15.0% (*n*=80)	Y-65.8% N-27.6% Un-6.6% (*n*=76)	Y-59.0% N-38.5% Un-2.6% (*n*=39)	Y-60.0% N-40.0% Un-0% (*n*=15)	ΔY = -6.7%

Note. Y = (YES) STEM Career Goal; N = (NO) No-STEM Career Goal; Un = Unsure, Undecided, or Unclear

Table 4-5

STEM Career Interest by Female and Male Gender within Condition Group

		STEM Career Goal					
		Year 1	Year 2	Year 3	Year 4	Year 5	Change Y1-Y5
SMA	Female	Y-65.6% N-6.9% un-27.6% (*n*=29)	Y-59.4% N-15.6% Un-25.0% (*n*=32)	Y-70.4% N-22.2% Un-7.4% (*n*=27)	Y-66.7% N-26.7% Un-6.7% (*n*=15)	Y-60.0% N-40.0% Un-0% (*n*=5)	ΔY = -5.6%
	Male	Y-89.7% N-3.5% Un-6.9% (*n*=29)	Y-72.0% N-12.0% Un-16.0% (*n*=25)	Y-84% N-8% Un-8% (*n*=25)	Y-66.7% N-26.7% Un-6.7% (*n*=15)	Y-72.7% N-27.3% Un-0% (*n*=11)	ΔY = -17%
Comparison	Female	Y-48.9% N-30.9% Un-20.2% (*n*=94)	Y-51.7% N-33.3% Un-14.9% (*n*=87)	Y-54.9% N-36.6% Un-8.5% (*n*=82)	Y-62.2% N-31.1% Un-6.7% (*n*=45)	Y-50.0% N-50.0% Un-0% (*n*=8)	ΔY = +1.1%
	Male	Y-56.7% N-32.8% Un-10.5% (*n*=67)	Y-47.3% N-38.2% Un-14.5% (*n*=55)	Y-56.9% N-37.3% Un-5.9% (*n*=51)	Y-54.2% N-45.8% Un-0% (*n*=24)	Y-25.0% N-75.0% Un-0% (*n*=4)	ΔY = -31.7%

Note. Y = (YES) STEM Career Goal; N = (NO) No-STEM Career Goal; Un = Unsure, Undecided, or Unclear

Race/Ethnicity. When examining the racial/ethnic categories of White, Hispanic/Latinx, Black, and Asian, from year one to year three White participants reporting STEM career interest declined by 7%, Hispanic participants increased by 2%, Black participants decreased by 7%, and Asian participants increased by 14% (Table 4-6). There was not adequate sample size of the remaining racial/ethnic identities to examine STEM career interest meaningfully in this type of analysis. Although change from year one to year four is shown in Table 4-6, examination of sample sizes and size and direction of differences of percentages over year four and five indicate it is questionable to draw conclusions about year four and five career interests by race/ethnicity. The study is ongoing and there will be more data available in the future.

STEM career interest significantly varied across the racial/ethnic groups of White, Hispanic/Latinx, Black, and Asian in year four (X^2 (8, N = 98) = 17.22, p =0.03; Fisher's exact = 0.01, Cramer's V=0.30) and was nearly significant in year two (X^2 (8, N = 198) = 14, p =0.08; Fisher's exact = 0.08, Cramer's V=0.19; Table 4-2). Effect sizes indicated a medium-large effect in year two and a large effect in year four (Table 4-2; Table 4-3).

Post-hoc examination of residuals indicated that in year two White students reported non-STEM career interest more than expected, and Black participants indicated STEM career interest less often than expected. It should be noted, however, that these relationships were not indicated using the exact test with Bonferroni corrections, and the overall test was not significant at the 0.05 alpha level. In year four post-hoc tests indicated that Black participants were less likely to report STEM career interest than expected, and Asian participants were more likely. As previously mentioned, however, year four results must be treated cautiously due to very low sample sizes in most categories. Taken together, it seems while there may be some STEM career interest trends by racial/ethnic identity categories, they may be better elucidated by future quantitative analyses with additional data or finer scale qualitative analysis.

Table 4-6
STEM Career Interest by Race/Ethnicity

	STEM Career Goal						
	Year 1	Year 2	Year 3	Year 4	Year 5	Change Y1-Y3	Change Y1-Y4
White	Y-62% N-23% Un-14% (*n*=77)	Y-51% N-39% Un-10% (*n*=69)	Y-55% N-34% Un-11% (*n*=65)	Y-48% N-46% Un-7% (*n*=44)	Y-47% N-53% Un-0% (*n*=15)	ΔY = -7%	ΔY = -14%
Hispanic/Latinx	Y-55% N-22% Un-24% (*n*=51)	Y-57% N-22% Un-22% (*n*=46)	Y-57% N-31% Un-12% (*n*=42)	Y-79% N-14% Un-7% (*n=14*)	Y-50% N-50% Un-0% (*n*=2)	ΔY = +2%	ΔY = +24%
Black	Y-53% N-31% Un-17% (*n*=36)	Y-37% N-40% Un-23% (*n*=30)	Y-46% N-42% Un-13% (*n*=24)	Y-13% N-75% Un-13% (*n*=8)	Y-50% N-50% Un-0% (*n*=4)	ΔY = -7%	ΔY = -40%
Asian	Y-58% N-21% Un-21% (*n*=35)	Y-58% N-21% Un-9% (*n*=34)	Y-72% N-28% Un-0% (*n*=18)	Y-91% N-9% Un-0% (*n*=11)	Y-50% N-50% Un-0% (*n*=2)	ΔY = +14%	ΔY = +33%

Note. Y = (YES) STEM Career Goal; N = (NO) No-STEM Career Goal; Un = Unsure, Undecided, or Unclear

SES. A consistently higher percentage of participants without SES disadvantage indicators reported STEM career interest compared to participants with a SES disadvantage indicator (Table 4-7). Also, over the five years of the study the percentage of participants without SES disadvantage showed a 9% increase in STEM career interest from year one to year five, while those with SES disadvantage showed a 20% decrease (Table 4-7).

Year two was the only year in which the Chi-square/Fisher's exact test approached significance in STEM career interest by SES results (X^2 (2, N = 198) = 5.08, p =0.08; Fisher's exact = 0.08, Cramer's V=0.16; Table 4-2). The Cramer's V Effect size indicated a small-medium effect (Table 4-2; Table 4-3). Post-hoc examination of residuals showed those with no SES disadvantage reported STEM career interest more than expected in year two.

Table 4-7
STEM Career Interest by SES Disadvantage

	STEM Career Goal					
SES Disadvantage	Year 1	Year 2	Year 3	Year 4	Year 5	Change Y1-Y5
Yes	Y-56% N=26% Un-18% (n=153)	Y-49% N-33% Un-18% (*n*=139)	Y-55% N-34% Un-11% (*n*=126)	Y-55% N-37% Un-8% (*n*=60)	Y-36% N-64% Un-0% (*n*=14)	ΔY = -20%
No	Y-64% N-17% Un-19% (n=64)	Y-66% N-24% Un-10% (*n*=59)	Y-68% N-26% Un-5% (*n*=57)	Y-63% N-34% Un-3% (*n=38*)	Y-73% N-27% Un-0% (*n*=15)	ΔY = +9%

Note. Y = (YES) STEM Career Goal; N = (NO) No-STEM Career Goal; Un = Unsure, Undecided, or Unclear

Taken as a whole, the Chi-square and Fisher's test analyses indicated the most consistent differences in STEM career interest by condition. While there seemed to be some relationship between STEM career interest and gender, race, and SES, it was less consistently detectable using these techniques and requires additional analysis and consideration.

Research Question 2

How stable was STEM career interest over three, four, and five year periods after secondary school? Did this stability vary by condition or gender?

Overall transitions and trajectories. Across the subsamples of participants with continuous year one to year three (Y1Y3), year one to year four (Y1Y4), and year one to year five (Y1Y5) data, about half of the participants maintained the same area of interest over the entire interval (55%, Y1Y3; 53%, Y1Y4; 54%, Y1Y5), a moderate percentage of participants switched interest area once (32%, Y1Y3; 22%, Y1Y4; 17%, Y1Y5) or twice (13%, Y1Y3; 21%, Y1Y4; 29%, Y1Y5), and a very small number of participants switched three times (4%) in the Y1Y4 group (Table 4-8; Table 4-9; & Table 4-10).

Over Y1Y3, of the participants who changed category, they most frequently changed during the Y1Y2 transition (19%), although this is not a dramatically higher percentage than those who changed during Y2Y3, or during both Y1Y2 and Y2Y3 (13%; Table 4-11). During transition points, participants most frequently maintained a STEM or non-STEM career interest. A larger portion of participants moved out of STEM career interest (14%) during Y1Y2 than other transitions (7%, Y2Y3; 9%, Y3Y4), and the greatest frequency of movement into STEM career interest was seen during the Y2Y3 transition (Table 4-12). Figure 4-1 illustrates how each type of transition in Table 4-12 is depicted in the Sankey diagrams.

Finally, Table 4-13 shows the frequencies of participants in each possible overall career trajectory for each time interval. They are "overall" trajectories because they detail the categories in which participants begin and end the Y1Y3, Y1Y4, and Y1Y5 time intervals. Categories in which participants began and ended the time interval in the same category were also broken down to indicate percentages who stayed in the same category throughout (uninterrupted) or moved into another category at a midpoint. The total percentage of participants who started and ended the interval in the same career interest category (Y1Y3, 67%; Y1Y4, 71%; Y1Y5, 69%) was higher than those who started out and ended up in different career interest categories (Y1Y3, 33%; Y1Y4, 28%; Y1Y5, 30%; Table 4-13). However, even amongst the participants who began and ended an interval within the same category, some switching occurred in the middle of the intervals. For instance, in the Y1Y3 interval, 18% of those who began and ended with STEM career interest changed during a middle interval, 11% of those who began and ended with non-STEM career interest changed during a middle interval, and 75% of those who began and ended undecided changed during a middle interval (Table 4-13). Sankey diagrams nicely illustrated these mid-point changes.

Table 4-8.
Times Participants Switched Career Interest Category from Years 1 to Year 3

Number of Transitions	Overall	Treatment		Gender		SMA		Comparison	
		SMA	Comparison	Female	Male	Female	Male	Female	Male
	n=175	*n*=48	*n*=127	*n*=102	*n*=71	*n*=24	*n*=23	*n*=78	*n*=48
0	55%	52%	56%	49%	63%	38%	70%	53%	60%
1	32%	29%	33%	40%	20%	42%	13%	40%	23%
2	13%	19%	11%	11%	17%	21%	17%	8%	17%

Note. This data includes all participants in Cohort 1, 2, and 3 with data points Y1, Y2, and Y3. The maximum number of transitions during this time period is 2. The Career Interest Groups are STEM career interest, non-STEM career interest, or Unsure.

Table 4-9.
Times Participants Switched Career Interest Category from Years 1 to Year 4

Number of Transitions	Overall	Treatment		Gender		SMA		Comparison	
		SMA	Comparison	Female	Male	Female	Male	Female	Male
	n=92	*n*=27	*n*=65	*n*=53	*n*=38	*n*=13	*n*=14	*n*=40	*n*=24
0	53%	48%	55%	51%	55%	31%	64%	58%	50%
1	22%	15%	25%	25%	18%	23%	7%	25%	25%
2	21%	30%	17%	21%	21%	39%	21%	15%	21%
3	4%	7%	3%	4%	5%	8%	7%	3%	4%

Note. This data includes all participants in Cohort 1, 2, and 3 with data points Y1, Y2, Y3, and Y4. The maximum number of transitions during this time period is 3. The Career Interest Groups are STEM career interest, non-STEM career interest, or Unsure.

Table 4-10.
Times Participants Switched Career Interest Category from Years 1 to Year 5

Number of Transitions	Overall	Treatment		Gender	
		SMA	Comparison	Female	Male
	n=24	*n*=13	*n*=11	*n*=10	*n*=13
0	54%	54%	55%	30%	69%
1	17%	15%	18%	30%	8%
2	29%	31%	27%	40%	23%

Note. This data includes all participants in Cohort 1, 2, and 3 with data points Y1, Y2, Y3, Y4 and Y5. The maximum number of transitions during this time period is 4. However, there are no participants with 3 or 4 transitions in this group. The Career Interest Groups are STEM career interest, non-STEM career interest, or Unsure.

Table 4-11.
Percentage of Participant Transition at Specific Timepoints

Time of Transition	Overall	Treatment		Gender	
		SMA	Comparison	Female	Male
	n=175	*n*=48	*n*=127	*n*=102	*n*=71
None	55%	52%	56%	49%	63%
Y1Y2	19%	17%	21%	27%	9%
Y2Y3	13%	13%	13%	14%	11%
Y1Y2 & Y2Y3	13%	19%	11%	11%	17%

Figure 4-1. Possible Year to Year Trajectories and Simplified Categories

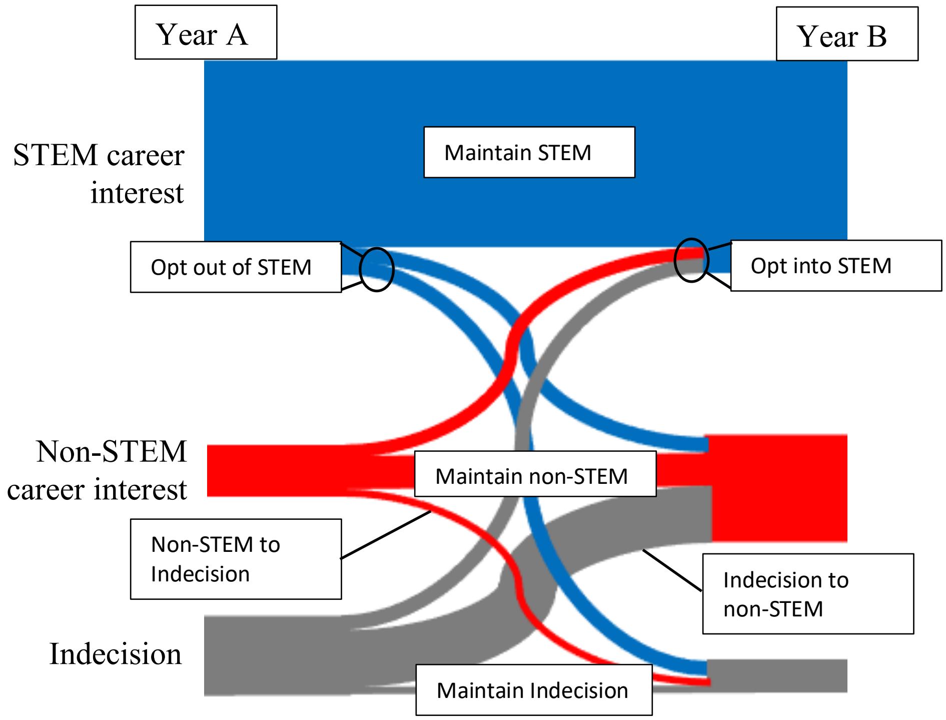


Table 4-12.

Percentages of Participants in each Transition Type during Yearly Intervals

	Y1Y2 (*n*=175)	Y2Y3 (*n*=175)	Y3Y4 (*n*=89)	Y4Y5 (*n*=23)
Maintain STEM	46%	47%	52%	48%
Opt-in to STEM	9%	13%	8%	4%
Opt-out of STEM	14%	7%	9%	
Maintain non-STEM	17%	25%	26%	48%
Non-STEM to Indecision	2%	3%	1%	
Maintain Indecision	5%	2%	1%	
Indecision to non-STEM	8%	2%	3%	

Note. Empty cells indicate that there were no participants in the category and time point.

Table 4-13.
Overall Trajectories

Trajectory	Sub-categories	Y1-Y3 *n* (%)	Y1-Y3 *Subcategory n (%)*	Y1-Y4 *n* (%)	Y1-Y4 *Subcategory n (%)*	Y1-Y5 *n* (%)	Y1-Y5 *Subcategory n (%)*
STEM to STEM		85 (49%)		46 (52%)		10 (43%)	
	Uninterrupted		*70 (82%)*		*34 (74%)*		*8 (80%)*
	Non-STEM interest at midpoint		*3 (4%)*				
	Unsure at midpoint		*12 (14%)*		*1 (2%)*		
	Mixed midpoint responses				*11 (23%)*		*2 (20%)*
STEM to non-STEM		13 (7%)		11(12%)		4 (17%)	
STEM to Unsure		6 (3%)		1 (1%)			
Non-STEM to non-STEM		28 (16%)		16 (18%)		6 (26%)	
	Uninterrupted		*25 (89%)*		*13 (81%)*		*5 (83%)*
	STEM interest at a midpoint		*2 (7%)*				
	Unsure at a midpoint		*1 (4%)*		*2 (13%)*		
	Mixed midpoint responses				*1 (6%)*		*1 (17%)*
Non-STEM to STEM		5 (3%)		3 (3%)		2 (9%)	
Non-STEM to Unsure		5 (3%)		2 (2%)			
Unsure to Unsure		4 (2%)		1 (1%)			
	Uninterrupted		*1 (25%)*				
	STEM interest at midpoint				*1 (100%)*		
	Non-STEM interest at midpoint		*3 (75%)*				
Unsure to STEM		15 (9%)		5 (6%)			
Unsure to non-STEM		14 (8%)		4 (4%)		1 (4%)	

Overall Sankey diagrams. Sankey diagrams help illustrate patterns of movement between categories of career interest over time. To depict change over time accurately only data from participants with data for all time points were included. Sankey diagrams for the intervals year one to three (Y1Y3), one to four (Y1Y4), and one to five (Y1Y5) were all constructed. The sample size is considerably higher for the Y1Y3 interval (n=175) as it includes collapsed data from cohorts one, two, and three. However, it is still important to examine the Y1Y4 interval (n=92) and the Y1Y5 year interval (n=24) since they cover a longer post-secondary time period. However, only the overall Y1Y5 diagram was included, as sample size was too small to draw meaningful conclusions when split across condition and gender groups.

Only diagrams from the same interval are comparable as they contain overlapping data from individuals. Y1Y3 contains individuals from all cohorts, Y1Y4 contains individuals from cohorts one and two, and Y1Y5 contains only cohort one individuals. Furthermore, the diversity of movements the diagrams show is likely impacted by sample size. The relative width of each line in the diagrams accurately reflects the percentage of the overall depicted subgroup.

Year 1 to 3. During the year one to year three interval (Y1Y3) the STEM and non-STEM interest categories were relatively stable, but the undecided category decreased over time (Figure 4-2). There was more movement from the STEM career category from year one to two (Y1Y2), which was the first year after high school, than from year two to year three (Y2Y3). Note the movement from STEM career interest into the undecided category during the Y1Y2 transition point, which was the first year of college/professional school/career. Movement out of the non-STEM career category was less than the movement from the STEM career category (although the STEM career category composed an overall higher percentage of participants) but was steady across the Y1Y2 Y2Y3 transition points. Likewise, movement out of the undecided category was considerable and consistent across both transition points (Figure 4-2).

Year 1 to 4. From Y1Y4 (Figure 4-3) again the STEM and non-STEM career interest categories were quite stable over the four years, yet this stability masks considerable movement that occurred between categories. In fact, when the overall trajectories of participants from Y1Y4 are quantified, even amongst participants who began and ended with STEM career interest, 26% switched to a different career interest category at time interval midpoints (Table 4-13). There was more overall movement out of the STEM career interest category during the Y1Y2 transition, and less movement out of the non-STEM category. The undecided category declined steadily over four years with more movement into STEM career interest than into non-STEM career interest.

Year 1 to 5. From Y1Y5 many of the same trends were evident, with overall STEM career interest declining, although not dramatically (61% to 52%), and non-STEM career interest increasing (35% to 48%; Figure 4-4). There was more movement from STEM career interest to non-STEM career interest than vice versa. The Y1Y2 transition seemed to be an important decision point for those interested in a STEM career, with many participants moving out of STEM career interest, but then during the Y2Y3 transition many undecided participants moved into STEM career interest.

Figure 4-2. Year 1 to Year 3 Overall

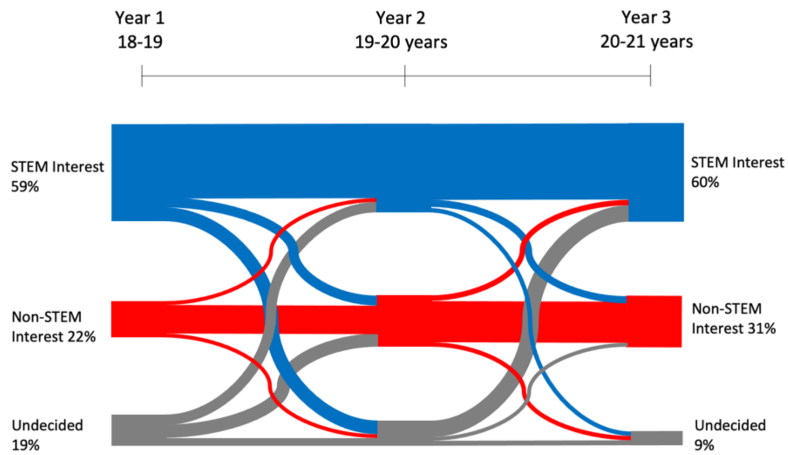


Figure 4-3. Year 1 to Year 4 Overall

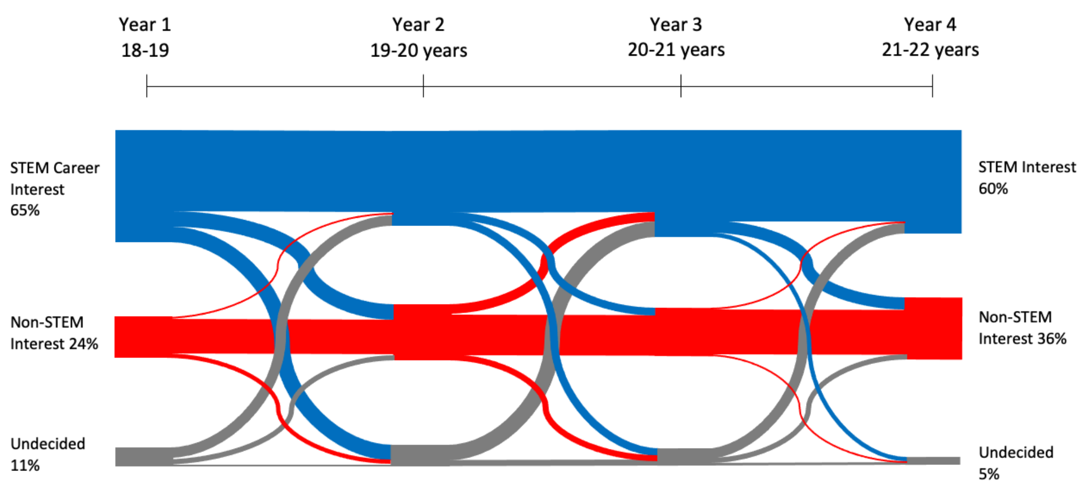
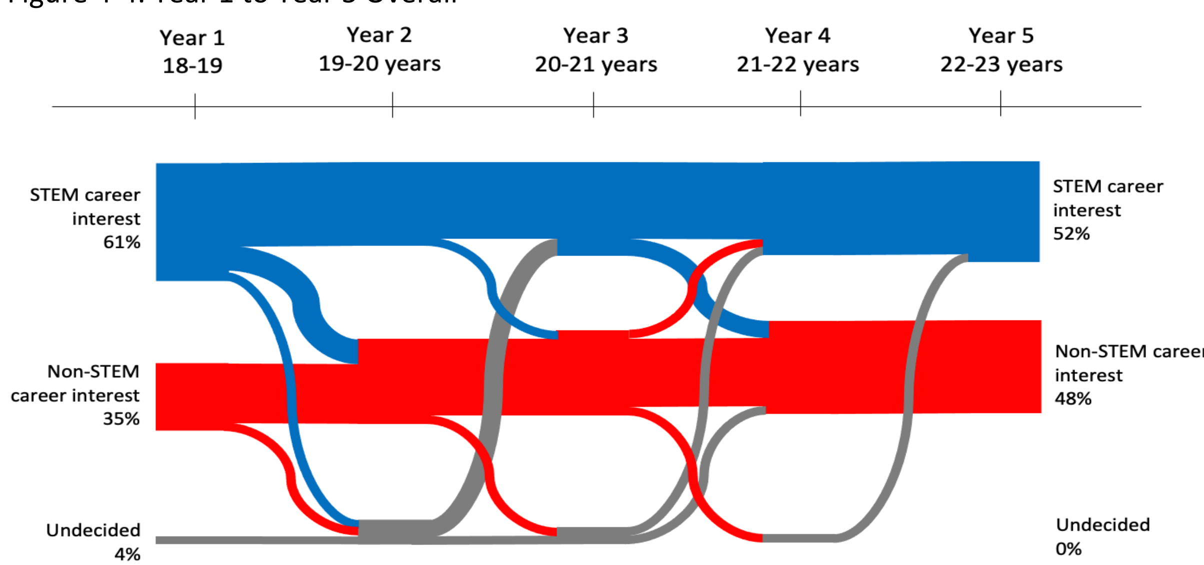


Figure 4-4. Year 1 to Year 5 Overall



Condition transitions and trajectories. Descriptive statistics indicated SMA participants switched career interest categories slightly more than comparison group participants. A higher percentage of comparison participants did not switch at all during the Y1Y3 interval, and a lower percentage switched two times (Table 4-8). This trend was echoed during the Y1Y4 interval (80% of comparison participants switched between zero to one time versus 63% of SMA participants; Table 4-9) as well as the Y1Y5 interval, although it was less pronounced in the Y1Y5 interval (Table 4-10). There were no notable time of transition differences over the four transition time periods between condition groups. (Table 4-11).

Over times points, SMA participants maintained STEM career interest at higher percentages while comparison participants maintained non-STEM career interests at higher percentages (Table 4-14). This trend was also evident when looking at the participant trajectories in terms of starting and ending categories for Y1Y3, Y1Y4, and Y1Y5 (Table 4-15). Also of note is that during the Y1Y2 transition a considerable percentage of SMA students opted out of STEM (19%), but then the same percentage (not necessarily the same individuals) opted into STEM during the Y1Y3 transition (19%), and then a similar percentage (20%) opted out again during the Y3Y4 transition period (Table 4-14).

Table 4-14.
Percentages of Participants in each Transition Type during Yearly Intervals by Condition

	Y1Y2 (*n*=175)		Y2Y3 (*n*=175)		Y3Y4 (*n*=89)		Y4Y5 (*n*=23)	
Trajectory	SMA	Comparison	SMA	Comparison	SMA	Comparison	SMA	Comparison
Maintain STEM	58%	41%	56%	43%	56%	50%	67%	27%
Opt-in to STEM	6%	10%	19%	11%	8%	8%		9%
Opt-out of STEM	19%	12%	8%	7%	20%	5%		
Maintain non-STEM	2%	23%	10%	31%	12%	31%	33%	64%
Non-STEM to Indecision	2%	2%	2%	3%		2%		
Maintain Indecision	4%	5%	2%	2%		2%		
Indecision to non-STEM	8%	8%	2%	2%	4%	3%		

Note. Empty cells indicate that there were no participants in the category and time point.

Table 4-15
Complete Trajectories by Condition

	Y1-Y3		Y1-Y4		Y1-Y5	
	SMA	Comparison	SMA	Comparison	SMA	Comparison
Trajectory	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)
STEM to STEM	31 (65%)	54 (43%)	15 (60%)	31 (48%)	8 (67%)	2 (18%)
STEM to non-STEM	4 (8%)	9 (7%)	4 (16%)	7 (11%)	2 (17%)	2 (18%)
STEM to Unsure	2 (4%)	4 (3%)		1 (2%)		
Non-STEM to non-STEM	1 (2%)	27 (21%)	2 (8%)	14 (22%)	1 (8%)	5 (45%)
Non-STEM to STEM		5 (4%)		3 (5%)		2 (18%)
Non-STEM to Unsure	1 (2%)	4 (3%)		2 (3%)		
Unsure to Unsure	1 (2%)	3 (2%)	1 (4%)			
Unsure to STEM	5 (10%)	10 (8%)	2 (8%)	3 (5%)		
Unsure to non-STEM	3 (6%)	11 (9%)	1 (4%)	3 (5%)	1 (8%)	

Note. Empty cells indicate that there were no participants in the category and time point.

Condition Sankey diagrams. The Sankey diagrams showing movement through career interest categories over time by condition were based on 175 responses during Y1Y3 (n=48 SMA; n=127 comparison), 92 responses during Y1Y4 (n=27 SMA; n=65 comparison), and 24 responses during Y1Y5 (n=13 SMA; n=11 comparison).

Condition Year 1 to 3. The percentage of participants who had STEM career interest in year one and ended with STEM Career interest in year three in both the SMA (77% in year 1; 75% in year 3) and comparison groups (53% in year 1; 54% in year 3) was remarkably stable. However, examination of just these percentages masks marked movement in and out of the STEM career interest (Figure 4-5 & Figure 4-6). There was considerable movement out of the STEM career interest group in the SMA group during the Y1Y2 interval, with less movement out during the Y2Y3 interval. The large movement out of the STEM group was balanced by a large movement from undecided to STEM in the Y2Y3 transition (Figure 4-6). Movement out of the STEM career interest group was more even across intervals in the comparison group. The non-STEM career interest group increased over time in both the SMA and comparison groups with inputs from both STEM and undecided. Movement out of the non-STEM group was consistent across the treatment groups as well as the two transition points (Y1Y2 & Y2Y3; Figure 4-5, Figure 4-6).

Condition Year 1 to 4. During the Y1Y4 interval, all categories of the comparison group remained relatively stable over the four years (61-58% STEM, 30-38% non-STEM, 9-5% undecided; Figure 4-8) with mostly small and balanced movements in and out of categories. There was a small but noticeable decrease in movement out of the STEM category over the three transition periods (Figure 4-8). The most notable movement out of the non-STEM group occured during the Y2Y3 transition period, but again this is a small difference (Figure 4-8).

In the SMA group, however, movement pattens looked quite different. A considerable portion of participants moved out of the STEM group during the Y1Y2 and Y3Y4 transition periods (Figure 4-7). During the Y1Y2 transition period most of the participants moved into the undecided category, and during the Y3Y4 period most moved into the non-STEM group, resulting in a substantial increase overall in the non-STEM percentage over the Y1Y4 interval (Figure 4-7). Furthermore, the movement of STEM interested students into undecided during the Y1Y2 transition looks to be mirrored by a movement of undecided individuals back into STEM in the Y2Y3 transition (Figure 4-7).

Figure 4-5. Year 1 to Year 3 SMA Group Participants

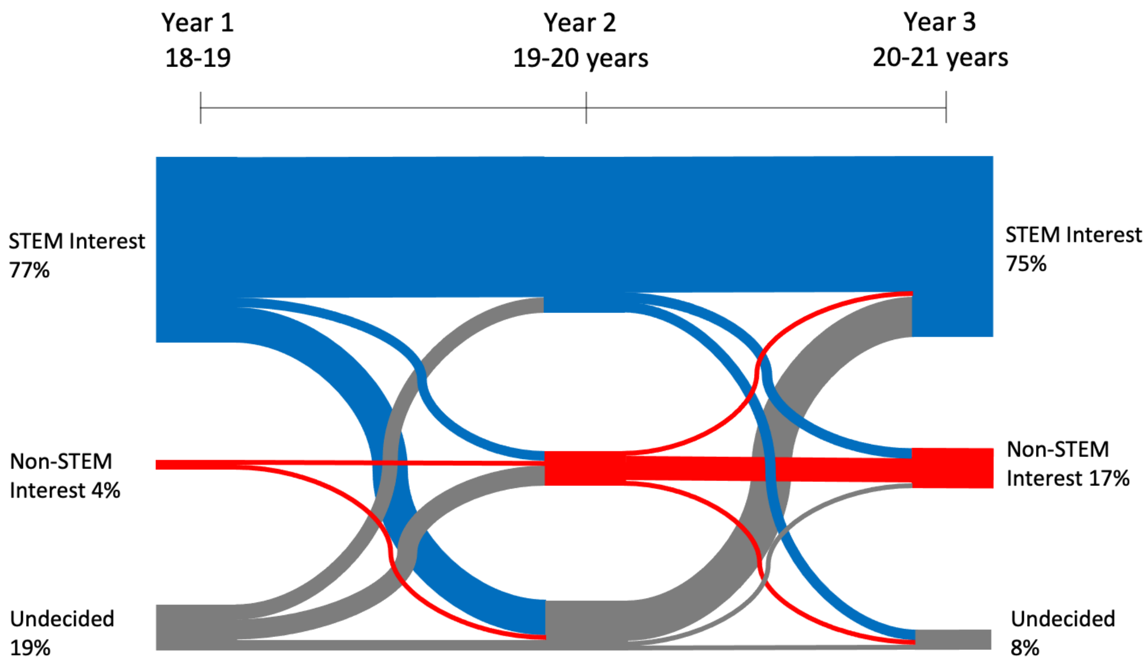


Figure 4-6. Year 1 to Year 3 Comparison Group Participants

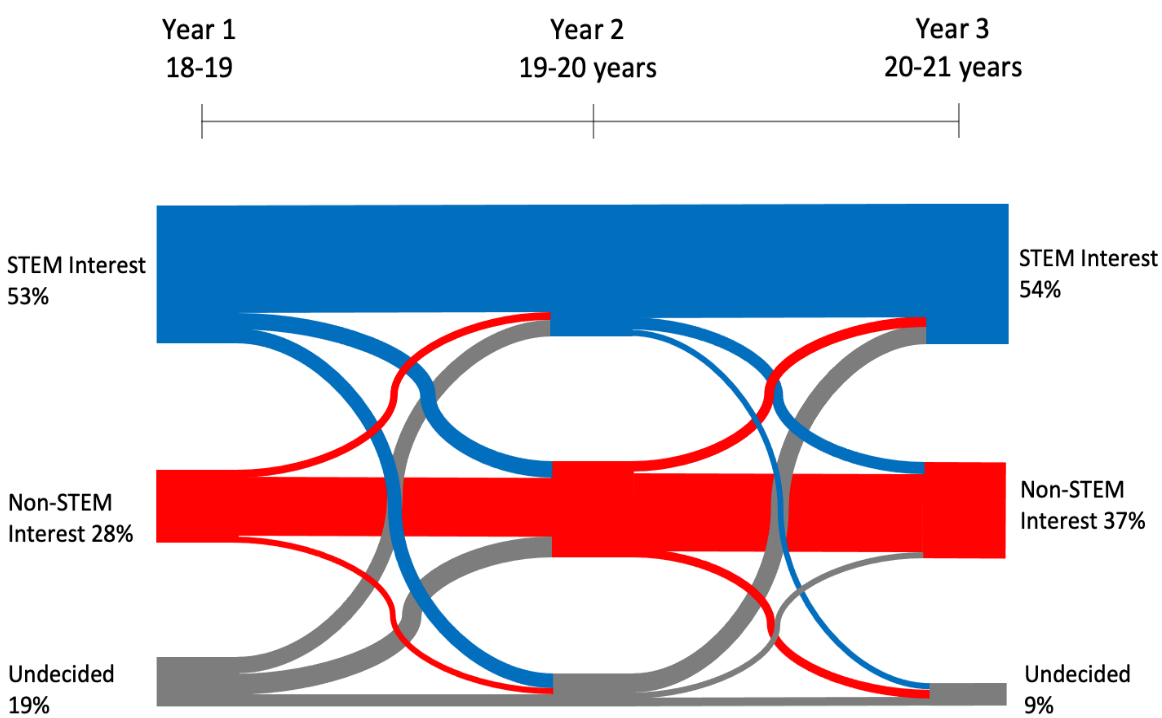


Figure 4-7. Year 1 to Year 4 SMA Group Participants

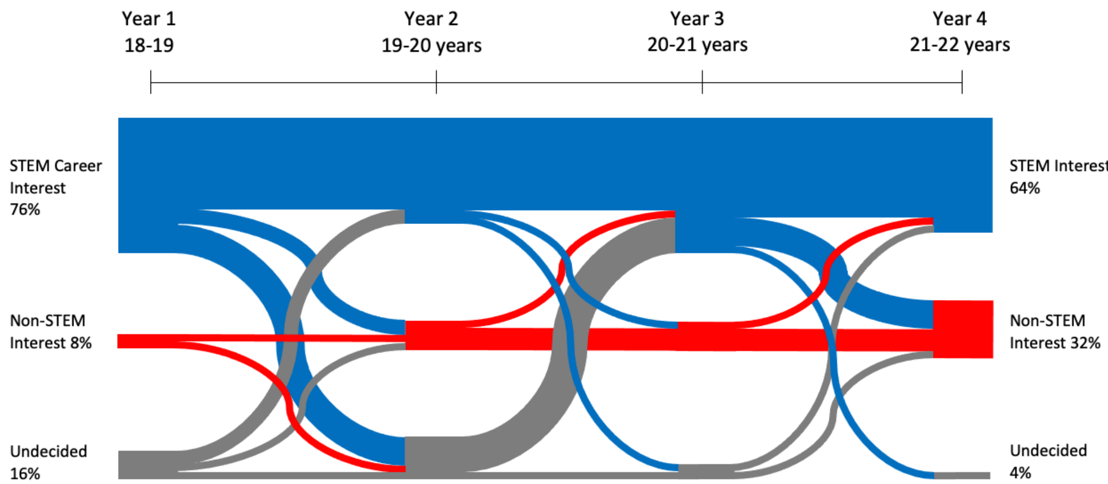
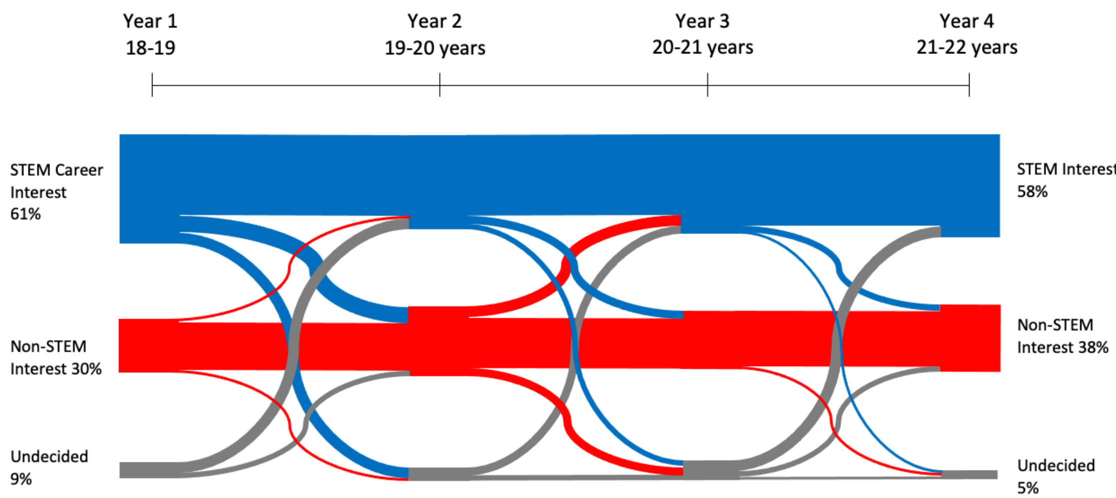


Figure 4-8. Year 1 to Year 4 Comparison Group Participants



Gender transitions and trajectories. There seems to be a broad trend of more females switching career interest categories than males. From Y1Y3 more males switched zero times compared to females, although fewer females switched twice (the maximum number of changes in the Y1Y3 interval) than males (Table 4-8). During the Y1Y4 interval the times that males and females switched is more balanced (Table 4-9), but again in the Y1Y5 interval a greater percentage of males (69%) did not switch at all compared to females (30%; Table 4-10). The Y1Y2 transition period (the year after high school) seemed to be an important decision point for females in particular, with 27% of females switching career interest category during this transition period compared to 9% of males (Table 4-11). In fact, during this time period, 15% of the female participants opted into STEM compared to 0% of males, although across time points greater percentages of males maintained STEM career interest (Table 4-16).

When trajectories were simplified to describe only career interests at the start and finish of a time interval, greater percentages of males began and ended in the same STEM career interest category in all three intervals (Table 4-17). Also, higher percentages of females moved from undecided into both STEM and non-STEM career interest compared to males (Table 4-17).

There were pronounced gender differences within the SMA group which were not present in the comparison group. For instance, during the Y1Y3 interval, 70% of SMA males did not change career interest category, compared to 38% of SMA females (Table 4-8). This difference was mirrored during the Y1Y4 interval (Table 4-9). Percentages were much more balanced across males and females in the comparison group (Table 4-8; Table 4-9).

Table 4-16.
Percentages of Participants in each Transition Type during Yearly Intervals by Gender

	Year 1 to Year 2 (*n*=173)		Year 2 to Year 3 (*n*=173)		Year 3 to Year 4 (*n*=88)		Year 4 to Year 5 (*n*=23)	
Trajectory	Female	Male	Female	Male	Female	Male	Female	Male
Maintain STEM	41%	54%	46%	49%	49%	57%	44%	54%
Opt-in to STEM	15%		10%	18%	12%	3%	11%	
Opt-out of STEM	11%	18%	10%	4%	6%	14%		
Maintain non-STEM	17%	17%	26%	23%	28%	22%	44%	46%
Non-STEM to Indecision	2%	3%	4%	1%	2%			
Maintain Indecision	5%	4%	3%	1%	2%			
Indecision to non-STEM	10%	4%	2%	3%	2%	5%		

Note. Empty cells indicate that there were no participants in the category and time point.

Table 4-17.
Complete Trajectories by Gender

	Y1-Y3		Y1-Y4		Y1-Y5	
Trajectory	Female *n* (%)	Male *n* (%)	Female *n* (%)	Male *n* (%)	Female *n* (%)	Male *n* (%)
STEM to STEM	40 (39%)	45 (63%)	25 (49%)	21 (57%)	3 (33%)	7 (54%)
STEM to non-STEM	9 (9%)	4 (6%)	6 (12%)	5 (14%)	3 (33%)	1 (8%)
STEM to Unsure	4 (4%)	2 (3%)	1 (2%)			
Non-STEM to non-STEM	16 (16%)	11 (15%)	8 (16%)	7 (19%)	1 (11%)	4 (31%)
Non-STEM to STEM	3 (3%)	2 (3%)	2 (4%)	1 (3%)	2 (22%)	
Non-STEM to Unsure	4 (4%)	1 (1%)	2 (4%)			
Unsure to Unsure	3 (3%)	1 (1%)	1 (2%)			
Unsure to STEM	13 (13%)	2 (3%)	5 (10%)			
Unsure to non-STEM	10 (10%)	3 (4%)	1 (2%)	3 (8%)		1 (8%)

Note. Empty cells indicate that there were no participants in the category and time point.

Gender Sankey diagrams. The Sankey diagrams showing movement through career interest categories over time by gender were based on 173 responses during Y1Y3 (*n*=102 female; *n*=71 male), 91 responses during Y1Y4 (*n*=38 female; *n*=53 male), and 23 responses during Y1Y5 (*n*=13 female; *n*=10 male).

Gender Y1Y3. A notable difference between the male and female Y1Y3 Sankey diagrams are that females started out with a greater portion of participants in the undecided category. However, most of these participants moved into STEM or non-STEM during the Y1Y2 transition (Figure 4-9 & Figure 4-10).

Gender Y1Y4. There was more diversity of types of movements amongst females compared to males in the Y1Y4 interval. Females had a steady but decreasing movement out of STEM from Y1Y2 to Y3Y4, but males had two distinct periods, one during Y1Y2 and one during Y3Y4. Females likewise showed steady movements in and out of the undecided category throughout the interval, but the movement out of the undecided category was concentrated during the Y2Y3 transition for males. Overall, there was much more movement of males from non-STEM to STEM, but only during the Y2Y3 transition (Figure 4-11 & Figure 4-12).

Gender within Condition. The percentage of female SMA participants with non-STEM interest increased from Y1Y3, and the those who were undecided decreased. The year one and year three percentages of SMA males were very similar. The notable movement amongst the male SMA participants was from STEM to undecided during the Y1Y2 transition, and undecided into STEM during the Y2Y3 period. A symmetrical movement pattern was also observed amongst the females SMA participants out of STEM to undecided and back from undecided into STEM (Figure 4-13 & Figure 4-14).

Overall, comparison group males showed a slightly higher percentage of participants who started and ended in the STEM career interest category, but the percentage of male and female participants with non-STEM career interest was very similar. Comparison females started out with higher percentages undecided, and there was more movement from undecided to both STEM and non-STEM interest groups during the Y1Y2 transition than males. Otherwise, movement patterns of comparison males and females appear quite similar (Figure 4-15 & Figure 4-16).

Figure 4-9. Year 1 to Year 3 Female Participants

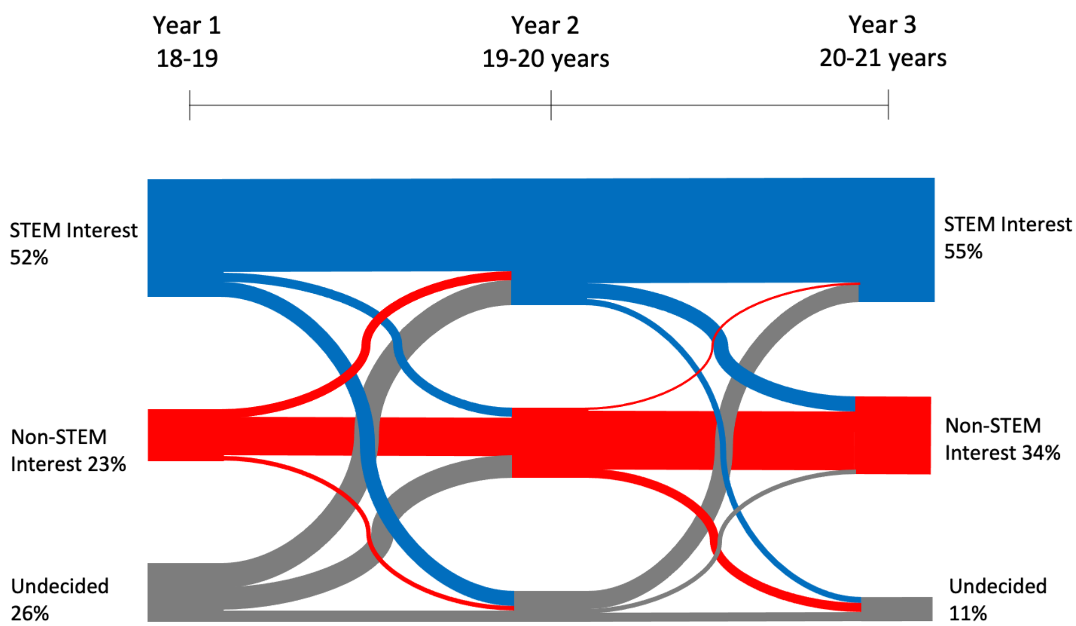


Figure 4-10. Year 1 to Year 3 Male Participants

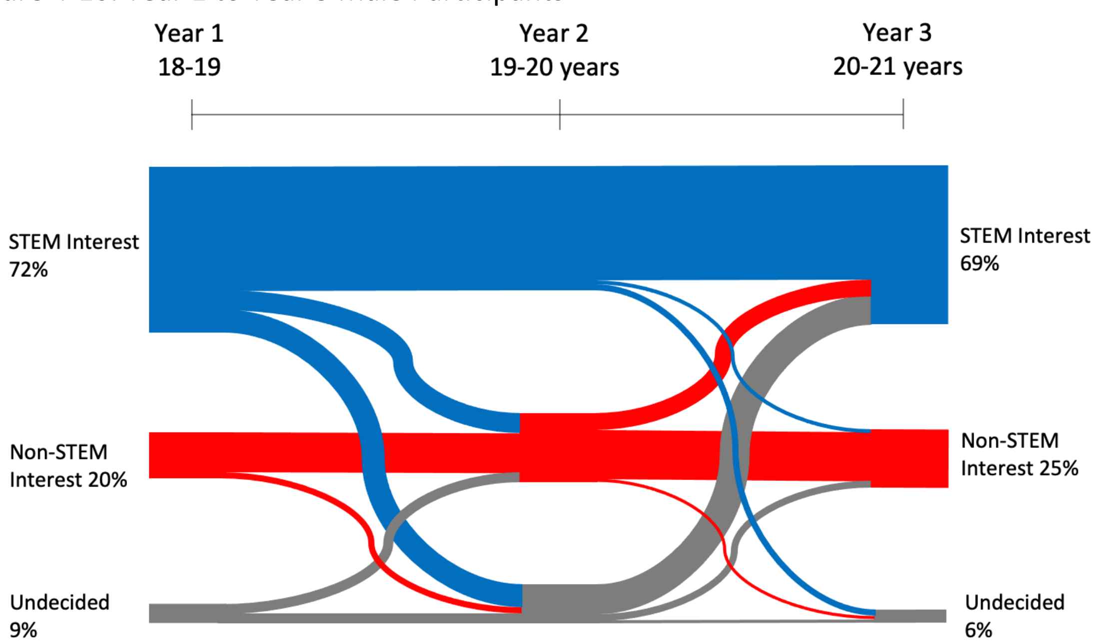


Figure 4-11. Year 1 to Year 4 Female Participants

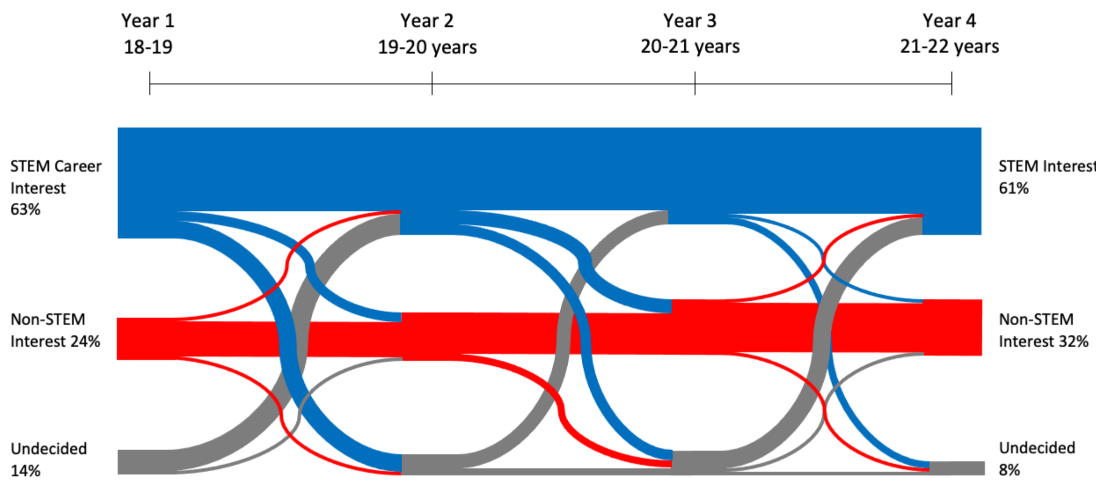


Figure 4-12. Year 1 to Year 4 Male Participants

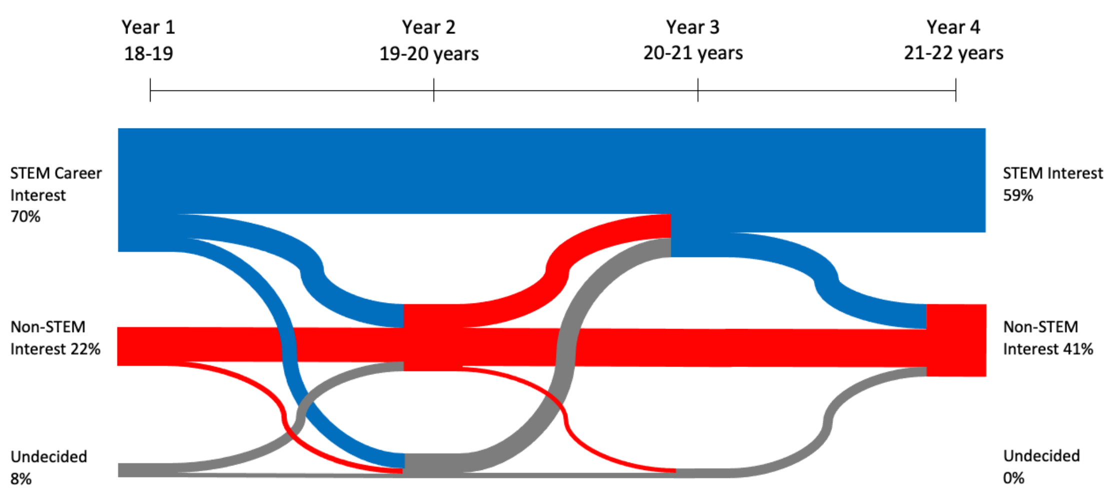


Figure 4-13. Year 1 to Year 3 Female SMA Participants

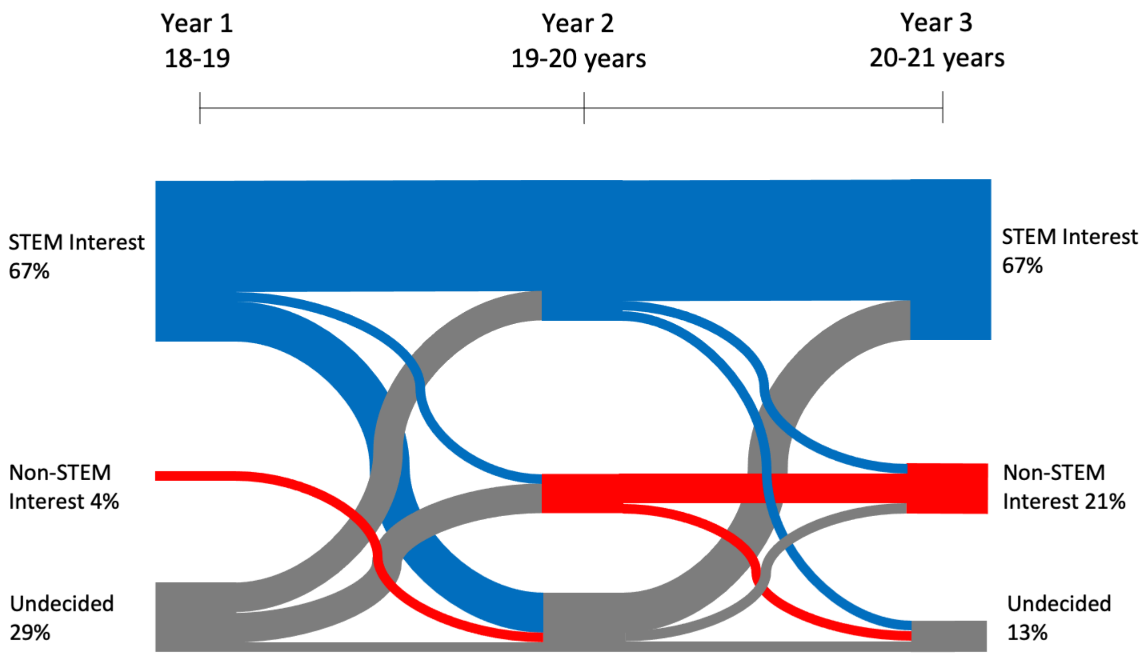


Figure 4-14. Year 1 to Year 3 Male SMA Participants

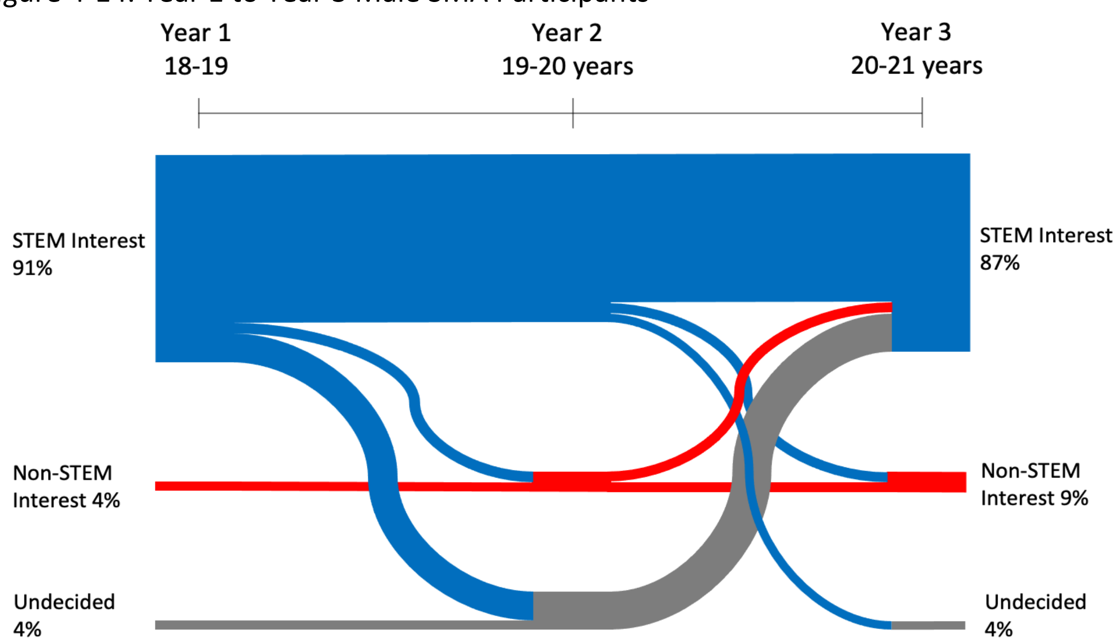


Figure 4-15. Year 1 to Year 3 Female Comparison Participants

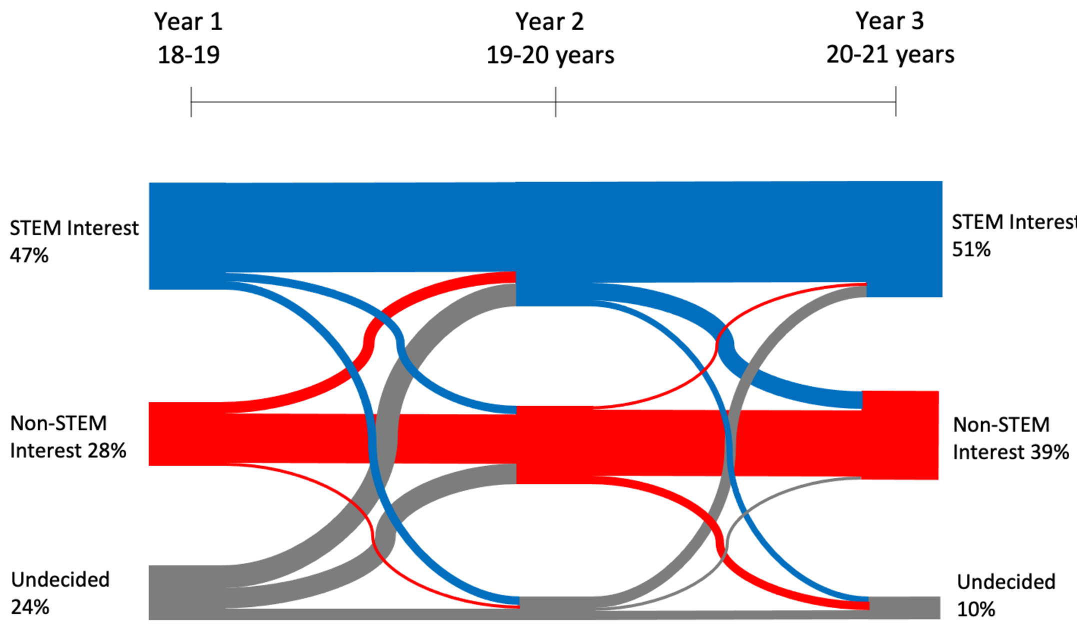
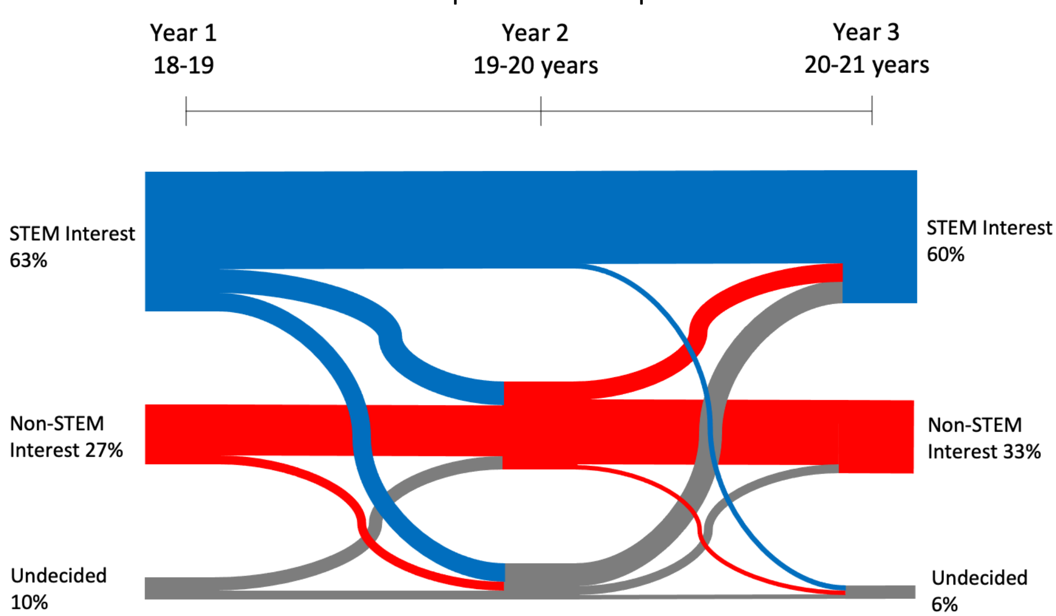


Figure 4-16. Year 1 to Year 3 Male Comparison Participants



Research Question 3

How did field of STEM career interest vary by condition, gender, or race/ethnicity?

Overall field of STEM career interest. Four fields of STEM career interest were more common across the participants: (1) health, (2) engineering, (3) computer science, and (4) research scientist. From year one to three overall interest in these areas was mostly steady, although the percentage of participants interested in natural resources and teaching math or science increased slightly, and interest in mathematics decreased slightly (Figure 4-17 & Figure 4-18).

Flow between the four most prevalent STEM fields as well as a compiled category comprising the other STEM fields, non-STEM interest, and the undecided category, is depicted in a Sankey diagram (Figure 4-19). Although there is a lot of noise in this diagram with so many categories, upon careful inspection there were some detectable trends. First, there was considerable movement between different STEM fields, the undecided category, and the non-STEM career interest category between year one and year three.

In particular, many participants moved in and out of health career interest. Slightly more undecided participants moved into the healthcare compared to other STEM fields. There is also a slightly larger portion of participants who entered into the healthcare interest category from the non-STEM interest group during the Y1Y2 transition. It seems based on these trends that the healthcare/medicine category is a unique category within STEM, and may be more appealing to people who are unsure about STEM careers. Finally, notice in Y1Y2 there was considerable movement out of computer science, with the largest portion moving to non-STEM interest; but very little movement into computer science. However, there was substantial movement back into computer science during the Y2Y3 transition, especially from the undecided category.

Figure 4-17.

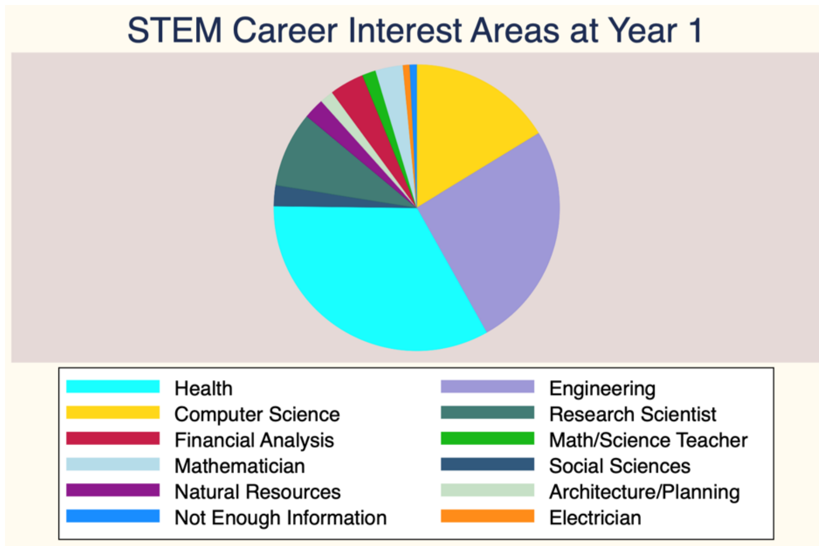


Figure 4-18.

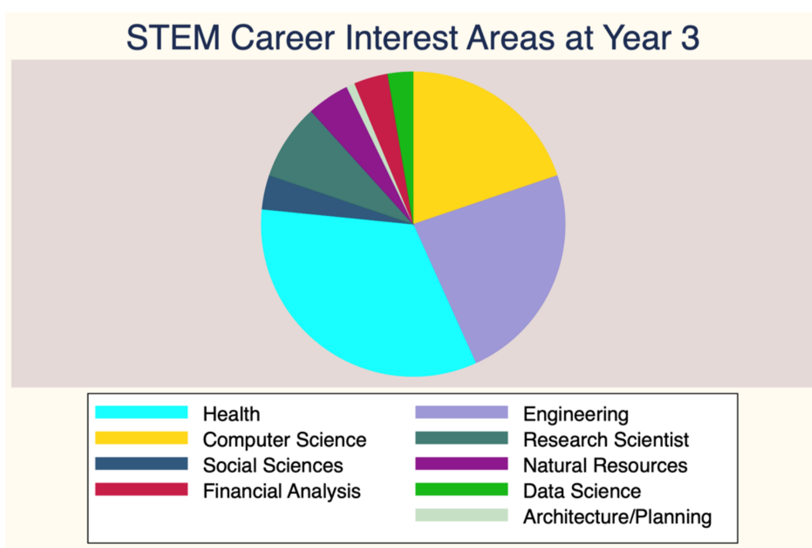
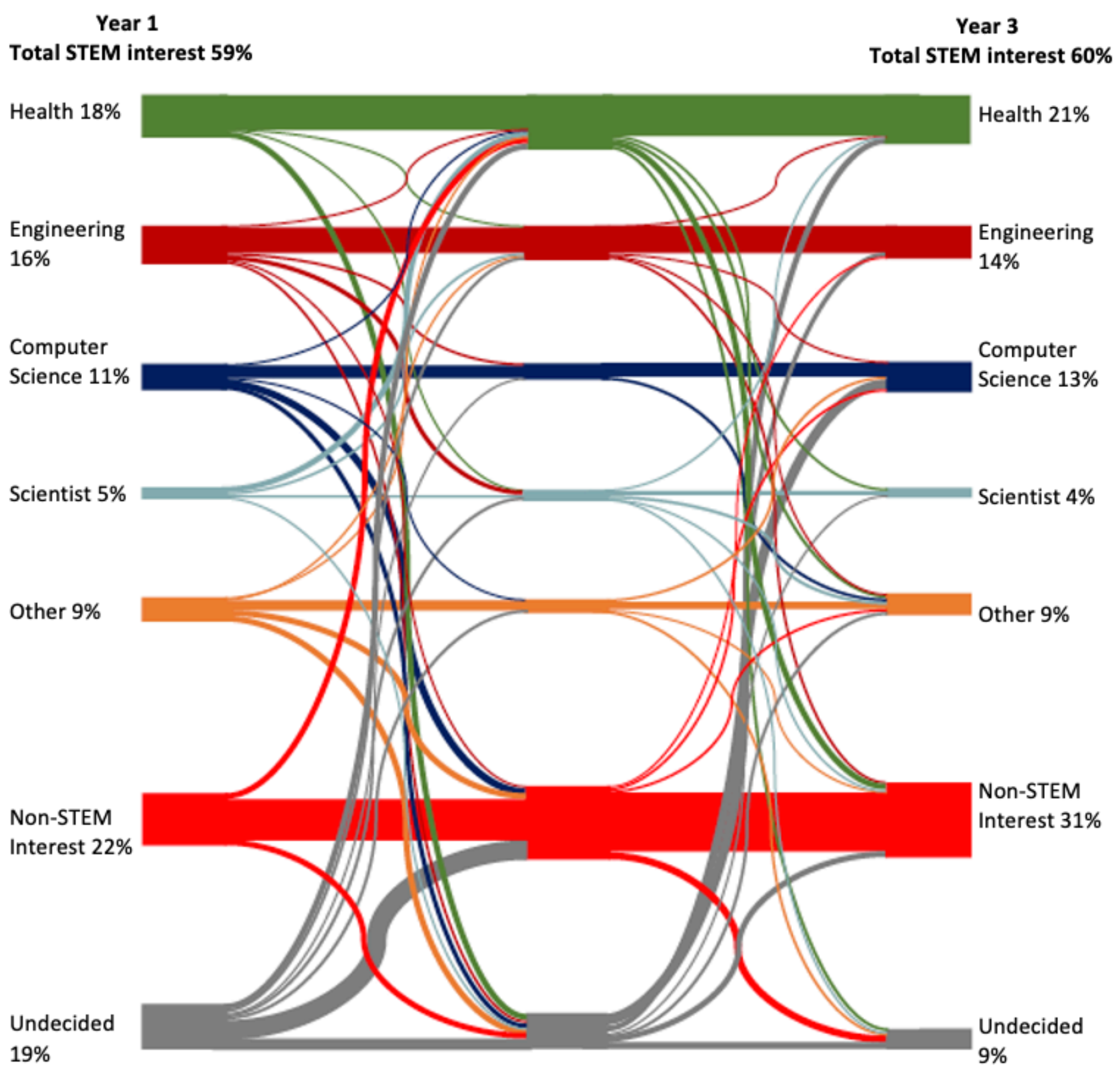


Figure 4-19. Sankey Diagram Showing Flow between Interest in Specific STEM fields between Year 1 and Year 3.



Condition. In year one, a greater portion of SMA participants reported interest in engineering and a research science career when compared to comparison group participants (Figure 4-20). Fewer reported an interest in healthcare/medicine. In year three these differences were much less pronounced, although healthcare/medicine interest was still more common in the comparison group (Figure 4-21).

These trends were also reflected in the Chi-square/Fisher's test results; condition had a significant effect on the distribution of participants across STEM field interest groups in years one (X^2 (4, N = 129) = 15.15, p =0.004; Fisher's exact = 0.004, Cramer's V=0.34) and two (X^2 (4, N = 109) = 10.62, p =0.03; Fisher's exact = 0.04, Cramer's V=0.31), but not three (Table 4-18). Post-hoc tests pointed to the healthcare category (SMA participants less prevalent than expected in year one) and the research scientist category (SMA more; comparison less represented than expected in year one and two) as key areas of difference (Table 4-19).

Table 4-18
Field of STEM Career Interest Chi-square and Fisher's Exact Test Results

		df	N	X^2	X^2 p-value	Fisher's p-value	Cramer's V
Year 1							
	Condition	4	129	15.15	0.004**	0.004**	0.34[e]
	Gender	4	129	16.7	0.002**	0.002**	0.36[e]
	Gender: Comparison	4	84	21.39	<0.001***	<0.001***	0.50[e]
Year 2							
	Condition	4	109	10.62	0.03*	0.04*	0.31[e]
	Gender	4	109	10.47	0.03*	0.03*	0.31[e]
	Gender: Comparison	4	72	19.86	0.001***	<0.001***	0.53[e]
Year 3							
	Gender	4	111	21.68	<0.001***	<0.001***	0.44[e]
	Gender: Comparison	4	72	22.3	<0.001***	<0.001***	0.56[e]
Year 4							
	Gender	4	58	14.88	0.005**	0.005**	0.51

Note. Only statistically significant or nearly statistically significant results are shown. Gender within both condition groups was significant in year 4, but they are not reported because the percentage of cells with an expected value of less than <5 was very high.
**p*<0.05, ***p*<0.01, ****p*<0.001
[a]small [b]small-medium [c]medium [d]medium-large [e]large; see Table 4-3

Figure 4-20.

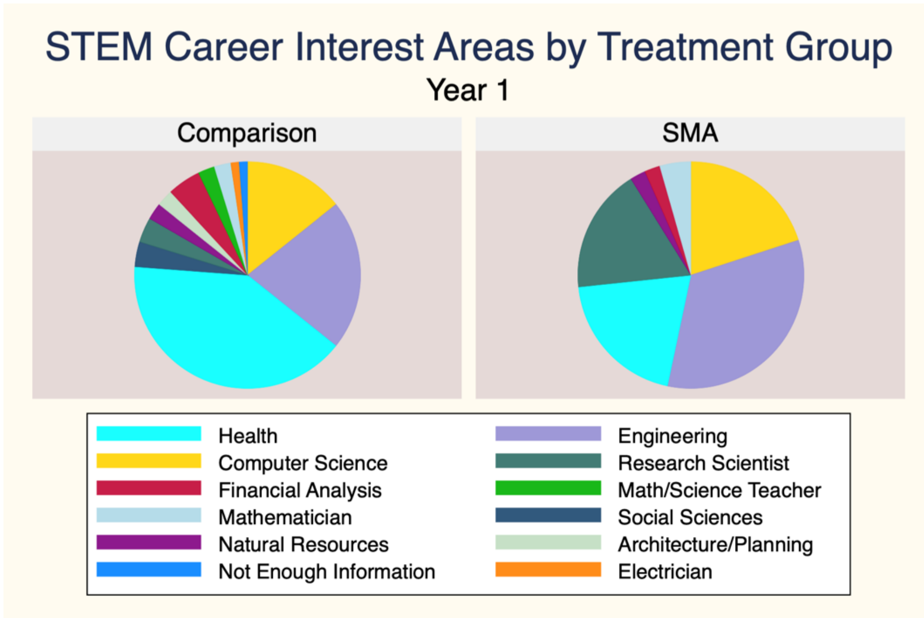


Figure 4-21.

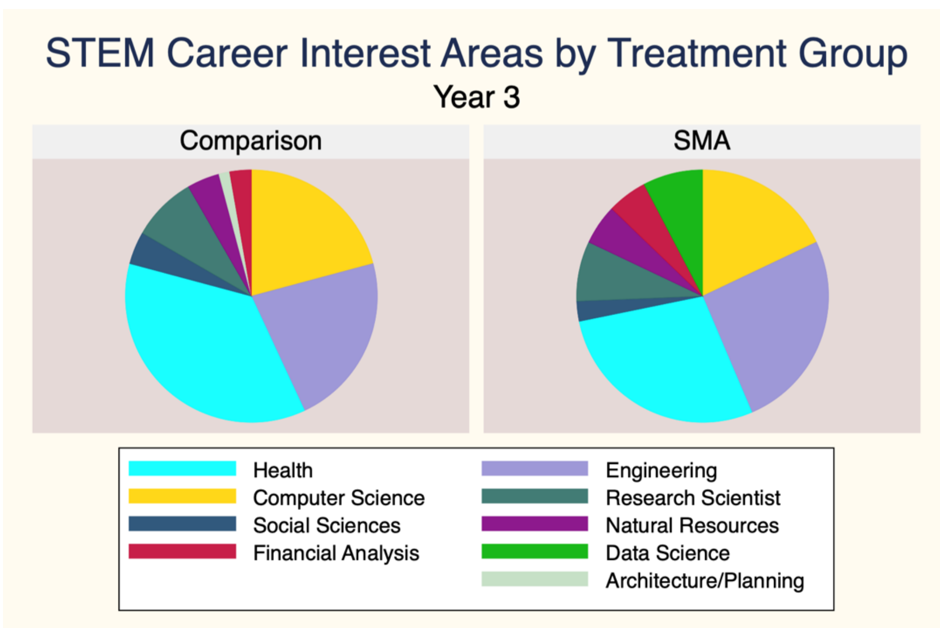


Table 4-19
Summary of STEM Career Interest Chi-square and Fisher's Exact Post Hoc Tests

		Computer Science	Engineering	Health	Research Scientist
Year 1					
Condition	SMA			less	more
	Comparison				less
Gender	Female	less		more	
	Male			less	
Comparison:					
Gender	Female	less		more	
	Male	more		less	
Year 2					
Condition	SMA				more
	Comparison				less
Gender	Female	more			
	Male	less			
Comparison:					
Gender	Female			more	
	Male			less	
Year 3					
Gender	Female	less		more	
	Male	more	more	less	
Comparison:					
Gender	Female	less		more	
	Male	more	more	less	
Year 4					
Gender	Female		less		
	Male		more		

Note. Less refers to the group being less represented in a given category than expected per the Chi-square test. More refers to the group being more prevalent in a category than expected by the Chi-square test.

Gender. The distribution of STEM career field of interest was quite different across the male and female groups in both year one and three (Figure 4-22 & Figure 4-23). A higher proportion of females reported healthcare/medicine interest, and a lower percentage reported computer science and engineering interest compared to males. In year three females reported slightly higher preferences for natural resource and research scientist careers.

These trends were reinforced by significant effects of gender in year one (X^2 (4, N = 129) = 16.70, p =0.002; Fisher's exact = 0.002, Cramer's V=0.36), year two (X^2 (4, N = 109) = 10.47, p =0.03; Fisher's exact = 0.03, Cramer's V=0.31), year three (X^2 (4, N = 111) = 21.68, p <0.001; Fisher's exact = p<0.001, Cramer's V=0.44), and year four (X^2 (4, N = 58) = 14.88, p =0.005; Fisher's exact = p=0.005, Cramer's V=0.51; Table 4-18).

Post-hoc tests highlighted differences in computer science representation with females less represented than expected in years one, two, and three; and males represented more than expected in years two and three (Table 4-19). There were also differences in health fields with females represented more and males less than expected in years one and three; as well as engineering, with males represented more than expected in years three and four, and females less than expected in year four (Table 4-19).

Gender within condition. Chi-square tests indicated differences in gender representation across STEM field interest in the comparison group in year one (X^2 (4, N = 84) = 21.39, p <0.001; Fisher's exact = p<0.001, Cramer's V=0.50), two (X^2 (4, N = 72) = 19.86, p <0.001; Fisher's exact = p<0.001, Cramer's V=0.53), and three (X^2 (4, N =72) = 22.30, p <0.001; Fisher's exact = p<0.001, Cramer's V=0.56; Table 4-18). The difference in STEM career interest across gender in the comparison group can be seen clearly in pie charts (Figure 4-24 & Figure 4-25). Gender differences within both condition groups were significant in year four, but sample sizes were very small, so results were not reported. Computer science (year one and three), engineering (year three), and health fields were all indicated as areas of difference by post-hoc tests (Table 4-19).

Figure 4-22.

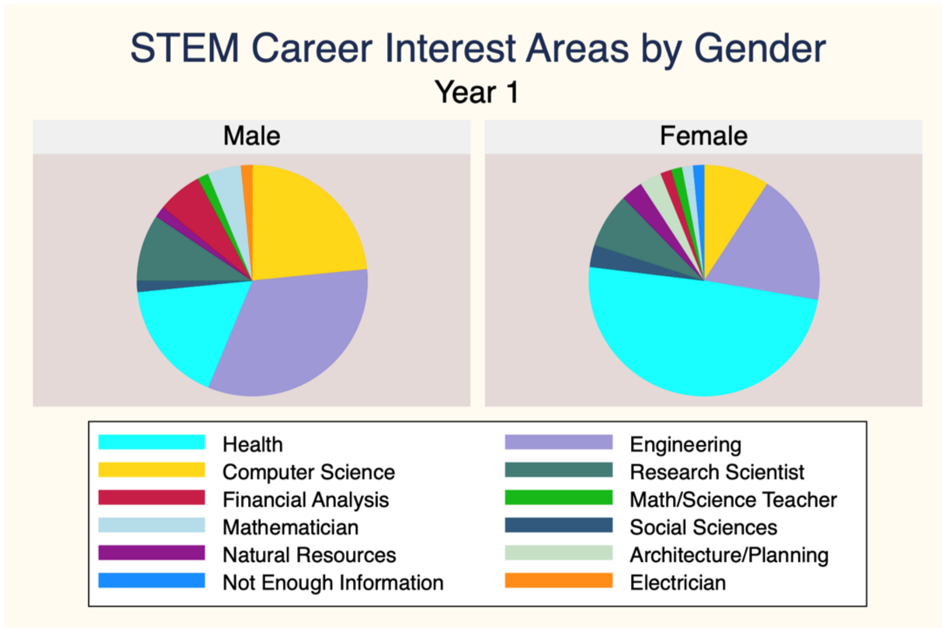


Figure 4-23.

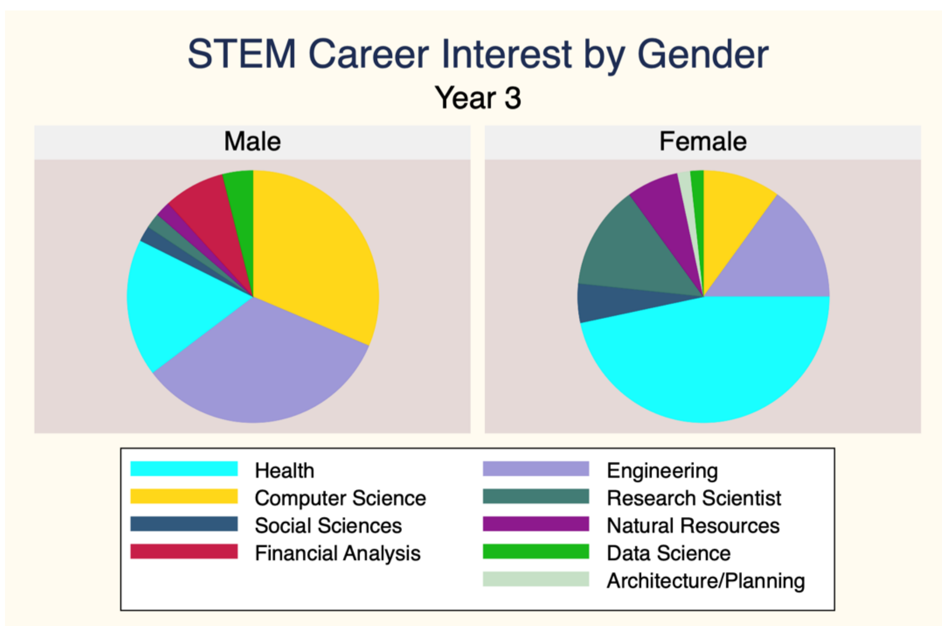
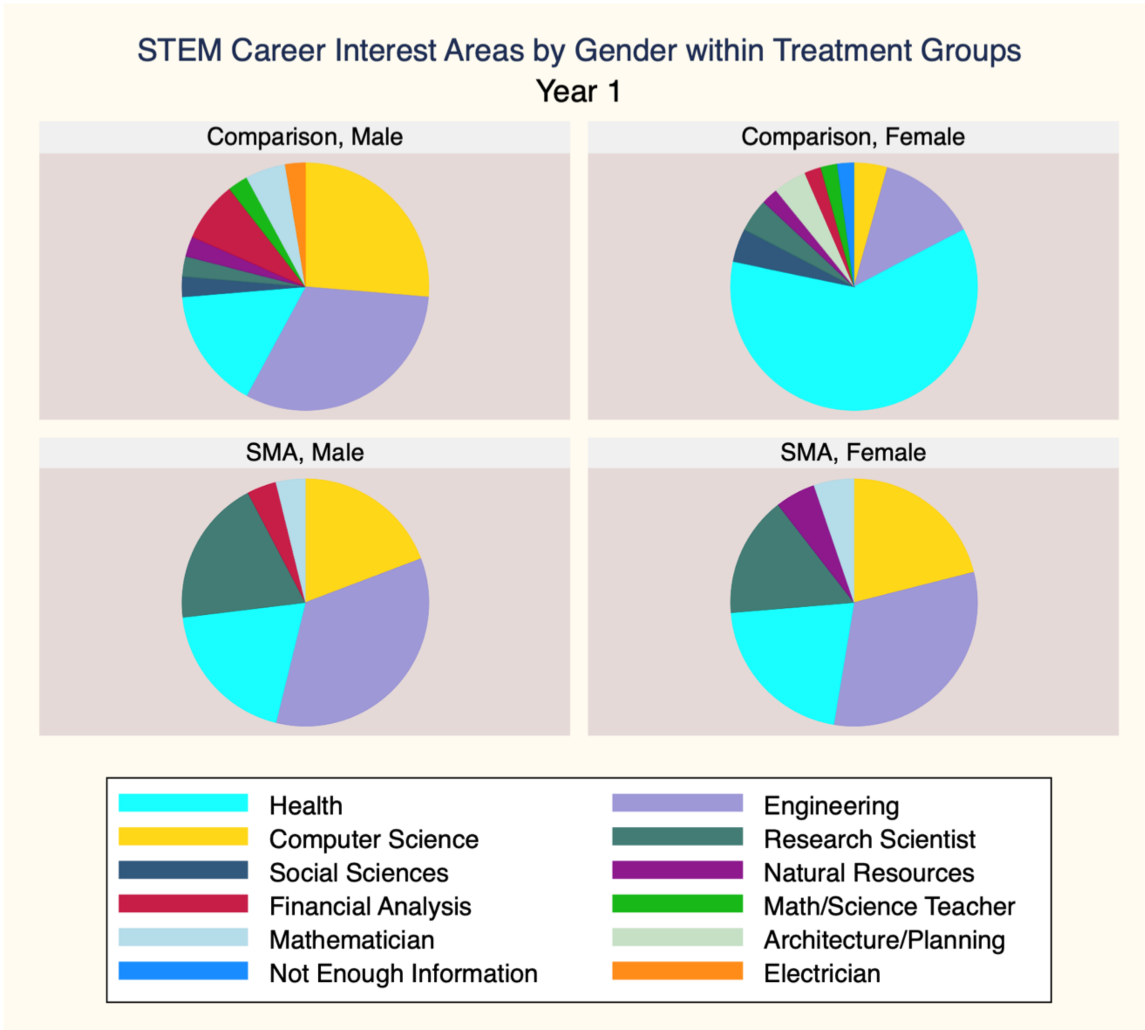
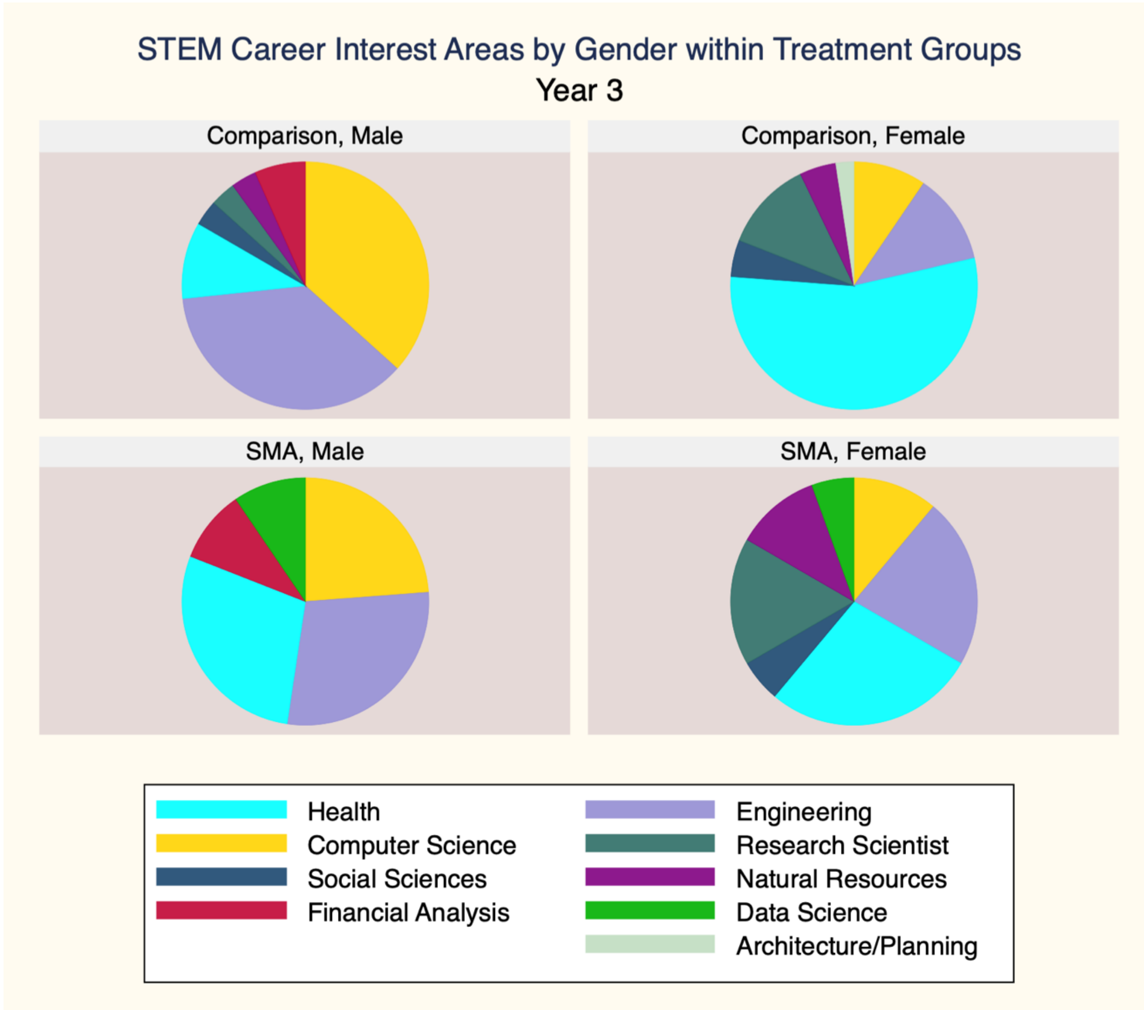


Figure 4-24.



STEM Career Interest Areas by Gender within Treatment Groups
Year 1
Comparison, Male
Comparison, Female
SMA, Male
SMA, Female
Health
Computer Science
Social Sciences
Financial Analysis
Mathematician
Not Enough Information
Engineering
Research Scientist
Natural Resources
Math/Science Teacher
Architecture/Planning
Electrician

Figure 4-25.



Race/Ethnicity. Although Chi-square/Fisher's test analyses did not indicate significant differences in STEM field career interests between racial/ethnic groups, Figures 4-26 and 4-27 show variation. In year one, White participants showed comparatively high engineering interest, Hispanic/Latinx participants reported high interest in health/medicine careers, and Black/African American participants showed high levels of computer science interest.

In year three White participants still exhibited relatively high levels of engineering interest; and health/medicine interest in the Hispanic/Latinx and Asian groups remained high. However, although a smaller portion of Black/African American participants were interested in computer science in year three compared to year one, interest in engineering, health/medicine, natural resources, and financial analysis was higher in year three. Interest in computer science was higher in the Asian subgroup in year three compared to year one. Interest in a research science career was higher in the Hispanic/Latinx subgroup in year three, but lower amongst the Asian and Black participants (Figure 4-26 & Figure 4-27).

Finally, given a strong gender effect on field of STEM career interest, Figures 4-28 and 4-29 show STEM field career interest by gender and race/ethnicity. These graphs were built with 106 responses in year one and 84 responses in year three. A high interest in healthcare/medicine was marked in females across all race/ethnicities, as well as Asian males. Taken as a whole, however, each distribution was unique broken down by race, gender, and year. Although broad-brush trends were evident, the interplay between field of STEM interest and the intersectionality between gender and race will require deeper and finer scale inquiry. This will especially be true when additionally considering the potential effects of participation in the SMA program.

Figure 4-26.

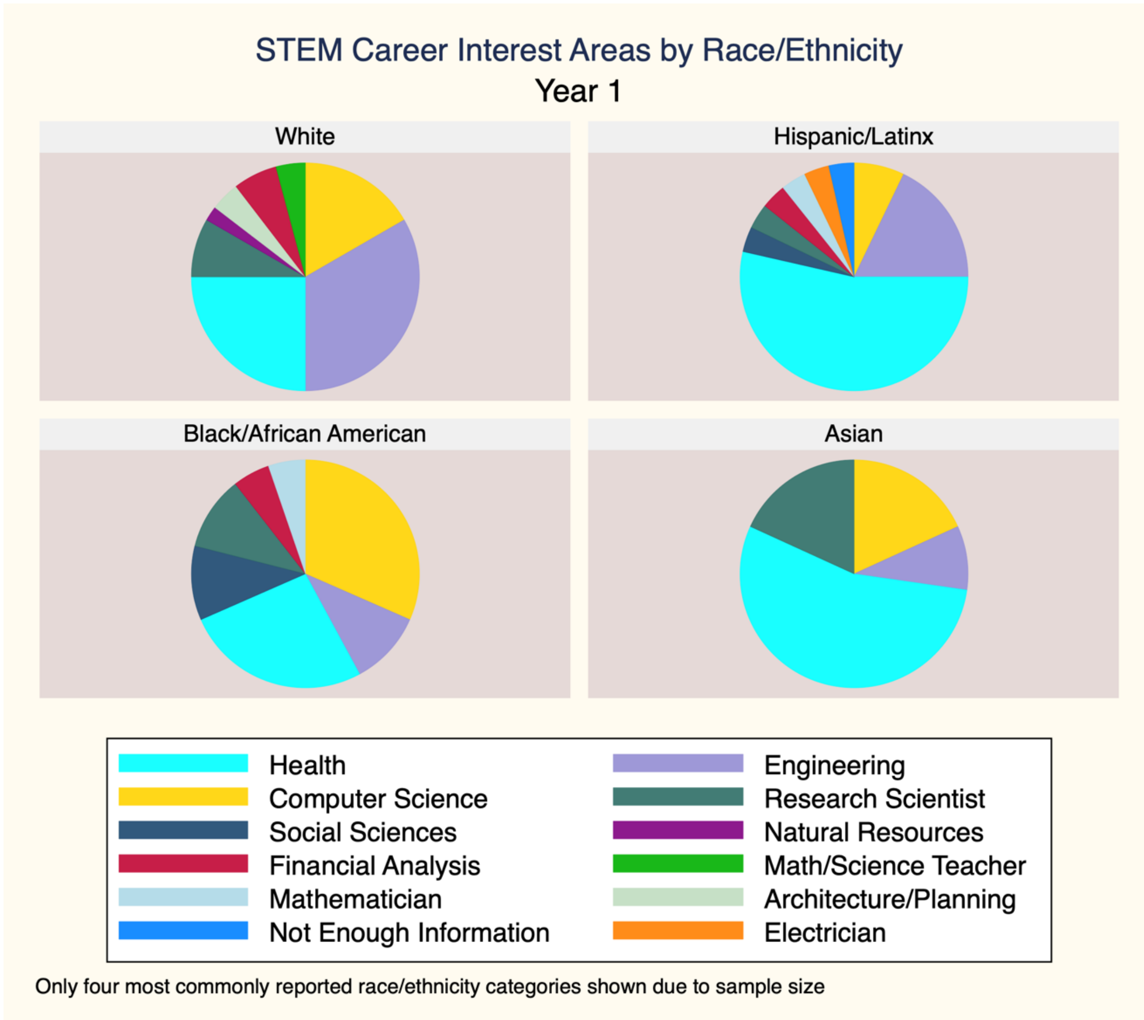
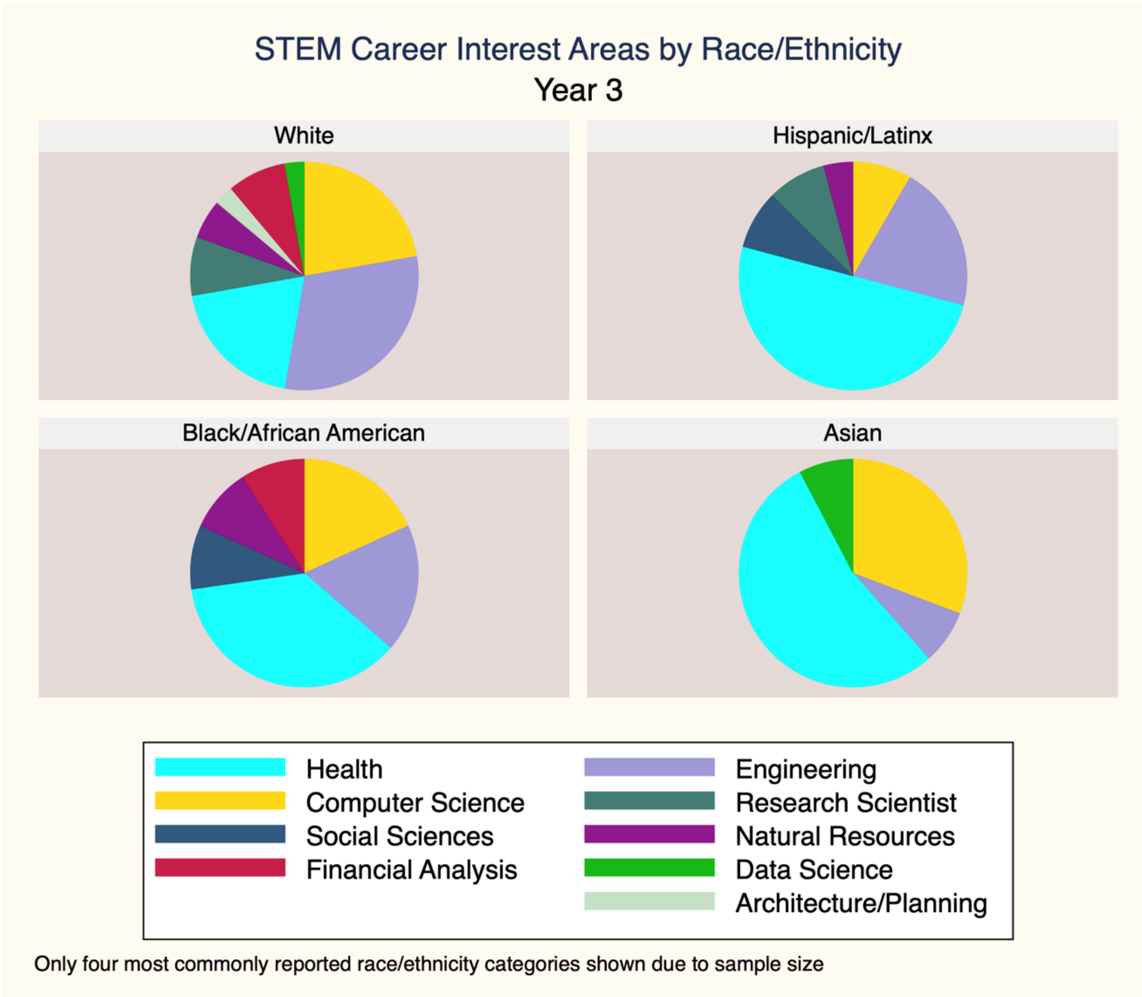

STEM Career Interest Areas by Race/Ethnicity
Year 1
White
Hispanic/Latinx
Black/African American
Asian
Health
Computer Science
Social Sciences
Financial Analysis
Mathematician
Not Enough Information
Engineering
Research Scientist
Natural Resources
Math/Science Teacher
Architecture/Planning
Electrician
Only four most commonly reported race/ethnicity categories shown due to sample size

Figure 4-27.



STEM Career Interest Areas by Race/Ethnicity
Year 3
White
Hispanic/Latinx
Black/African American
Asian
Health
Computer Science
Social Sciences
Financial Analysis
Engineering
Research Scientist
Natural Resources
Data Science
Architecture/Planning
Only four most commonly reported race/ethnicity categories shown due to sample size

Figure 4-28.

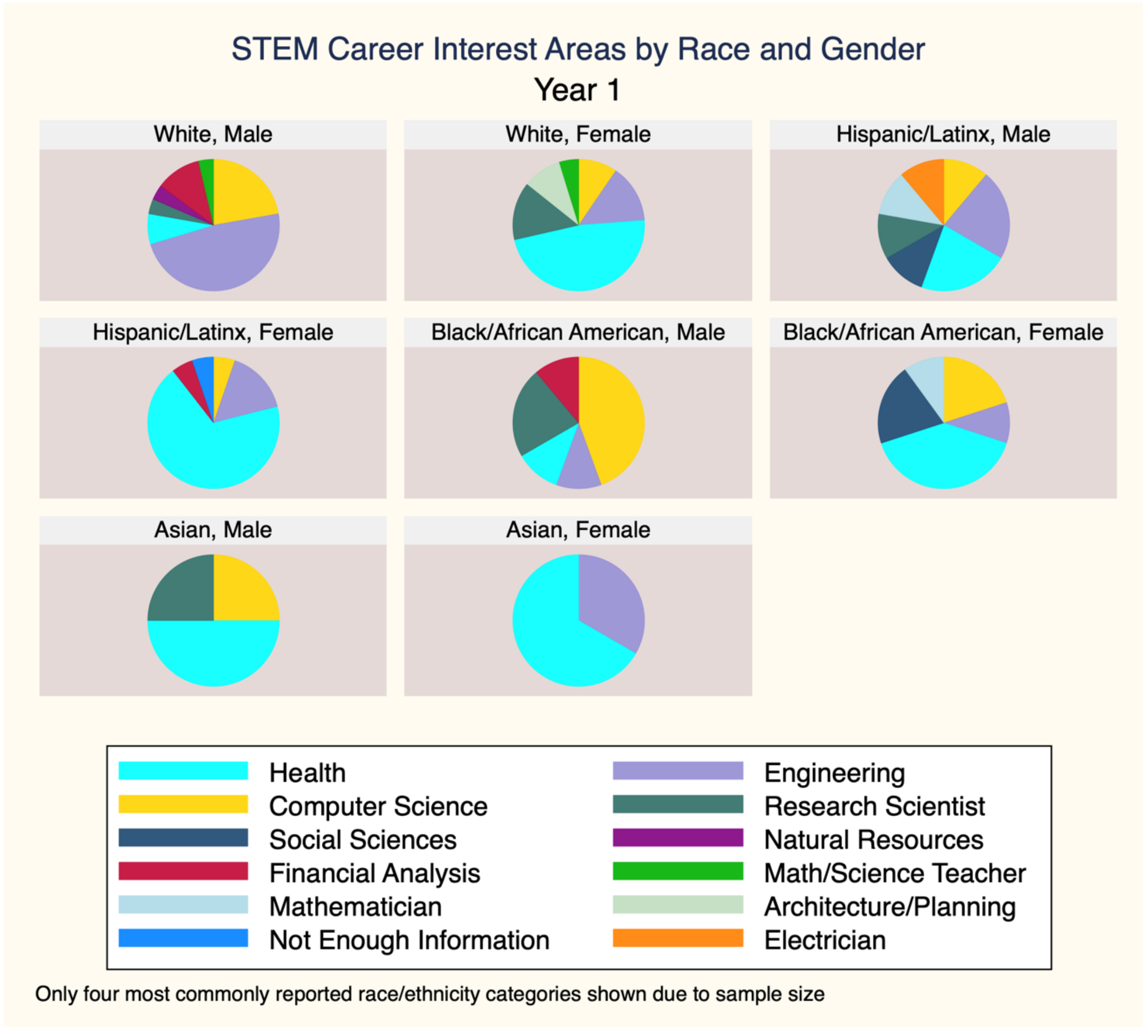
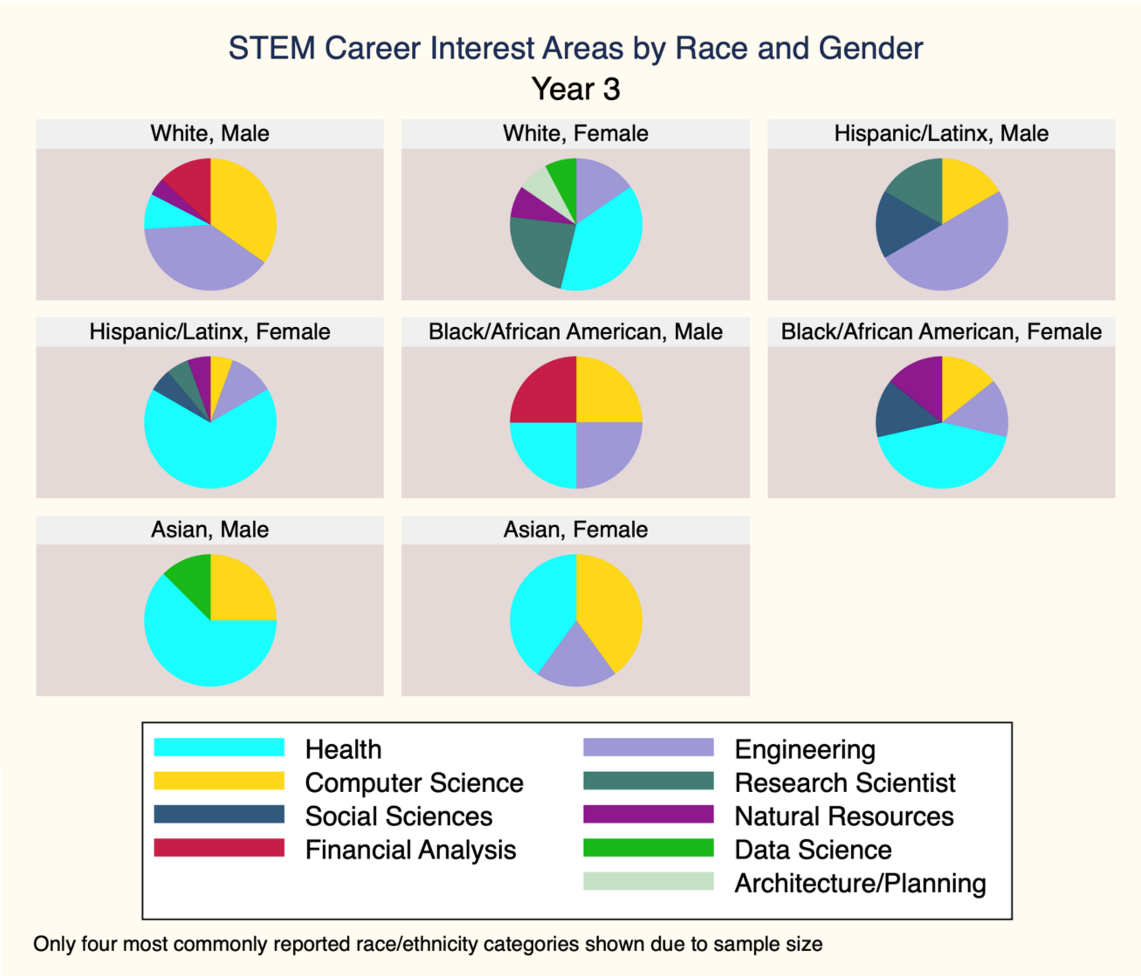

STEM Career Interest Areas by Race and Gender
Year 1
White, Male
White, Female
Hispanic/Latinx, Male
Hispanic/Latinx, Female
Black/African American, Male
Black/African American, Female
Asian, Male
Asian, Female
Health
Computer Science
Social Sciences
Financial Analysis
Mathematician
Not Enough Information
Engineering
Research Scientist
Natural Resources
Math/Science Teacher
Architecture/Planning
Electrician
Only four most commonly reported race/ethnicity categories shown due to sample size

Figure 4-29.



Research Question 4

Did STEM career aspiration vary by year, condition, gender, race/ethnicity, socioeconomic class, or the interactions between these variables in the five years after post-secondary school?

Research questions one and two addressed similar effects on science career interest; coded as STEM, non-STEM, or undecided from participant responses regarding their desired career. In research question three the specific field of STEM career interest amongst those interested in a STEM career was investigated. The field of STEM career interest was derived from responses investigated in research questions one and two. Finally, for research question four, the outcome variable was science aspirations as measured by a composite of four Likert-style survey questions (Table 3-9). These questions are: “I would like to study science in the future”, “I would like to have a job that uses science in the future”, “I would like to become a scientist”, and “I think I could be a good scientist one day.” So, although it is expected that science career interest as measured by participant identification of their most desired career would be somewhat related to the science aspiration measure, it is also important to note that the two measures are distinct.

A mixed-effect model was utilized to test the effects of condition, gender, race, socioeconomic status (SES), year, the interaction of condition and gender, and the interaction race and gender on science aspirations. Plots of studentized residuals were examined to assure assumptions regarding normality, variance, and outliers were met. Results showed condition as the only included variable that was associated with varying science aspirations (Table 4-21). SMA participants averaged between 0.70 and 1.2 point higher science aspiration scores than comparison participants over the four years (Table 4-20). A point correlates to a five-point Likert scale. This equates to SMA participants on average reporting between “agree” and “strongly agree” to the science aspiration questions, while comparison participants respond between “neutral” and “agree.”

An inquiry of the relationships between science aspiration scores and STEM career aspirations and STEM field aspirations is beyond the scope of this study, but a preliminary look showed that there is considerable variation between participants who responded that they desire a STEM career (*M*=4.00, *SD*=0.88) and those who desired a non-STEM career (*M*=2.67, *SD*=0.79) in year one. Those who indicated interest in engineering (*M*=4.40, *SD*=0.54) and research science careers (*M*=4.75, *SD*=0.49) expressed higher science aspirations in year one than those interested in healthcare/medicine (*M*=3.81, *SD*=0.92) and computer science (*M*=3.56, *SD*=0.97) careers.

Table 4-20

Science Aspiration Descriptive Statistics

	Y1			Y2			Y3			Y4			Y5		
	n	mean	*SD*	*n*	mean	*SD*	*n*	mean	*SD*	*n*	mean	*SD*	*n*	mean	*SD*
Condition															
SMA	59	4.36	0.71	58	4.17	0.77	53	4.11	0.75	30	4.24	0.64	16	4.41	0.86
Comparison	162	3.35	0.95	143	3.46	0.98	133	3.42	1	68	3.43	1.14	12	3.23	1.18
Gender															
Female	123	3.53	1.04	119	3.6	1.03	108	3.62	1.01	59	3.64	1.12	12	3.58	1.18
Male	96	3.73	0.92	80	3.75	0.9	76	3.63	0.96	38	3.76	1.02	15	4.2	1.12
Race															
White	77	3.73	0.99	69	3.62	0.95	65	3.62	0.92	44	3.47	1.12	15	3.63	1.15
Hispanic	51	3.45	0.88	46	3.61	0.97	42	3.35	1	12	3.6	1.35	2	3.5	2.12
Black	36	3.46	1.05	30	3.65	1.03	23	3.53	0.93	8	3.84	0.88	4	4.44	1.13
Asian	19	3.75	0.93	19	3.59	0.8	18	3.53	0.83	11	3.89	0.5	2	4	1.41
SES															
disadvantage	153	3.54	0.98	139	3.54	0.96	125	3.48	0.97	58	3.45	1.17	14	3.52	1.25
no disadvantage	64	3.83	0.99	59	3.94	0.97	57	3.89	0.99	38	3.98	0.85	14	4.29	0.93

Table 4-21

Mixed Effect Model Estimates

	Chi-square	*df*	*p*
Condition	37.43	1	<0.001***
Gender	0.05	1	0.83
Race	4.62	4	0.33
SES	5.06	4	0.28
Year	1.17	1	0.28
Condition: Gender	0.03	1	0.86
Gender: Race	5.71	4	0.22

*p<0.05, **p<0.01, ***p<0.001

CHAPTER 5

DISCUSSION

Research Question 1

Was there an association between condition, gender, race/ethnicity, or socioeconomic class and the STEM career interests of participants in the five years after secondary school?

Results clearly showed STEM career interests are not distributed evenly across groups of condition, gender, race/ethnicity, and socioeconomic status. SMA participants were more likely to express interest in a STEM career, males were more likely to express interest in a STEM career, females were more likely to indicate indecision, and those without an indicator of socioeconomic disadvantage were more likely to express STEM career interest.

The most consistent and prominent relationship indicated by the results was between condition and STEM career interest. These results point to out-of-school science programs as being an important space to foster STEM career interest and reinforce previous studies highlighting the positive effects of out-of-school science programs (Dabney et al., 2012).

However, while the evidence presented in this study certainly points to the positive effects of the SMA program, there are limitations to scope of the conclusions that can be drawn. All out-of-school time science programs are different, so the effects observed in this study cannot be generalized to all programs, especially considering the unique features of the SMA program. Since participants were not randomly assigned to the SMA and comparison groups, we cannot attribute the observed differences in STEM career interest and interest retention over time to participation in the SMA program with certainty.

Notably, the two groups did begin the study with differing levels of STEM career interest. Although the comparison group participants may also be more likely to begin the study with existing science career interest than the general population (since they were either recruited at the Museum of Science and Industry, Chicago, or had visited a science museum in the past year), it is still reasonable to expect the SMA group to exhibit higher science career interest after participating in an out-of-school time science-focused program during high school. Indeed, 77% of SMA group participants had STEM career interest in year one compared to 53% of comparison group participants in year one (Figure 4-5 & Figure 4-6). In a 2019 study, Price et al. found that about half of SMA participants recalled having science career interest before participating in the program, which is very similar to the level of STEM career interest amongst comparison group participants in this study. The same study showed an increase in science career interest in SMA program participants over the course of the program (Price et al., 2019). This provides support that the observed difference in science career interest between SMA and comparison groups at the beginning of this study (after high school and program participation) is at least partially attributable to participation in the SMA program.

However, the two groups, although not identical, were similar in terms of gender identity, age, type of school attended, race/ethnicity, SES, and grades earned during high school, which adds confidence that the differences between the groups were not solely based on existing differences between the groups. Furthermore, since this study was focused on relative change in career interest over time, as well as how participants moved in and out of career interest categories over time, the differing levels of STEM career interest at the outset of the study are not detrimental to the confidence in the results of this study. Given these considerations, including the similarity between the groups, the method of analysis, and the evidence of existing STEM career interest being at least partially attributable to the SMA program; the results presented in this study provide very strong evidence of the effects of the SMA program on STEM career interests, despite noted limitations.

The relationships found with STEM career interest and gender, race/ethnicity, and socioeconomic class were less clear and consistent over time than those with condition, and in some cases were impacted by low sample size. The presence of some statistically significant relationships, however, highlights these areas as important for future inquiry and consideration. Given the connection between career decisions and science identity (Holmegaard et al., 2014), as well as the interplay between gender and racial identity and science identity development; a natural next step would be a qualitative analysis of participant interviews to understand more deeply the connection between STEM career decisions, gender, race/ethnicity, and SES.

Research Question 2

How stable was STEM career interest over three, four, and five year periods after secondary school? Did this stability vary by condition or gender?

Construction and analysis of Sankey diagrams overall showed a high degree of movement between STEM, non-STEM, and undecided career interest categories. This is consistent with the findings of Cannady et al. (2014) and Lykkegaard and Ulriksen (2019); and supports the notion that it is important to recognize and understand varied paths to STEM career interest. Although the paths that began and ended within the same category were still the most common, they still only accounted for just over half of the participants. Furthermore, of participants displaying a seemingly uninterrupted trajectory, 20% indicated a different career interest in the middle of their trajectory.

Similar to the results of Lykkegaard and Ulriksen (2019), the portion of participants with undecided career interests declined steadily in the years after high school. The year after high school was shown to be a particularly important year for career decision making. In particular, the Sankey diagrams constructed by condition illustrated that a significant portion of the SMA participants moved out of STEM career interest between year one and two, which was balanced by a movement back into STEM the next year. There was again a movement out of STEM between year three and four. The results showing movement out of STEM in the first year after high school are consistent with results from other studies (DeWitt & Archer, 2015), and provide further evidence that this is an important year for STEM career decision-making.

In general, females seemed to be more likely to both be undecided in career interests after high school, and to switch career interests more overall. The year after high school is notably an important career decision point for females, with large movements both in and out of STEM career interest. It is possible that females were doing more identity work during this period, especially STEM college majors. Interestingly, patterns of movement showed more pronounced gender differences within the SMA group than in the comparison group.

Overall, there were interesting patterns of movement through career interest categories by condition and gender, and the next step is to contextualize and explain these patterns with qualitative findings from paired interviews.

Research Question 3

How did field of STEM career interest vary by condition, gender, or race/ethnicity?

Cannady et al. (2014) suggested that use of a linear STEM pipeline view of STEM career progression may mask important differences in STEM and engineering subfields. In this study important trends were uncovered when STEM fields were analyzed separately. STEM field career interests clearly varied by condition and gender. SMA participants were more likely to indicate interest in a research scientist career, but less likely to have health/medicine career interest than comparison participants.

Gender results showed females were less likely to express interest in computer science and engineering but more likely to show interest in health/medicine. Unfortunately, these trends mirror documented patterns of underrepresentation of women in STEM fields (Miller & Wai, 2015; Moote, Archer, & DeWitt, 2020; NSF, 2018).

Wong's (2015) finding that underrepresented racial/ethnic minority students may aspire to applied science careers more frequently than White students is mirrored in the distribution of participants across race/ethnicity; with Hispanic/Latinx, Black, and Asian participants aspiring to health/medicine careers at higher rates than White students (Figure 25 & Figure 26). The exception to this trend is that in year three Hispanic/Latinx participants showed a comparatively high interest in research science careers. In this study the sample sizes were limited to explore racial/ethnic trends in STEM career interest, but it is clear that there are important trends to uncover, especially in regards to the interaction between race and gender, as well as race and condition.

Finally, there were significant effects of gender within condition group, but using post-hoc tests uncovered these differences were significant in the comparison group but not the SMA participants. Indeed, when visually comparing the distribution of males and females within condition groups, the distribution across STEM fields of males and females in the SMA group is much more similar than that of males and females in the comparison group (Figure 4-24 & Figure 4-25). This suggests that participation in the SMA program may have helped to mediate some of the effects of structural bias and barriers leading to underrepresentation of females in engineering and computer science. This result may be further explained by the work by Price et al. (2019), who found relationships with staff to be especially impactful for young women in the SMA program and connected to higher levels of STEM career interest.

More focused investigation of particular STEM areas and how they may relate differently to student science identity and SMA participation is necessary to unpack what is behind these trends, especially when considering that a broad definition of STEM careers was used in this study. For instance, Wong (2015) found that some applied science fields, such as medicine, were more attractive to some minority ethnic groups because they are both intrinsically and extrinsically rewarding. Indeed, in this study health seemed to be a unique field in how participants viewed health careers. In the latter years of the study participants were queried if they viewed their most desired career as a STEM career. More participants marked health careers as “non-STEM” than any other STEM career category. Furthermore, compared to engineering and research scientist careers, participants interested in health careers and computer science careers reported lower average science career aspirations (as measured by the DeWitt et al. 2010 composite score). Finally, health career interest differed across SMA participation, gender, and race/ethnicity identity. A higher percentage of comparison group participants, males, and those identifying as Hispanic/Latinx, Black, and Asian were interested in health fields.

Engineering, a career in which a smaller percentage of young women in this study were interested in, has also been identified as problematic for gender equity in other studies. Moote et al. (2020) found some unique trends amongst their study participants aspiring to an engineering career. Lower percentages of young women aspired to engineering careers, and the young women who did aspire to engineering careers had higher self-concept and motivation, but a lower desire to help others compared to their male counterparts (Moote et al., 2020). Further, Moote et al. (2020) concluded that engineering is associated with masculinity from the age of 10. This association is related to the elitist culture and practices of engineering. The authors go on to recommend that future efforts to improve participation in engineering be focused on changing the culture and practices of engineering rather than trying to raise student engineering aspirations.

This recommendation aligns well with the science identity framework of this study. The culture and practices of science can be disinviting or misaligned with the identities of non-White males. This is especially true in some science sub-fields in which the greatest gender disparities exist, such as engineering. As echoed in the recommendations of Moote et al. (2020), science spaces, communities, cultures, and practices must be modified to be welcoming and inclusive of people with diverse identities. Aspiring and current scientists must *not* be expected to modify their identities to be included in science careers and practices. Thus, the onus of change is on the STEM community, not youth aspiring to STEM careers.

This is especially true in informal science-focused youth programs, which are important spaces in which STEM career interest can be fostered compatibly with youths' diverse and changing identities. There is evidence both from past qualitative studies and this study that the SMA program has been successful in supporting science career aspirations, especially amongst young women. In this study, there was less disparity between female SMA participants compared to male SMA participants in STEM fields in which persistent underrepresentation of women exists (Figure 4-24).

This finding is most likely related to SMA providing a supportive and diverse environment where youth can explore and develop their career interests and skills in a way that is not at odds with their own identity development. The SMA environment/programming was designed based on a positive youth development model and was focused on and adaptable to the youth and their personal development and perspectives, rather than the youth being expected to adjust their identities to fit into the SMA program (Mroczkowski, 2021; Price et al., 2019). It seems that by designing science-programming to be secondary to youth development, science interest can more freely develop in this environment.

Other notable features of the SMA program that have been found to be impactful and may contribute to less pronounced STEM underrepresentation trends in SMA graduates are strong relationships with staff, a scaffolded program structure, meaningful opportunities and experiences, and a diverse and supportive peer environment resulting in a strong sense of belonging (Mroczkowski et al., 2021; Price et al., 2019). Some of the meaningful experiences reported by SMA program participants directly relate to gender and race/ethnicity identity, such as Black excellence events, women in science events, and diverse speakers. Furthermore, in interview data, participants cite the overall diversity of youth and staff, especially in terms of gender and racial/ethnic identity, as being impactful (Mroczkowski, 2021). These factors very likely contribute to an inclusive environment in which young women and underrepresented racial/ethnic minorities can develop a strong science identity. Finally, family connections are privileged and fostered in the SMA program, so individuals are less likely to feel a disconnect between their identity at home and their identity at the program.

These findings are especially important considering that although cultural centers such as museums have been highlighted as potentially supportive community spaces for youth development (Mroczkowski, 2021), some studies have found evidence of science museums being problematic learning spaces for girls (Dawson, et al., 2020). One recent study found there was a disconnect between science learning and enacting the identities they were invested in for girls in a particular science museum setting (Dawson, et al., 2020). Our results show that museum spaces such as the Museum of Science and

Industry, Chicago can be equitable and powerful spaces for youth development and science STEM career development, but that programming must be done mindfully. This also highlights the need for future qualitative study focusing on the connection between the identity development of SMA program participants and their specific career choices, which can further inform other youth development programs, especially those housed in museums.

Research Question 4

Did STEM career aspiration vary by year, condition, gender, race/ethnicity, socioeconomic class, or the interactions between these variables in the five years after post-secondary school?

Our result that science aspirations as measured by a construct did not vary by gender, race/ethnicity, or SES is congruent with the work of Dewitt et al. (2010, 2014), DeWitt & Archer (2015), and Wong (2015). These studies found that while many young people have high science aspirations or enjoy science, this does not necessarily translate to STEM career participation. Thus, trends were expected to vary across STEM career interest and science aspirations.

Further investigation is required to unpack the effect of condition on science career aspirations. For instance, next steps would include investigating the relationship between science aspirations and variables such as STEM career interest, STEM field career interest, and science self-image.

Implications

Disparities in representation in STEM careers along gender and racial/ethnic lines are persistent and intractable despite long-term national and international attention. The first recommendation based on Kurt Lewin's model (1947) for systemic change proposed by Estrada et al. (2016) to diversify STEM in higher education is to track and increase awareness of institutional progress towards diversifying STEM. Expanding this idea to a national scope, it is important that know how many young people are interested in STEM careers, and how this interest stays the same or changes.

This study shows how using Sankey diagrams can help elucidate trends of movement in and out of STEM career interest more clearly, especially when specific factors of interest, such as participation in the SMA program, are of interest. The unique longitudinal quasi-experimental study design employed in this study allows for investigation of the influence of participation in a long-term out-of-school youth development program on career interest and/or decisions. This study design affords for greater confidence in programmatic impact results, and the five-year longitudinal time frame allows for greater insight into post-secondary career interests. Thus, this study fills an important need amongst the body of literature investigating the long-term impacts of informal science-focused youth development programs.

These results can then be used to inform programs designed to support youth in their overall development and career decisions during and after post-secondary school. For instance, movement trends highlighted the year after high school as an especially important year for STEM career decision-making, especially for young women. Thus, the SMA program may decide to extend its outreach program to include program alumni during their first year of college.

Across the four research questions, the overarching result is that there is a relationship between condition, or participation in the SMA program, and the outcome variables of STEM career interest and science aspirations. There is also evidence that participation in the SMA program may help mediate barriers impeding young women in STEM fields in which women are underrepresented. This is in line with evidence that participation in out-of-school programs can lead to long-term interest or engagement with science and science career interest (Dabney et al., 2012; Krishnamurthi et al., 2014; McCreedy & Dierking, 2013; NRC, 2015). Afterschool programs and out-of-school programs provide important opportunities to lessen the opportunity gap (Deutsch, 2019), as they often have broader participation of youth from diverse socioeconomic, gender, and racial/ethnic backgrounds, and therefore these programs can offer meaningful and engaging science opportunities to a more diverse audience (Afterschool Alliance, 2015).

Limitations and Future Directions

There are two main limitations of this study. The sample is somewhat small and not randomly distributed amongst the treatment groups. Therefore, the scope of the conclusions and generalizations that can be drawn from quantitative analyses, especially subgroup analyses, were limited. Also, since the treatment (SMA participants) and comparison groups were not assigned randomly, we cannot draw the conclusion that observed differences in condition groups are only due to participation in the program. However, data collection in ongoing and will continue for as long as possible, thus more data covering a longer period post-high school will be available every year.

Furthermore, there are accompanying longitudinal interviews of SMA participants available, and subsequent analysis of these interviews will help to elucidate the reasons behind the quantitative trends observed in this study. Qualitative examination of the relationship between STEM career interest and racial/ethnic identity is especially important as the usefulness of the inferential quantitative analyses in this study was limited due to sample size and data structure. Gender, class, race/ethnicity, and the intersections between these identities interact with career aspiration formation and paint a complex picture. Thus, a longitudinal mixed-methods study designed to better understand this complex process through the experiences of young women, underserved racial/ethnic minorities (especially young women of color), is a logical next step.

REFERENCES

Afterschool Alliance (2015). *Full STEM ahead: Afterschool programs step up as key partners in STEM education.* Washington, DC.

Archer, L. & DeWitt, J. (2016). *Understanding young people's science aspirations: How students form ideas about 'becoming a scientist'.* New York, NY: Routledge.

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2012). Science aspirations, capital, and family habitus: How families shape children's engagement and identification with science. *American Educational Research Journal, 49*(5), 881-908.

Archer, L. DeWitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2013). Not girly, not sexy, not glamorous: primary school girls' and parents' constructions of science aspirations. *Pedagogy, Culture, and Society, 21*(1), 171-194.

Archer, L. DeWitt, J., & Willis, B. (2014). Science aspirations: Masculinity, capital, and power. *Journal of Research in Science Teaching, 51*(1), 1-30.

Aschbacher, P. R., Li, E., & Roth, E. J. (2010). Is science me? High school students' identities, participation, and aspirations in science, engineering, and medicine. *Journal of Research in Science Teaching, 47*, 564-582.

Askinadze, A., Liebeck, M., Conrad, S. (2019). Using venn, Sankey, and UpSet diagrams to visualize students' study progress based on exam combinations. *Companion Proceedings 9th International Conference on Learning Analytics & Knowledge (LAK19), Tempe, AZ, USA*. Retrieved from https://dbs.cs.uni-duesseldorf.de/publikationen/2019/visla_2019_askinadze_et_al.pdf.

Berge, D. (2015). Chi-squared test of fit and sample size— A comparison between a random sample approach and a chi-square value adjustment method. *Journal of Applied Measurement, 16*(2), 204-17.

Blickenstaff, J.C. (2005). Women and science careers: leaky pipeline or gender filter? *Gender and Education, 17*(4), 369-386.

Brickhouse, N. (1994). Bringing in the outsiders: Reshaping the sciences of the future. *Journal of Curriculum Studies, 26*(4), 401-416.

Brickhouse, N.W. (2001). Embodying science: A feminist perspective on learning. *Journal of Research in Science Teaching, 38*, 282-295.

Brickhouse, N.W., Lowery, P., & Schultz, K. (2000). What kind of girl does science? The construction of school science identities. *Journal of Research in Science Teaching, 37,* 441-458.

Brickhouse, N.W., & Potter, J.T. (2001). Young women's scientific identity formation in an urban context. *Journal of Research in Science Teaching, 38*(8), 965-980.

Bronfenbrenner, U. (1979). *The ecology of human development: Experiments by nature and design.* Cambridge, MA: Harvard University Press.

Brown, B.A. (2004). Discursive identity: Assimilation into the culture of science and its implications for minority students. *Journal of Research in Science Teaching, 41*(8), 810-834.

Calabrese Barton, A. (1998). *Feminist science education.* New York, NY: Teachers College Press.

Calabrese Barton, A., Tan, E., & Rivet, A. (2008). Creating hybrid spaces for engaging school science among urban middle school girls. *American Educational research Journal, 45,*68-103.

Calabrese Barton, A., & Yang, K. (2000). The culture of power and science education: Learning from Miguel. *Journal of Research in Science Teaching, 37*(8), 871-889.

Cannady, M.A., Greenwald, E., & Harris, K.N. (2014). Problematizing the STEM pipeline metaphor: Is the STEM pipeline metaphor serving our students and the STEM workforce? *Science Education, 98*(3), 443-460.

Carlone, H.B. & Johnson, A. (2007). Understanding the science experiences of successful women of color: Science identity as an analytic lens. *Journal of Research in Science Teaching, 44*(8), 1187-1218.

Catalano, R.F., Berglund, M.L., Ryan, J. M., Lonczak, H.S., & Hawkins, J.D. (2004). Positive Youth Development in the United States: Research Findings on Evaluations of Positive Youth Development Programs. *The ANNALS of the American Academy of Political and Social Science (AAPSS), 591*(1), 98-124.

Chang, M.J., Eagan, M.K., Lin, M.H., & Hurtado, S. (2011). Considering the impact of racial stigmas and science identity: Persistence among biomedical and behavioral science aspirants. *The Journal of Higher Education, 82*(5), 564-596.

Chemers, M.M., Zurbriggen, E.L., Syed, M., Goza, B.K., & Bearman S. (2011). The role of efficacy and identity in science career commitment among underrepresented minority students. *Journal of Social Issues, 67*, 469-491.

Cohen, J. (1988). *Statistical power and analysis for the behavioral sciences.* Hillsdale, NJ: Lawrence Erlbaum Associates.

Croll, P. (2008). Occupational choice, socio-economic status and educational attainment: A study of the occupational choices and destinations of young people in the British Household Panel Survey. *Research Papers in Education, 23*(3): 243-268.

Cundiff, J.L., Vescio, T.K., Loken, E., & Lo, L. (2013). Do gender-science stereotypes predict science identification and science career aspirations among undergraduate science majors? *Social Psychology of Education, 16*, 541-554.

Dabney, K.P., Tai, R.H., Almarode, J.T., Miller-Friedmann, J.L., Sonnert, G., Sadler, P.M. & Hazari, Z. (2012). Out-of-school time science activities and their association with career interest in STEM. *International Journal of Science Education, Part B, 2*(1), 63-79.

Dawson, E., Archer, L., Seakins, A., Godec, S., DeWitt, J., King, H., Mau, A., & Nomikou, E. (2020). Selfies at the science museum: Exploring girls' identity performances in a science learning space. *Gender and Education, 32*(5), 664-681.

Deutsch, N. (2019, April). Why defunding after-school programs will widen the opportunity gap. *Fortune.*

DeWitt, J. & Archer, L. (2015) Who aspires to a science career? A comparison of survey responses from primary and secondary school students. *International Journal of Science Education, 37*(13), 2170-2192.

DeWitt, J., Archer, L., & Osborne, J. (2014). Science-related aspirations across the primary-secondary divide: evidence from two surveys in England. *International Journal of Science Education, 36*(10), 1609-1629.

DeWitt, J. Archer, L., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2010). High aspirations but low progression: The science aspirations-careers paradox amongst minority ethnic students. *International Journal of Science and Mathematics Education, 9,* 243-271.

Du, X. & Wong, B. (2019). Science career aspiration and science capital in China and UK: A comparative study using PISA data. *International Journal of Science Education, 41*(15), 2136, 2155.

Ellis, J., Fosdick, B.K., Rasmussen, C. (2016). Women 1.5 times more likely to leave STEM pipeline after calculus compared to men: Lack of mathematical confidence a potential culprit. *PLoS ONE 11*(7), 1-14.

Engineering Infrastructure Diagramming and Modeling (978-0-309-03639-9). (1986). Retrieved from Washington, DC: http://www.nap.edu/catalog/587/engineering-infrastructure-diagraming-and-modeling

Estrada, M., Burnett, M., Campbell, A.G., Campbell, P.B., Denetclaw, W.F., Gutierrez, C.G., Hurtado, S., John, G.H., Matsui, J., McGee, R., Okpodu, C.M., Robinson, T.J., Summers, M.F., Werner-Washburne, M., Zavala, M. (2016). Improving underrepresented minority persistence in STEM. *Life Sciences Education, 15*(5), 1-10.

Falk, J.H., Koke, J., Price, C.A., & Pattison, S. (2018). Investigating the cascading, long term effects of informal science education experiences report. Beaverton, Oregon: Institute for Learning Innovation.

Gee, J.P. (2000). Identity as an analytic lens for research in education. *Review of Research in Education, 25*, 99-125.

Hazari, Z., Sadler, P.M., & Sonnert, G. (2013). The science identity of college students: exploring the intersection of gender, race, and ethnicity. *Journal of College Science Teaching, 42*(5), 82-91.

Heileman, G.L., Babbitt, T.H., & Abdallah, C.T. (2015). Visualizing student flows: Busting myths about student movement and success. *Change: The Magazine of Higher Learning, 47*(3), 30-39.

Herrera, F.A., Hurtado, S., Garcia, G.A., & Gasiewski, J. (2012). A model for redefining STEM identity for talented STEM graduate students. *Paper Presented at the American Educational Research Association Annual Conference,* Vancouver, BC.

Holmegaard, T., Madsen, L.M., & Ulriksen, L. (2014). The choose or not to choose science: Constructions of desireable identities among young people considering a STEM higher education programme. *International Journal of Science Education, 36*(2), 186-215.

Jeong, H.J., & Lee, W.C. (2017). Rethinking the assumptions of chi-squared and Fisher's exact tests. *Biometrics and Biostatistics International Journal, 6*(1), 300-301.

Kane, J. (2011). Young African American children constructing academic identities in an urban science classroom. *Science Education, 96*, 457-487.

Kim, H-Y. (2017). Statistical notes for clinical researchers: Chi-squared test and Fisher's exact test. *Restorative Dentistry and Endodontics, 42*(2), 152-155.

Krishnamurthi, A., Ballard, M., & Noam, G. (2014). *Examining the impact of afterschool STEM programs*. Washington, DC: Noyce Foundation.

Lauer, M. (2019, November). Expanding NIH's definition of socio-economic disadvantaged to be more inclusive and diversify the workforce. *Extramural NEXUS*, National Institutes of Health (NIH). Retrieved online from https://nexus.od.nih.gov/all/2019/11/26/expanding-nihs-definition-of-socio-economic-disadvantaged-to-be-more-inclusive-and-diversify-the-workforce/

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation.* Cambridge: Cambridge University Press.

Lemke, J. (1990). *Talking science: Language, learning and values.* Norwood, NJ: Ablex.

Lerner, J.V., Phelps, E., Forman, Y., & Bowers, E. (2009). Positive youth development. In Lerner, R.M., & Steinberg, L. (Eds.), *Handbook of adolescent psychology, Volume 2* (pp. 524-558). Hoboken, NJ: John Wiley & Sons.

Lewin, K. (1947). *Frontiers in group dynamics.* London, UK: Social Science Paperbacks.

Lykkegaard, E. & Ulriksen, L. (2019). In and out of the STEM pipeline – a longitudinal study of a misleading metaphor. *International Journal of Science Education, 41*(12), 1600-125.

Lyons, T. & Quinn, F. (2010, November). *Looking back: Students' perceptions of the relative enjoyment of primary and secondary school science.* Paper presented at the STEM in Education Conference, Queensland University of Technology, Brisbane, Australia.

Mann, A. Legewie, J. & DiPrete, T.A. (2015, February). The role of school performance in narrowing gender gaps in the formation of STEM aspirations: A cross-national study. *Frontiers in Psychology*. Retrieved from https://doi.org/10.3389/fpsyg.2015.00171

Maltese, A.V. & Tai, R.H. (2010). Eyeballs in the fridge: Sources of early interest in science. *International Journal of Science Education, 32*(5), 669-685.

McCreedy, D. & Dierking, L.D. (2013). Cascading influences: Long-term impacts of informal STEM experiences for girls. Philadelphia, PA: The Franklin Institute.

McDonald, J.H. (2014). Tests for nominal variables: Chi-square test of independence. In McDonald, J.H., *Handbook of Biological Statistics, 3rd edition* (59-67). Retrieved from http://www.biostathandbook.com/chiind.html

McHugh, M.L. (2013). The chi-square test of independence. *Biochemia Medica, 23*(2), 143-149.

Miller, D.I., & Wai, J. (2015). The bachelor's to Ph.D. STEM pipeline no longer leaks more women than men: a 30-year analysis. *Frontiers in Psychology, 6*, 1-10.

Moote, J., Archer, L., DeWitt, J., & MacLeod, E. (2020). Comparing students' engineering and science aspirations from age 10 to 16: Investigating the role of gender, ethnicity, cultural capital, and attitudinal factors. *Journal of Engineering Education, 109,* 34-51.

Morse, C. (2014). *Visualization of Student Cohort Data With Sankey Diagrams via Web-Centric Technologies* (master's thesis). University of New Mexico, Albuquerque, New Mexico.

Mroczkowski, A.L., Price, C.A., Harris, N.C., & Skeeles-Worley, A.D. (2021). Youths' perceptions of features of a museum-based youth development program that create a supportive community context: A qualitative case study. *Journal of Adolescent Research.*

National Research Council (2015). *Identifying and Supporting Productive STEM Programs in Out-of-School Settings.* Retrieved from http://www.nsf.gov/pubs/2014/nsf14590.htm

National Science Foundation. (2014). *STEM education data and trends 2014.* Retrieved from https://www.nsf.gov/nsb/sei/edTool/data/college

National Science Foundation, National Science Board. (2018). *Science and Engineering Indicators 2018.* Retrieved from https://nsf.gov/statistics/2018/nsb20181/report.

Nature (2016). Is science only for the rich?. *Nature 537*, 466-470.

Neild, R.C., Wilson, S.J., & McClanahan, W. (2019). *Afterschool programs: A review of evidence under the Every Student Succeeds Act*. Philadelphia, PA: Research for Action.

Niu, L. (2017). Family socioeconomic status and choice of STEM major in college: An analysis of a national sample. *College Student Journal, 51*(2), 298-312.

NSF Approved STEM Fields (2014). Retrieved from the Big Ten Academic Alliance website on March 4, 2021. https://www.btaa.org/docs/default-source/diversity/nsf-approved-fields-of-study.pdf?sfvrsn=1bc446f3_2

Osborne, J.W., & Walker, C. (2006). Stereotype threat, identification with academics, and withdrawal form school: Why the most successful students of colour might be most likely to withdraw. *Educational Psychology, 26*, 563-577.

Phillips, K.W. (October 1, 2014). How diversity makes us smarter. *Scientific American.* Retrieved from https://www.scientificamerican.com

Price, C.A., Kares, F., Segovia, G., & Brittian Loyd, A. (2019). Staff matter: Gender differences in science, technology, engineering or math (STEM) career interest development in adolescent youth. *Applied Developmental Science, 23*(3), 239-254.

Prinzie, P. & Onghena, P. (2005). Cohort sequential design. In B. Everitt & D. Howell (Eds.), *Encyclopedia of Statistics in Behavioral Science* (pp.319-322). Chichester, West Sussex, JK: John Wiley & Sons.

RStudio (Version 1.0.153). [Computer software]. RStudio, Inc.

Riegle-Crumb, C., Moore, C., & Ramos-Wada, A. (2010). Who wants to have a career in science or math? Exploring adolescents' future aspirations by gender and race/ethnicity. *Science Education, 95*(3).

Rozek, C.S., Svoboda, R.C., Harackiewicz, J.M., Hulleman, C.S., & Hyde, J.S. (2017). Utility-value intervention with parents increases students' STEM preparation and career pursuit. *PNAS, 114 (5)*, 909-914.

Sadler, P.M., Sonnert, G., Hazari, Z., & Tai, R. (2012). Stability and volatility of STEM career interest in high school: A gender study. *Science Education, 96*(3), 411-427.

Sahin, A., Gulacar, O. & Stuessy, C. (2015). High school students' perceptions of the effects of international science Olympiad on their STEM career aspirations and twenty-first century skill development. *Research in Science Education, 45*, 875-805.

Schoon, I., Ross, A., & Martin, P. (2007) Science related careers: aspirations and outcomes in two British cohort studies. *Equal Opportunities International, 26*(2), 129-143.

Seltman, H.J. (2009). Mixed models. A flexible approach to correlated data. In *Experimental Design and Analysis, Chapter 15* (pp. 357-378). Retrieved from http://www.stata.cmu.edu/_hseltman/309/Book/Book.pdf

Shan, G., & Gerstenberger, S. (2017). Fisher's exact approach for post hoc analysis of a chi-squared test, *PloS one, 12*(12), 1-12: e0188709

Stata (Version 14.2 for Mac). [Computer software]. College Station, TX: StataCorp.

St. Clair, R., & Benjamin, A. (2011). Performing desires: the dilemma of aspirations and educational attainment. *British Educational Research Journal, 37*(3), 501-517.

Steinke, J. (2017). Adolescent girls' STEM identity formation and media images of STEM professionals: Considering the influence of contextual clues. *Frontiers in Psychology, 8*, 1-15.

Strand, S., & Winston, J. (2008). Educational aspirations in inner city schools. *Education Studies, 34*(4), 249-267.

Staus, N. L., Falk, J. H., Price, C. A., Tai, R. H. & Dierking, L. D. (2021). Measuring the long-term effects of informal education experiences: Challenges and potential solutions. *Disciplinary and Interdisciplinary Science Education Research.* doi: /10.1186/s43031-021-00031-0

Strayhorn, T. (2015). Factors influencing black males' preparation for college and success in STEM majors: A mixed methods study. *The Western Journal of Black Studies, 39,* 45-63.

Syed, M., Azmitia, M., & Cooper, C.R. (2011). Identity and academic success among underrepresented minorities: An interdisciplinary review and integration. *Journal of Social Issues, 67*(3), 442-468.

Tai, R.H., Qi Liu, C., Maltese, A.V., Fan, X. (2006). Planning early careers in science. *Science, 312,* 1143-1144.

Tan, E., Calabrese Barton, A., Kang, H., & O'Neill, T. (2013). Desiring a career in STEM-related fields: How middle school girls articulate and negotiate identities-in-practice in science. *Journal of Research in Science Teaching, 50*(10), 1143-1179.

Thomson, R., Bell, R., Holland, J., Henderson, S., McGrellis, S., & Sharpe, S. (2002). Critical moments: Choice, change and opportunity in young people's narratives of transition. *Sociology – the Journal of the British Sociological Association, 36*(2), 335-354.

Tobias, S. (1990). They're not dumb. They're different. A new tier of talent for science. *Change 22*, 11-30.

Trujillo, G., & Tanner, K.D. (2014). Considering the role of affect in learning: Monitoring students' self-efficacy, sense of belonging, and science identity. *CBE Life Sciences Education, 13*, 6-15.

Turner, S.L. & Lapan, R.T. (2005). Evaluation of an intervention to increase non-traditional career interest and career-related self-efficacy among middle-school adolescents. *Journal of Vocational Behavior, 66*, 516-531.

Tytler, R. (2014). Attitudes, identity, and aspirations toward science. In N.G. Lederman & S.K. Abell (Ed.). *Handbook of Research on Science Education* (82-103). London: England: Routledge.

van den Hurk, A., Meelissen, M., & van Langen, A. (2019). Interventions in education to prevent STEM pipeline leakage. *International Journal of Science Education, 41*(2), 150-164.

Webb, R. M., Lubinski, D., & Benbow, C. P. (2002). Mathematically facile adolescents with math-science aspirations: New perspectives on their educational and vocational development. *Journal of Educational Psychology, 94*(4), 785-794.

Weinburgh, M.H. & Steele, D. (2000). The modified attitudes toward science inventory: Developing an instrument to be used with fifth grade urban students. *Journal of Women and Minorites in Science and Engineering, 6*, 87-94.

Wenger, E. (1998). *Communities of practice*. New York, NY: Cambridge University Press.

West, B.T., Welch, K.B., & Galecki, A.T. (2006). *Linear mixed models: A practical guide using statistical software.* Retrieved from ProQuest Ebook Central.

White, J.W., & Lowenthal, P.R. (2011). Minority college students and tacit "codes of power": Developing academic discourses and identities. *The Review of Higher Education, 34*(2), 283-318.

Williams, J.L. & Deutsch, N.L. (2016). Beyond between-group differences: Considering race, ethnicity, and culture in research on positive youth development programs. *Applied Developmental Science, 20,* 203-213.

Wong, B. (2015). Careers "from" but not "in" science: Why are aspirations to be a scientist challenging for minority ethnic students? *Journal of Research in Science Teaching, 52*(7).

Yoshikawa, H., Mistry, R. & Wang, Y. (2016). Advancing methods in research on Asian American children and youth. *Child Development, 87*(4), 1033-1050.

Young, J.L., Feille, K.K., & Young, J.R. (2017). Black girls as learners and doers of science: A single-group summary of elementary science achievement. *Electronic Journal of Science Education, 21*(2), 1-20.

Appendix A

NSF Approved STEM Fields

CHEMISTRY
Chemical Catalysis
Chemical Measurement and Imaging
Chemical Structure, Dynamics, and Mechanism Chemical Synthesis
Chemical Theory, Models and Computational Methods Chemistry of Life Processes
Environmental Chemical Systems
Macromolecular, Supramolecular, and Nanochemistry Sustainable Chemistry
Chemistry, other (specify)
COMPUTER AND INFORMATION SCIENCE AND ENGINEERING (CISE)
Algorithms and Theoretical Foundations Communication and Information Theory Computational Science and Engineering Computer and Information Security Computer Architecture
Computer Systems, Networking, and Embedded Systems Databases
Data Mining and Information Retrieval
Graphics and Visualization
Human Computer Interaction
Informatics
Machine Learning
Natural Language Processing
Robotics and Computer Vision
Software Systems and Software Engineering CISE, other (specify)
ENGINEERING
Aeronautical and Aerospace Bioengineering
Biomedical
Chemical Engineering
Civil Engineering
Computer Engineering
Electrical and Electronic
Energy
Environmental
Industrial Engineering & Operations Research Materials
Mechanical
Nuclear
Ocean
Optical Engineering
3/7/2014

NSF Approved STEM Fields

ENGINEERING (continued)
Polymer
Systems Engineering Engineering, other (specify)
GEOSCIENCES

Atmospheric Chemistry
Aeronomy
Biogeochemistry
Biological Oceanography
Chemical Oceanography
Climate and Large-Scale Atmospheric Dynamics Geobiology
Geochemistry Geodynamics Geophysics
Glaciology
Hydrology Magnetospheric Physics Marine Biology
Marine Geology and Geophysics Paleoclimate
Paleontology and Paleobiology Petrology
Physical and Dynamic Meteorology Physical Oceanography Sedimentary Geology
Solar Physics
Tectonics
Geosciences, other (specify)
LIFE SCIENCES
Biochemistry Biophysics
Cell Biology Developmental Biology Ecology
Environmental Science Evolutionary Biology Genetics
Genomics Microbiology Molecular Biology Neurosciences Organismal Biology Physiology
3/7/2014
LIFE SCIENCES (continued)
Proteomics
Structural Biology Systematic Biology
Life Sciences, other (specify)
MATERIALS RESEARCH
Biomaterials
Ceramics
Chemistry of materials Electronic materials Materials theory Metallic materials Photonic materials Physics of materials Polymers
Materials Research, other (specify)
MATHEMATICAL SCIENCES
Algebra, Number Theory, and Combinatorics Analysis
Applied Mathematics
Biostatistics
Computational and Data-enabled Science Computational Mathematics Computational Statistics
Geometric Analysis
Logic or Foundations of Mathematics Mathematical Biology
Probability
Statistics
Topology
Mathematics, other (specify)
PHYSICS AND ASTRONOMY
Astronomy and Astrophysics
Atomic, Molecular and Optical Physics Condensed Matter Physics
Nuclear
Particle Physics
Physics of Living Systems

Plasma
Solid State
Theoretical Physics
Physics, other (specify)

NSF Approved STEM Fields

3/7/2014

NSF Approved STEM Fields

PSYCHOLOGY
Cognitive
Cognitive Neuroscience Computational Psychology Developmental
Experimental or Comparative Industrial/Organizational Neuropsychology
Perception and Psychophysics Personality and Individual Differences Physiological
Psycholinguistics
Quantitative
Social
Psychology, other (specify)

SOCIAL SCIENCES
Archaeology
Biological Anthropology
Cultural Anthropology
Anthropology, other
Communications
Decision Making and Risk analysis Economics (except Business Administration) Geography
History and Philosophy of Science International Relations
Law and Social Science
Linguistics
Linguistic Anthropology
Medical Anthropology
Political Science
Public Policy
Science Policy
Sociology (except Social Work)
Urban and Regional Planning
Social Sciences, other (specify)

STEM EDUCATION AND LEARNING RESEARCH
Engineering Education
Mathematics Education
Science Education
Technology Education
STEM Education and Learning Research, other (specify)
3/7/2014

Appendix B

List of Questionable Fields and What they were coded
“yes” indicates STEM field, “no” indicated non-STEM field

Accountant	yes
actuarial science	yes
actuary	yes
banking	no
commercial real estate analyst	no
content creator	no
cosmetology	yes
criminal justice	no
cybersecurity analyst	yes
electrician	yes
EMT & Outdoor guide	yes
finance	no
financial career	no
financial planning	no
game design	yes
game development, focus in art	no
graphic artist	no
graphic design/visual artist	no
Graphic designer, artist	no
holistic healthcare sciences	yes
homicide detective	no
Math teacher	yes
physical therapy	yes
political tech	yes
program analyst for government contractor or community organizer	no
speech language pathologist/translator	yes
storyboard artist or something involving graphic design, creating films and animation	no
Storyboard artist/graphic designer	no
technical writing/copywriter	no
therapist, naturopathic doctor	yes
UX/UI design (I looked it up, a digital experience designer)	yes