Investigating the effect of an immersive extracurricular STEM program on underrepresented and disadvantaged high school students' self-efficacy, science anxiety, and career aspirations

Nikki Mertz
INVESTIGATING THE EFFECT OF AN IMMERSIVE EXTRACURRICULAR
STEM PROGRAM ON UNDERREPRESENTED AND DISADVANTAGED HIGH
SCHOOL STUDENTS’ SELF-EFFICACY, SCIENCE ANXIETY, AND CAREER
ASPIRATIONS

by

NIKKI MERTZ

A DISSERTATION

Submitted in partial fulfillment of the requirements
for the degree of Doctor of Philosophy
in
The Biotechnology Science and Engineering Program
to
The School of Graduate Studies
of
The University of Alabama in Huntsville

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ABSTRACT
The School of Graduate Studies
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Degree Doctor of Philosophy Program Biotechnology Science and Engineering

Name of Candidate Nikki Mertz

Title: Investigating the effect of an immersive extracurricular STEM program on underrepresented and disadvantaged high school students' self-efficacy, science anxiety, and career aspirations

This mixed methods study was designed to assess how an immersive extracurricular STEM program affected a student's self-efficacy, science anxiety, and career aspirations. This study utilized the SIC-STEM survey to quantify student self-efficacy in science and the STEM Semantics survey to quantify student interest in STEM. Both surveys also assessed student interest in pursuing careers in STEM. The Science Anxiety survey was used to evaluate how student anxiety in science changed throughout the study. A subject matter survey was utilized to quantify student understanding and comprehension of an advanced science topic. Focus groups were used as the qualitative piece to tie everything together. The L.A.B.S. (Launching Aspiring Biotechnology Scientists) program for underrepresented and disadvantaged high school students at HudsonAlpha Institute for Biotechnology was used as the setting for this study. Thirty-five high school students in three separate cohorts participated in the study, with most considered to be underrepresented, disadvantaged, or both. Increasing diversity in the STEM workforce is crucial to ensure the continuation of STEM innovation for decades to come. Providing underrepresented and disadvantaged high school students with opportunities to discover that there is a way for them to succeed in a STEM career will make strides to help them
overcome systemic barriers and increase diversity. Significant results were not achieved when examining the three groups independently. However, significant results were seen when comparing genders. Findings suggest that female students’ confidence in working in a laboratory setting and interest in pursuing a STEM degree were positively affected by their participation in the L.A.B.S. program. Continuing to offer programs such as L.A.B.S. and finding ways to support diverse students will help the overall goal of having an inclusive and diverse STEM workforce in the future.
ACKNOWLEDGMENTS

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In memory of Jennifer Hardinger and Dr. Kimberly Strong.
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<td>STEM</td>
<td>Science, Technology, Engineering, and Mathematics</td>
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<td>L.A.B.S.</td>
<td>Launching Aspiring Biotechnology Scientists</td>
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<td>CRISPR</td>
<td>Clustered Regularly Interspaced Short Palindromic Repeats</td>
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<td>US</td>
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<td>Programme for International Student Assessment</td>
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<td>OECD</td>
<td>Organisation for Economic Cooperation and Development</td>
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CHAPTER 1

INTRODUCTION

1.1 Overview

One way to ensure the continuation of STEM innovation for decades to come is by increasing diversity in the STEM workforce. Students who face discrimination are more likely to doubt their math and science abilities, making them less likely to pursue a career where those subjects are primary[1]. To help students overcome systemic barriers and increase diversity in STEM, providing underrepresented and disadvantaged high school students with opportunities to explore STEM experiences is crucial. Student participation in STEM activities in settings with a more diverse group of peers has been linked to better academic outcomes[2]. However, access to these activities is often a barrier due to availability or cost. The L.A.B.S. program for underrepresented and disadvantaged high school students at HudsonAlpha Institute for Biotechnology directly addresses this need by offering a no-cost after-school learning experience in foundational biology topics and lab skills. The program culminates in a week-long intensive summer session focusing on a cutting-edge biotechnology technique, CRISPR. This approach is unique because there are currently no other programs in Alabama teaching hands-on CRISPR labs and no free after-school or summer STEM programs in Madison County, AL, outside of those offered through HudsonAlpha. Giving students the opportunity to
build these foundational skills and apply them in an advanced science experiment should increase their confidence and interest in their ability to pursue and succeed in a career within the STEM workforce.

1.2 The Need for Diversity in STEM

In recent years, an emphasis has been placed on increasing student interest in STEM fields and in pursuing STEM careers. STEM careers have an underrepresentation of women and racial minorities, and recent studies have shown that highly talented students, once interested in STEM careers, are changing to other non-STEM options[3], [4]. Lesser pay and a non-inclusive environment lacking matched-background mentors are all factors that racial minorities and women have reported as a reason for turning away from the STEM workforce. The emphasis on the STEM workforce is due, in part, to upholding America's position in the global economy, increasing concerns about sustainability, and ensuring students can attain rewarding and profitable careers[5], [6]. Therefore, a need to draw students' interest in STEM fields must meet the demand for future STEM innovation, economic growth, and sustainability requirements. The focus in college tends to be on promoting student achievement to ensure students persist in STEM majors, even though most students in college have already decided on their career trajectories [7]. Therefore, it might be more beneficial to increase interest in STEM careers for high school students who have yet to decide upon a career path.

Employment in STEM occupations is projected to increase 8% between 2019 and 2029 compared to only a 3.4% increase in non-STEM occupations, as reported by the U.S. Bureau of Labor Statistics[8]. According to a report by the U.S. Census Bureau,
women make up 48% of US workers but only 27% of the STEM workforce[9]. Even though this is a significant gain from 1970, when women made up just 8% of the STEM workforce, they are still underrepresented. Similar statistics of underrepresentation can be seen in certain racial groups as well. Black and Hispanic individuals comprise 12% and 15% of the U.S. workforce but only account for 5% and 6% of the STEM workforce, respectively[10].

Disadvantaged students are defined as those whose family, social, or economic circumstances hinder their ability to learn at school[11]. Access to schools with higher scores on national and state standardized tests is tied to higher housing costs and exclusionary zoning within school districts[12]. This barrier correlates with low-income students usually only having access to lower-performing schools with fewer resources since these schools are disproportionately located in disadvantaged areas[13]. Lower-performing schools tend to lack funding to help increase their performance because most funding for public schools comes from the local community[14]. Black, Hispanic, and other students of color often attend schools with fewer resources. Schools with 90% or more students of color spend $733 less per student per school year compared to schools with white students making up 90% or more of the population[15].

With attendance at these lower-performing schools, disadvantaged students also have little to no access to AP courses[16]. Even when disadvantaged students have access to AP courses, they remain underrepresented. Hispanic and Black students represent 38% of students in schools that offer AP courses, yet only 29% of students enrolled in at least one AP course[17]. Taking AP courses in high school gives students
an upper hand in college readiness and reduces the time it takes to earn a degree. AP courses also increase students' interest and persistence in STEM careers[18].

1.3 Active Learning and Implications

An effective way to increase students' interest and performance is to have them participate in active learning. Active learning requires students to fully engage by discussing, thinking about, and investigating the subject they are studying. Students should also propose solutions to problems they identify[19]. Compared to more traditional teaching methods, such as lecturing, active learning has been shown to increase student retention and interest in the subject matter[20]. In particular, studies have shown that active learning in STEM fields increases student performance[21]. Also, underrepresented groups in undergraduate STEM classes benefited and narrowed gaps when active learning was the mode of teaching employed in the classroom[22].

Another benefit of active learning is that students collaborate with their peers and learn from them as well. Instead of learning solely from the instructor, peer-to-peer collaboration tends to motivate the student and can help facilitate learning of challenging subject matter and increase their self-efficacy[23]. Self-efficacy is a judgment of one's ability to deal with any situation based on one's skill set[24]. Support from peer groups has been especially beneficial to women who pursue a STEM career, and high STEM self-efficacy is a strong predictor of career choice for women[25], [26]. When students see their peers excited and interested in a subject matter, it increases their interest in that subject, which is especially true in STEM courses[27]. Self-efficacy influences performance, goals, interests, and persistence[28], [29]. Self-efficacy in STEM courses is
one of the best motivators for persistence, and active learning has been shown to increase self-efficacy[30].

The L.A.B.S. program is for underrepresented and disadvantaged high school students who have stated they are interested in pursuing a STEM career. Students receive direct instruction in foundational subject matter, then apply that information during active learning activities. The L.A.B.S. students work with their peers in HudsonAlpha Institute for Biotechnology's state-of-the-art laboratories with equipment they would not otherwise have access to in their high school. Background information and laboratory experiments reinforce content covered in school and enrich new material. By incorporating hands-on activities, active learning, peer group discussions, independent thinking, and positive reinforcement, the L.A.B.S. program provides these underrepresented and disadvantaged students with the knowledge and skills necessary to pursue a STEM major in college, work in a laboratory setting to gain research experience, and ultimately join the STEM workforce.

As part of a culmination of the L.A.B.S. program, students will spend a week in the summer exploring a cutting-edge biotechnology technique. Studies have shown that high school students become excited and more interested in learning about STEM subjects and their real-world applications when state-of-the-art techniques are brought into the classroom. Social media posts, news stories, and the internet give students almost instant access to information about the latest technology. Students realize these new techniques are not found in their textbooks but rather in real life, making the material more appealing and engaging. Students have a greater appreciation for the real-world applications of these techniques. 71% of students stated they are more interested in
continuing in STEM at the next level of study and in their careers after exposure to the most up-to-date techniques in their classroom[31]–[33]

1.4 Social Cognitive Career Theory

Social cognitive career theory (SCCT) is a broad theory that is used to help explain career outcomes by focusing on the interplay between goals, outcome expectations, and self-efficacy[29], [34]. This theory is culturally sensitive and useful when addressing career development in diverse populations[35]–[37]. The SCCT model has also been used to study high school students’ STEM career goal development[38], [39]. SCCT incorporates the use of three interconnected models, but they can also each stand on their own as an individual framework. These are the Choice, Interest, and Performance Models[40]. The Performance Model is beyond the scope of this study and will not be included.

Self-efficacy and outcome expectations of activities that a student performs has a direct affect on the ensuing cultivation of their interests. Also, the students’ developing interests from engaging in these activities help promote goal formation. These goals then perpetuate the likelihood that students will continue to engage in activities. A feedback loop is ultimately established for the achievements gained from the activities in which the students engage. That engagement will help maintain or change self-efficacy and outcome expectations, which will then maintain or change interest and continue the feedback loop essential in the described Interest Model[40].

The Choice Model delves further into the goals and actions described in the Interest Model. The goals are defined as career-related goals, and the actions investigate
the measures the students take that are required for them to implement the career-related
goals. The Choice Model looks at the individual and how the things they learn and
activities they engage in influence their subsequent choices[40]. SCCT’s Choice Model
is seen in Figure 1.1 below.

**Figure 1.1: SCCT Choice Model**
This figure is a model of person, contextual, and experimental factors affecting career-
related choice behavior[29].

SCCT ascertains that choice behaviors are influenced by choice goals, contextual
supports, contextual barriers, and self-efficacy[37], [41]. L.A.B.S. strives to help
underrepresented and disadvantaged students acquire opportunities that will help them
learn about potential STEM-career options, educate them on STEM subjects, overcome
barriers, and gain self-efficacy by completing multiple lab experiments. Consequently,
this study hypothesizes that these factors will help pique students’ interest in STEM
careers and increase self-efficacy, and SCCT supports this[37].
1.5  **Problem Statement**

Numerous reports have stated that STEM careers are one of the fastest-growing job sectors, driven by our society becoming more dependent on technology. An increasing number of students coming out of high school ready to pursue higher education opportunities and careers in STEM-related fields will be required to ensure the US maintains competitiveness and excellence at the global level. The National Research Council stated in a 2011 report that "Science, mathematics, engineering, and technology are cultural achievements that reflect people's humanity, power the economy, and constitute fundamental aspects of our lives as citizens, workers, consumers, and parents"[42]. Equipping high school students with skills and confidence that will allow them to pursue degrees and careers in STEM fields will help the US accomplish the goal of remaining competitive.

Since 2010 there has been an increase in the number of STEM graduates from US colleges and universities, but there is little indication that the diversity of the STEM workforce has changed[43]. Black and Hispanic college STEM graduates are underrepresented by about half their proportion of the population[44], [45]. In addition, women also have a history of underrepresentation, making up only 28% of the STEM workforce while maintaining 47% of the total US workforce[46]. Increasing diversity in STEM degrees and careers is crucial to long-term economic growth and global competitiveness[47].

The barriers that disadvantaged students must overcome to be successful can seem insurmountable simply due to economics. In particular, low-income students lose ground to wealthier students that can attend paid after-school and summer learning
opportunities[48]. Programs that specifically target disadvantaged students can help bridge this gap. No-cost educational options in STEM-related fields can help overcome the lack of AP courses, higher-performing schools, and standardized testing preparedness[49]. Providing a way to even the playing field for disadvantaged students will reduce disparity in the STEM workforce.

1.6 Research Question

The primary goal of this study is to assess how an immersive extracurricular STEM program affects a student’s self-efficacy, science anxiety, and career aspirations. Utilizing the setting of the L.A.B.S. program, underrepresented and disadvantaged high school students interested in STEM will have an avenue to gain experience and confidence, get reinforcement of concepts learned in school, and be introduced to cutting-edge technology in a way that allows them to understand its significance and help them persist in their STEM-based career goal. This study will use several validated instruments, a subject matter survey, and focus group questions to evaluate the outcome (see Appendix A).

The three validated instruments present a way to measure qualitative data quantitatively using Likert scales[50]. Pre/post-testing of CRISPR knowledge will be analyzed by two-tailed, paired T-testing to determine the difference between the means of the tests[51]. Focus group data will utilize the scissor-and-sort technique along with coding to identify themes[52], [53]. By using a mixed-methods research approach, a more complete picture of the effect of the L.A.B.S. program can be ascertained when
compared to standalone quantitative and qualitative studies[54]. All instruments, assessments, and evaluations used in this project have IRB approval (see Appendix B).

This project will seek to provide insight for teachers, instructors, science curriculum designers, and administrators on the importance of offering engaging after-school STEM activities to underrepresented and disadvantaged students. These opportunities will strengthen students' motivation, interest, and retention in pursuing a STEM-based degree in college and a STEM-based career after graduation. For the US to stay competitive in the global market, the persistence of females and minorities in STEM degrees and jobs must be addressed earlier than college. Addressing these issues at the high school level might give students greater confidence and motivation to pursue STEM-based degrees and careers, despite the current lack of diversity.

Chapter 2 will serve as the literature review by presenting the current research on STEM careers, the lack of diversity in STEM careers, ways to increase retention in STEM fields, and barriers to STEM access. Chapter 3 will discuss this investigation's methodology, research design, and procedures. Chapters 4 and 5 will interpret the study's results focused on the various groups investigated. Chapter 6 will concentrate on the conclusions and overall summary of the research.
CHAPTER 2

LITERATURE REVIEW

2.1 Overview

This literature review will present an overview of the history of STEM in the US and the current state of STEM education. It will discuss how the US is ranked internationally in STEM knowledge. It will outline barriers to STEM education for women and minorities and how they have caused a gap in the STEM workforce and decreased retention for STEM majors within those groups. This review will address ways to bridge and overcome the STEM gap. It will also outline factors influencing how high school students make higher education and career choices.

2.2 History of STEM

The acronym STEM was first introduced in 2001 by the National Science Foundation and encompassed the fields of science, technology, engineering, and math[55]. While the STEM movement has been brought to the forefront in recent years, the U.S. government has commissioned reports on the state of STEM in the country since 1945[56]. The first report was in response to threats of competition from Japan and Germany[57]. NASA was formed in July 1958 when Congress passed the National Aeronautics and Space Act, which was a response to the launch of the Sputnik satellite by
the Soviet Union. Later in 1958, the National Science Foundation was formed when Congress passed the National Defense Act. These two Acts sparked interest in STEM subjects in the U.S. and provided 1 billion dollars in fellowships, loans, and scholarships for students in STEM fields. Just over a decade later, NASA astronauts were the first humans to walk on the moon. During this timeframe, there was a significant focus on generating a workforce with the ability to ensure the global competitiveness of the U.S. in STEM subjects.

Throughout the years, many more reports have been written addressing the current state of STEM in the United States. Most of the reports discuss central themes, including ways to increase interest in students attaining STEM degrees and entering STEM careers, the need for a STEM-literate society, and guidelines for how schools can support students interested in STEM subjects. It is necessary to continue addressing these themes to meet the needs of a developing and increasingly technological society[57].

A report issued by the National Academies of Sciences in 2005 discussed the fact that US students were not achieving in STEM subjects at the same rate as other countries. Links between increased knowledge-intensive jobs dependent upon technological and scientific advances, global prosperity, and continued innovation to address societal problems were examined. The report highlighted the need for a focus on education in STEM subjects if the US was going to remain competitive and maintain prosperity in these areas[58].
2.3 Current State of STEM Education

PISA is an international assessment given to 15-year-old students every three years that measures what these students have learned in math, science, and reading[59]. The exam was developed by the OECD[60]. In 2018, the last year the assessment was conducted, 79 countries administered the PISA exam to more than 600,000 students. According to the PISA, the U.S. currently ranks 30th in math and 11th in science out of 79 countries[61]. Due to COVID-19, the next PISA exam will be administered in late 2022[59].

American students' basic STEM knowledge has moderately improved over the past 20 years but continues to lag behind numerous other countries[61], [62]. Only about 20% of students entering college are ready for courses usually required for a STEM degree[63]. Other countries have done a better job preparing their students for college and have outpaced the United States in the number of science and engineering degrees completed in the past 15 years. American-conferred bachelor's degrees in that timeframe have only comprised 10% of the global total, while India comprised 25% and China 22%[64]. However, the demand for STEM degrees continues to grow among US employers.

To address the issues within the US STEM education ecosystem, the Federal government's NSTC Committee on STEM Education developed a five-year scheme in 2018 known as the Federal STEM Education Strategic Plan. This plan has three main goals: 1) Build strong foundations for STEM literacy; 2) Increase diversity, equity, and inclusion in STEM; and 3) Prepare the STEM workforce for the future[65]. The first goal will be met by ensuring every American has the opportunity to become digitally
literate and master basic STEM concepts. The second goal will be met by providing lifelong learning access to high-quality STEM education, especially for those that have been underrepresented in the STEM fields and careers. The third goal will be met by providing authentic learning experiences that prepare and encourage students to pursue STEM careers[65]. Numerous independent agencies and Federal departments with STEM activities, education programs, and investments have committed to help ensure this plan comes to fruition by participating in one or more of the multiple objectives of the Federal STEM Education Strategic Plan. The strategic plan further outlines pathways to help achieve these goals, as seen in the schematic outline on the next page.

The 2020 STEM strategic plan progress report discussed federal implementation efforts during 2019 and 2020. Over $3 billion was invested into 174 programs between 17 Federal departments and independent agencies[66]. The Federal Coordination in STEM Education Subcommittee (FC-STEM) serves as the facilitator of the strategic plan to help communicate between the different partners about best practices and support common educational goals by coordinating activities and utilizing the resources and expertise of each partner. FC-STEM also gathers all assessment and survey data among all partners. That data showed that STEM interest, engagement, and pursuit of advanced degrees in STEM increased due to participation in these programs. Assessments that identified gaps in target audiences were used to influence revisions and refine programs[66].

The COVID-19 pandemic not only substantially impacted the global economy, healthcare, and unemployment rates but also affected education. Known socioeconomic differences for minorities and lower-income students were exacerbated
Figure 2.1: Federal STEM Education Strategic Plan
This figure is a schematic illustration of the organizational structure of the Federal STEM Education Strategic Plan released in December 2018. Three aspirational goals support the Strategic Plan’s vision. Four pathways contain objectives to guide efforts by the Federal government and broader STEM education community to realize the Strategic Plan’s vision and goals[66].
when at-home schooling was required due to the lack of access to internet services and computers. Community colleges with a significant proportion of low-income students also saw a sharp decline in enrollment during the pandemic[62].

Overall, trends that have been seen for years continue with only slight improvement. Students in the US are not where they should be to maintain the increasing need for a technologically-skilled workforce. There is still a lack of diversity in STEM fields, with women, Black, and Hispanic representation under their proportion of the population. Lack of access and support for these groups is still an issue. Even though these factors are known, and efforts have been made to address them, more must be done to overcome them.

2.4 Barriers to STEM Education

Numerous things are seen as barriers to education in the STEM fields, including cost and time, lack of access, and lack of diversity. The cost of higher education can be detrimental to specific groups for many reasons. People from low socioeconomic backgrounds have been disproportionately affected by the COVID-19 pandemic, have higher educational debt, have more significant family obligations, and have much less or no intergenerational wealth[46], [67]. Therefore, potential students from these groups cannot overcome short-term financial needs to pursue the potential long-term gains of a career in STEM and the advanced degree required. The average total educational debt for doctoral recipients is $31,000, with almost two-thirds of that made up of graduate debt. In contrast, Black doctoral recipients have an average total educational debt of $77,000[67].
It can take five or more years to obtain an advanced STEM degree. During this period, students must navigate and overcome obstacles in their path. The main obstacle is determining if they can afford graduate school. Students must take into consideration any debt incurred prior to graduate school and how much more debt they might incur during graduate school. Factors such as cost of living, healthcare, access to funding or income, childcare, and incidentals can add additional burdens, especially to students from disadvantaged populations. Recent graduates with a bachelor's STEM degree can earn up to $36,000 more per year by going straight into the workforce than students pursuing an advanced STEM degree[67], [68].

Another significant barrier to a quality STEM education is a lack of access. Urban and rural communities, in particular, do not have adequate high school-level science and math curriculums, which should prepare students for technical jobs right out of high school or ensure they can compete at the collegiate level. More than 50% of the high schools in the US do not offer calculus, 40% do not offer physics, 25% offer no chemistry, and 20% do not provide algebra II[69]. Informal learning experiences, such as museums, zoos, botanical gardens, and national parks, are often not found in urban and rural areas. These experiences can be valuable for science literacy and continued interest since only about 5% of anyone's life is spent inside a classroom[70]. Traveling to areas that do have informal learning experiences is not always an option for disadvantaged families.

Another significant barrier to STEM education's persistence is the workforce's lack of diversity. What does a scientist look like? What does a mathematician, engineer, or computer technologist look like? These might seem like basic questions, but for
students considering pursuing a degree or career in STEM, they can help shape their science identity. A student's sense of belonging has been linked to retention[71]. When college seniors in STEM were asked if they felt a sense of belonging in their field, white men were the most likely to feel a sense of belonging, whereas women of color were the least likely[71]. Students that reported a greater sense of belonging also tended to remain in STEM. White men make up only 30% of the US population yet make up over 50% of the STEM workforce[72]. This means that women and minority males do not often see people that look like them in STEM. Increased representation in the STEM workforce will lead to an increase in retention of underrepresented STEM majors.

2.5 Impacts of the STEM Gap

The STEM gap is the discrepancy in the representation of women and people of color compared to men in STEM and the lack of skilled laborers from those demographics[73]. Income disparities are one of the factors perpetuating the STEM gap. Data from the U.S. Bureau of Labor Statistics shows that the average annual wage for someone in a non-STEM career is $38,000, while the average yearly salary for someone in a STEM career is $90,000. However, women in STEM only make about $66,000 annually[74]. So, even when pursuing these higher-paying professions, women still face gender pay gaps.

Another factor in the STEM gap is the lack of retention for both women and minorities. One reason for the lack of retention is taking longer than the traditional four years to complete a STEM degree. Reasons for taking longer to complete a degree can be traced back to when students take certain level STEM courses. Women tend to take
lower-level STEM courses in high school, making it necessary to take more foundational classes in college and extend their time[75]. Likewise, minorities tend to take lower-level STEM courses at the beginning of their college careers and then must take higher-level courses later[76]. Both of these circumstances extend the time required to complete a STEM degree. Better planning, more course offerings, and access to counselors and advisors that can help guide women and minorities can help retention. These options can ensure students take classes at the right time to finish STEM degrees without incurring extra costs due to lengthier programs.

The COVID-19 pandemic accelerated an already-known trend by creating an imbalance in labor markets by adding to the skilled labor shortage. STEM fields did not see a significant decline in employment during the pandemic. However, there was a decline in STEM education during the pandemic[77]. Currently, 30% of the job openings in the US are in STEM fields, but only 11% of the population hold a STEM degree. This exacerbates the skilled labor shortage even more and might require companies to look to other countries to fill the void[74], [78].

In order to maintain the nation's position of being a leader in technological advancement and economic growth, the US must find ways to narrow the STEM gap. This includes overcoming pay disparities and training students to become researchers and teachers capable of educating future generations of STEM students[79]. It also includes increasing the retention of women and minorities in STEM majors so that they can become a part of the STEM workforce.
2.6 Overcoming the STEM Gap

As mentioned previously, active learning can increase students' interest, performance, and retention in the STEM fields. Various types of active learning implementations are effective such as flipped classrooms, problem-based learning, electronic audience response clickers, and collaborative groups. However, the most influential factor is the amount of time spent on active learning. Classrooms that only spent one-third of their time engaging in active learning were no better than traditional learning, but those that spent two-thirds of their time were much more effective[22].

Science anxiety is a combination of fearful, negative emotions and cognition in the context of science learning[80]. The causes of science anxiety are numerous and have been attributed to both society and elementary educators. A common misconception is that only a few people have the talent for doing science. The fact that memorization is stressed in school settings rather than analytical thinking leads to anxiety because students fear they cannot tackle science topics. Science anxiety has been reduced in classes with large enrollments that utilize active learning[81], [82].

Underrepresented groups in STEM have benefited the most from active learning environments. In passive learning classrooms, minority students in STEM earned 0.6 standard deviations lower on test scores and were less likely to pass the class than those overrepresented in STEM. In active learning classrooms, however, there was an increase in both the probability of minority students passing the STEM class and a decrease in the difference in test scores between the two groups[22], [83], [84]. The benefits of active learning for underrepresented STEM students can help retention, which can help lessen the STEM gap.
Another way to overcome the STEM gap is to offer access to extracurricular, after-school, and summer programs for underrepresented students in STEM. Numerous studies have cited positive outcomes for both minorities and girls that participate in these programs. Participation in additional STEM programs, increased interest, increased enrollment in STEM-based courses in school, increased self-confidence, and decreased science anxiety have all been attributed to after-school and summer STEM programs. Students participating in after-school and summer programs also have a high rate of graduation from high school and communicate intentions to continue to college and major in STEM fields[85]–[90].

2.7 Higher Education and Career Choices

Numerous studies have tried identifying factors influencing students' higher education and career choices. Some studies have looked at the differences between race or gender when making these decisions, while others have not placed students into specific categories. When students are not categorized, the most influential factors in students' choice of higher education and careers are access to STEM programs beyond the classroom, teachers utilizing active learning techniques in the classroom, self-efficacy, and parental influences[91]–[94]. The most influential factors on students' higher education and career choices based on their gender or race are parental influences, access to STEM programs beyond school, and science identity[93], [95]–[98].
CHAPTER 3

METHODOLOGY

3.1 Introduction

Current literature and historical evidence have shown that females and underrepresented minorities have less self-efficacy, more science anxiety, and are less likely to pursue STEM degrees and careers[3], [4]. This study aimed to determine if students participating in the L.A.B.S. program have a higher level of interest in continuing to pursue a STEM degree or career, a decreased sense of science anxiety, and an increased sense of self-efficacy after completing the program. This study was also designed to see if the incorporation of cutting-edge science technology and hands-on experimental learning has any additional effect on the previously mentioned items. These effects were also examined in relation to the gender or race of the participating students. Hopefully, providing students with opportunities like the L.A.B.S. program will help overcome these well-documented barriers, leading to a higher sense of self-efficacy, lower science anxiety, and the confidence to pursue a degree or career in STEM.

Overcoming underrepresentation in both gender and race will lead to a more diverse workforce. This inclusion is beneficial as groups with more diversity have been shown to outperform a more homogenous group of people regarding problem-solving, even when the homogenous group of people has been labeled high-ability problem
solvers[99]. A diverse group allows for problems to be approached differently and
develop more innovative solutions because the backgrounds of the people making up
diverse groups have had differing exposures, perspectives, and experiences that provide
unique problem-solving skills. Since virtually all STEM fields require a high degree of
problem-solving, a diverse workforce can only enhance scientific progress and
success[100], [101].

3.2 Context of the Study

There is an increasing demand for a more diverse STEM workforce. One way to
meet this demand is to foster an inclusive environment by creating learning opportunities
where everyone feels accepted, valued, and capable in a research setting. Opportunities
that can increase interest, enthusiasm, and confidence can help ensure that a more diverse
and inclusive STEM workforce is heading in the right direction. Since underrepresented
and disadvantaged high school students have less access and more barriers to these
environments, it is imperative that programs are instituted to give all students equitable
educational opportunities. The L.A.B.S. program fills this need by selectively choosing
students from these populations and having them work and learn together as peers in a
setting where they are not only valued and accepted but challenged and engaged with the
latest STEM technologies.

The L.A.B.S. program recruits high school students from the local community via
an application process. The after-school part of the program is held from 4:15 - 6:15 pm,
two times per week for six weeks in both the Fall and Spring semesters. The Summer
session is held from 8 am – 5 pm for five days in the Summer. The students receive a total of 88 contact hours in the L.A.B.S. program.

This study took place at HudsonAlpha Institute for Biotechnology, a non-profit research institute in Huntsville, Alabama. HudsonAlpha has a three-fold mission of conducting genomics-based research to improve human health and well-being; sparking entrepreneurship and economic development; and providing educational outreach to nurture the next generation of biotech researchers and entrepreneurs, as well as to create a biotech literate public[102]. Table 3.1 illustrates the dates for the L.A.B.S. program and data collection for the three groups of students.

<table>
<thead>
<tr>
<th>L.A.B.S. Program and Data Collection Schedule</th>
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<tbody>
<tr>
<td><strong>Group 1</strong></td>
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<td>Summer 2020 virtually</td>
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<tr>
<td>*Indicates when data collection occurred for the study</td>
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<tr>
<td><strong>Group 2</strong></td>
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<tr>
<td>Spring 2022</td>
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<tr>
<td>Summer 2022*</td>
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### 3.3 Primary Research Questions

Multiple validated instruments, pre/post-testing of CRISPR knowledge, and focus group interviews were used to address the following five specific research questions.
1) Does participation in the L.A.B.S. program affect students' self-efficacy and outcome expectations and influence students' interest in STEM-based careers?

2) Does participation in the L.A.B.S. program affect the persistence of science anxiety?

3) Does participation in the L.A.B.S. program affect students' perceptions about whether they would find themselves in a supportive environment while pursuing a STEM career, how important a STEM career is perceived, and their interest in pursuing educational opportunities that could lead to a career in STEM?

4) Does the L.A.B.S. program help alleviate barriers for underrepresented and disadvantaged students?

5) Is the CRISPR project being taught in a manner that allows for student comprehension and understanding?

The first such instrument is the Student Interest and Choice in STEM (SIC-STEM) survey[103]. The SIC-STEM survey looks, in part, at how their self-efficacy and outcome expectations influence students' interest in STEM-based careers. Participation in a program like L.A.B.S., where outcomes will be successful based on the tried-and-true tools, lessons, and experiments used, will shift students' outcome expectations to the positive. Since active learning is utilized in the L.A.B.S. program and active learning has been shown to increase self-efficacy, an instrument used to measure this outcome is essential. The SIC-STEM survey comprises three separate constructs: Science, Math, and Engineering and Technology. Each construct contains a 15-question survey and uses
Likert scaling to measure positive or negative student responses to a statement. For this study, only the Science construct survey will be used because it is most relevant to the content in the L.A.B.S. program.

Another instrument used in this study was the Science Anxiety Questionnaire developed as part of the Science Anxiety Clinic at Loyola University Chicago[104]. The L.A.B.S. program attempts to overcome several causes of science anxiety, including engaging students in active learning and instilling confidence with hands-on activities. Still, it would be neglectful not to address the potential for science anxiety to persist. Therefore, an instrument measuring it is also essential for this study. The Science Anxiety Questionnaire comprises 44 statements using Likert scaling to record results. However, only 40 of the 44 questions will be utilized due to the out-of-date nature of 4 of the questions. For example, the question asking how fearful a student felt about replacing a bulb on a movie projector was omitted because most current students are unfamiliar with movie projectors.

The final instrument used was the STEM Semantics Survey explicitly focused on students' interests in Science, Technology, Engineering, and Math, respectively, and then in a STEM-based career[105]. It also utilizes a Likert scale to measure results, but students rate contrasting adjectives instead of evaluating a statement.

A subject matter survey will determine if the CRISPR project is being taught in a manner that allows for student comprehension and understanding. The questions in the survey will be assembled in a pre-test and post-test format and will cover content taught in conjunction with the CRISPR project. Using the same questions in the pre-and post-test allows evaluation of the program’s effect on students' ability to remember,
understand, and apply the material. This pre/post testing will also ensure the content of
the L.A.B.S. program was effective and can be used successfully for future cohorts of
students.

The three validated instrument surveys will be used to help answer the first three
research questions. The validated instrument surveys and focus group questions will be
used to answer the fourth research question. The subject matter survey will be used to
answer the fifth research question. All student surveys and questions can be found in the
appendices.

3.4 Participants

The L.A.B.S. program offers applications to any high school student, but special
consideration is given to high school students underrepresented in STEM based on
gender or race and those considered disadvantaged based on ability, access, or household
income. Applicants must be in the 8th-11th grade when applying for the program, and
they must submit a transcript from their school to verify their grade and eligibility. They
must write a strong personal statement that effectively communicates their interest in the
L.A.B.S. program and why they should be selected. It should be free of grammatical and
typographical errors.

Once applications are received, the demographic data for each applicant is
categorized and scored. The four categories for demographic data are gender,
race/ethnicity, household size, and household income. A selection committee made up of
6-10 members of the Educational Outreach team at HudsonAlpha reviews the personal
statements provided by each applicant and scores them. The possible scores are shown in the following tables:

**Table 3.2**

** Applicant Gender **

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</tr>
<tr>
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**Table 3.3**

** Applicant Race/Ethnicity **

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<tr>
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<td>No (includes Asian and White)</td>
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<tr>
<td>0</td>
<td>Two or more races, Prefer not to say, or Unknown</td>
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**Table 3.4**

** Household Size **

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<tr>
<td>2</td>
<td>4-6</td>
</tr>
<tr>
<td>1</td>
<td>1-3</td>
</tr>
</tbody>
</table>
### Table 3.5
#### Household Income

<table>
<thead>
<tr>
<th>Score</th>
<th>Score Descriptor</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>Less than $20,000</td>
</tr>
<tr>
<td>6</td>
<td>$20,000-$34,999</td>
</tr>
<tr>
<td>5</td>
<td>$35,000-$49,999</td>
</tr>
<tr>
<td>4</td>
<td>$50,000-$74,999</td>
</tr>
<tr>
<td>3</td>
<td>$75,000-$99,999</td>
</tr>
<tr>
<td>2</td>
<td>$100,000-$149,999</td>
</tr>
<tr>
<td>1</td>
<td>$150,000+</td>
</tr>
</tbody>
</table>

### Table 3.6
#### Personal Statement – Grammar

<table>
<thead>
<tr>
<th>Score</th>
<th>Score Descriptor</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>Statement is proofread well, with only 1-3 errors</td>
</tr>
<tr>
<td>3</td>
<td>Statement has room for improvement, with 4-7 errors</td>
</tr>
<tr>
<td>2</td>
<td>Statement needs much improvement, with 8+ errors</td>
</tr>
</tbody>
</table>

### Table 3.7
#### Personal Statement – Advocation

<table>
<thead>
<tr>
<th>Score</th>
<th>Score Descriptor</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>Applicant presents a well-written case to advocate being in the program</td>
</tr>
<tr>
<td>3</td>
<td>Applicant states interest but does little to support/advocate participation</td>
</tr>
<tr>
<td>2</td>
<td>Applicant shows little support or interest as to why he/she should be selected</td>
</tr>
</tbody>
</table>
After all personal statements have been scored, they are combined with the
demographic data scores to determine a final weighted score for each applicant. The
demographic data scores make up 70% of the total weighted score for each applicant, and
the personal statement scores make up the remaining 30%. The top 16 scoring applicants
are selected for the program.

Three different groups of L.A.B.S. students participated in this study. Parental
consent and student assent were gathered from all study participants. Any student for
whom assent or parental consent forms were not completed was removed from the data
population. Groups 1 and 2 took the validated instrument surveys only at the end of the
program; group 3 took them at the beginning and end of the program. All three groups
took the subject matter surveys at the beginning and end of the Summer session. All
three groups also participated in focus groups.

Group 1 attended L.A.B.S. from the Fall of 2019 through the Summer of 2021.
The in-person Summer session of 2020 was canceled due to the COVID-19 pandemic
and was held in the Summer of 2021 instead. Group 1 study data was collected during
the Summer of 2021. The expected sample size was n ≈ 16; however, due to the impact
of the pandemic, the actual sample size was n = 6. Group 2 attended L.A.B.S. from the
Fall of 2020 through the Summer of 2021. Group 2 study data was collected during the
Summer of 2021. The expected sample size was n ≈ 16; however, the actual sample size
was n = 15. Group 3 attended L.A.B.S. from the Fall of 2021 through the Summer of
2022. Group 3 study data was collected during the Fall of 2021 and the Summer of 2022.
The expected sample size was n ≈ 16; however, the actual sample size was n = 14.
3.5 Data Collection and Analysis

Data for the three validated instruments and subject matter surveys were collected by utilizing Google forms. The Google account is a corporate workspace account with HIPAA-level security. Survey result data was stored securely on my password-protected computer. The subject matter surveys were analyzed using paired t-tests. Significance was determined at the p < 0.05 level. Groups 1 and 2 post-survey data were compared to Group 3 post-survey data using Mann-Whitney U tests. T-test analysis was also used for group 3's pre- and post-validated instrument surveys and for any Group 1 or 2 post-survey data that passed the Mann-Whitney U test.

Focus group data were collected on a microSD card utilizing a Mevo camera recording system. Once the focus group sessions were completed, the files were transferred to and stored on a password-protected computer, and the files were deleted from the microSD card. An independent transcriber transcribed the focus group recordings, and the transcribed data were analyzed using the scissor-and-sort method to identify themes[53].

3.6 Procedures

The L.A.B.S. program is spread out over three sessions. The first session runs for six weeks in the Fall semester, and the second session runs for six weeks in the Spring semester. The students meet twice weekly for 2 hours each day during both sessions for 48 hours. The third session runs for one full week during the Summer for 40 hours. Overall, the students receive 88 hours of instruction and immersion in the STEM program between all three sessions.
The first two sessions are used to build basic lab skills and introduce concepts that the students need for the culminating CRISPR experiment in the Summer. Table 3.8 displays the curriculum or experiments taught and skills the students utilized or learned.

### Table 3.8
L.A.B.S. Fall and Spring Program

<table>
<thead>
<tr>
<th>Session/Week</th>
<th>Curriculum/Experiments</th>
<th>Skills Learned/Demonstrated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall/Week 1</td>
<td>Lab Safety and Lab Math</td>
<td>How to safely work in a lab setting; how to do basic lab math that will be utilized during the program to make solutions and reagents for the students' use</td>
</tr>
<tr>
<td>Fall/Week 2</td>
<td>Micropipetting; Strawberry DNA Extraction</td>
<td>How to use a micropipette accurately and confidently; how to crudely extract DNA from plants; designed and tested a new lysis solution</td>
</tr>
<tr>
<td>Fall/Week 3</td>
<td>Lab Station Shuffle; Plasmid Transformation</td>
<td>How to correctly use equipment found in a lab; made several solutions for use later in the program; performed a plasmid transformation into bacterial cells; determined the expression of plasmid DNA based on the genes present</td>
</tr>
<tr>
<td>Fall/Week 4</td>
<td>Human PV92 Alu Insertion Detection; PCR</td>
<td>How to extract DNA from a saliva sample; how to score genotypes and determine genotype and allelic frequencies in the human population; how to amplify specific DNA sequences for analysis</td>
</tr>
<tr>
<td>Fall/Week 5</td>
<td>Gel Electrophoresis and Analysis; Lab Math and Micropipetting Assessments</td>
<td>How to run agarose gel; how to identify DNA bands on an agarose gel; how to interpret the presence of DNA bands of differing sizes; assessments to measure students' lab math and micropipetting knowledge</td>
</tr>
<tr>
<td>Session/Week</td>
<td>Curriculum/Experiments</td>
<td>Skills Learned/Demonstrated</td>
</tr>
<tr>
<td>-------------</td>
<td>------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Fall/Week 6</td>
<td>Chromatography; Human Non-Polyposis Colorectal Cancer Detection</td>
<td>How to separate complex mixtures; cell cycle regulation and checkpoints; explore the link between family medical history and potential hereditary genes for certain cancers</td>
</tr>
<tr>
<td>Spring/Week 1</td>
<td>Micropipetting; Lab Media Preparation</td>
<td>Review of micropipetting after the long break; prepare LB agar for use in an upcoming lab</td>
</tr>
<tr>
<td>Spring/Week 2</td>
<td>Genetic Engineering Lab Series</td>
<td>During these four weeks, the students worked on two projects. The Genetic Engineering series encompassed restriction digests, ligation, gel electrophoresis, transformation, colony PCR, and protein purification. The Oral &amp; Surface Microbiome exploration is a student-driven project where they picked oral and environmental locations to swab and grew the contents of the swab on a nutrient agar plate and then chose bacterial colonies to isolate and culture, stain to classify gram reaction and determine the shape, and test for sensitivity to common antiseptics, disinfectants, and antibiotics</td>
</tr>
<tr>
<td>Spring/Week 3</td>
<td>Genetic Engineering Lab Series</td>
<td></td>
</tr>
<tr>
<td>Spring/Week 4</td>
<td>Oral &amp; Surface Microbiome Exploration Lab</td>
<td></td>
</tr>
<tr>
<td>Spring/Week 5</td>
<td>Student Presentations</td>
<td>Students designed presentations to explain their Oral &amp; Surface Microbiome project and presented them to the class</td>
</tr>
<tr>
<td>Spring/Week 6</td>
<td>Student Presentations</td>
<td></td>
</tr>
</tbody>
</table>

The Summer session curriculum involved more intense experiments than the after-school sessions. Several experiments took multiple days and allowed the students to use various skills they had learned in the first two sessions. In one student-driven experiment, the students chose a plasmid of interest, induced the expression of a gene on the plasmid in broth culture, performed a plasmid miniprep to isolate the plasmid, and
then transformed it into a bacterial strain. The students also brought in food, extracted the DNA, and amplified it via PCR to determine if it had been genetically modified. To explore DNA fingerprinting, the students extracted their DNA and amplified it using PCR to identify STRs in their genome. These STRs are used by the FBI and law enforcement to identify victims and suspects and allow for more discussions on population genetics. The model organism, *C. elegans*, a nematode worm, was used in an RNA interference experiment to silence a mutant gene. Invited guest speakers also talked to the students about their career paths and what they do in their jobs daily.

The CRISPR project performed by the students had many facets to help ensure they gained a complete understanding of this complex topic. An introduction and discussion about CRISPR, including, what it is, its history, the critical components, and the ethics surrounding gene editing, were done on the first day. To help visualize the CRISPR system, students performed a hands-on activity where they built a 2D paper model of the system and applied their knowledge of complementary DNA bases to find and identify the target sequence using a hands-on activity[106]. Students also utilized an online interactive activity to introduce the concept of using CRISPR-Cas9 to knock out genes to identify their function[107]. Experiments utilizing both HDR and NHEJ were performed, respectively, to ensure the students understood the two repair mechanisms of CRISPR-induced double-strand breaks. The HDR experiment was performed using Out of the Blue CRISPR and Genotyping Extension kits from Bio-Rad[108].

The way CRISPR was integrated into the Summer session and how the NHEJ experiment was designed and incorporated were derived from several previous studies[109]–[113]. The goal of the NHEJ CRISPR experiment was to deactivate the
green fluorescent protein (GFP) gene in a plasmid transformed into E. coli. Due to time constraints, the plasmids used in the experiment were purchased or constructed before the Summer session. The pGLO plasmid was purchased from Bio-Rad. The Cas9 plasmid was provided for no charge by Addgene. Four sgRNAs were purchased from IDT (see Appendix C). The sgRNAs were ligated into the digested Cas9 plasmid and transformed into E. coli, and the resulting clones were sequenced (see Appendix D).

To ensure the students felt like they were doing all the steps in an actual CRISPR experiment, they went through the steps and designed plasmids that express a sgRNA that targets GFP. The students explored the nucleotide sequence of GFP and the plasmid containing the gene that expresses it to identify potential target sites. To correctly identify the target sites, determine the location of PAM sites, and construct sgRNA-containing cas9 plasmids, students used the molecular cloning program SnapGene[114]. The students also analyzed the sequencing results of the plasmids to ensure that the sgRNAs had been ligated into the plasmids correctly.

Once the plasmid construction had been verified, students co-transformed the sgRNA-cas9 plasmid and the GFP plasmid into bacterial cells. The students employed antibiotic selection to confirm plasmid transformation. Students induced relevant genes to be expressed from the plasmids. After incubation of the transformed cells, students counted the number of total colonies and fluorescent colonies to obtain the percentage of fluorescent colonies in control and experimental conditions. Comparing the types of colonies allowed the students to determine the efficiency of the sgRNAs. Groups 1 and 2 also designed six more potential sgRNAs in different locations within the GFP sequence (see Appendix E). Plasmid constructs containing the new sgRNAs were made and
ultimately tested by Group 3. Allowing students to learn about or participate in all the steps of the NHEJ CRISPR experiment should influence their post-subject matter survey.

The students took the validated instrument surveys and the subject matter survey and participated in focus groups, according to Table 3.8.

Table 3.9
L.A.B.S. Assessment Timeframe

<table>
<thead>
<tr>
<th>Group</th>
<th>Validated Instrument Surveys</th>
<th>Subject Matter Survey</th>
<th>Focus Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>End of the Summer session</td>
<td>Start and end of the Summer session</td>
<td>End of the Summer session</td>
</tr>
<tr>
<td>2</td>
<td>End of the Summer session</td>
<td>Start and end of the Summer session</td>
<td>End of the Summer session</td>
</tr>
<tr>
<td>3</td>
<td>Start of the Fall session and end of the Summer session</td>
<td>Start and end of the Summer session</td>
<td>End of the Summer session</td>
</tr>
</tbody>
</table>

3.7 Limitations and Delimitations of this study

A limitation of this study was the wide range of participants ages and grade levels. Students in 9th grade do not have the same experiences as those in 12th grade. Older high school students have likely given considerably more thought to their career aspirations and goals than younger students. The older students most likely have had more advanced courses where they might have already gained some self-efficacy and have a lessened sense of science anxiety. In an ideal study design, the groups would be large enough to be separated by age and experience and compared in that fashion. Another limitation included the COVID-19 pandemic, which caused the number of students participating in Group 1 to be reduced.
A delimitation of this study addressed the lack of validated instrument surveys at the start of the Fall sessions for Groups 1 and 2. Data collected from the validated instrument surveys during the start of the Fall semester for Group 3 was used to determine a change in science anxiety, self-efficacy, and career inspiration for all three groups. The difference, if any, seen in these groups are relevant for Group 3 but much less reliable for Groups 1 and 2.
CHAPTER 4

GROUPS 1 & 2: DATA & ANALYSIS

4.1 Introduction

Increasing diversity has been an integral part of the STEM movement over the last few years. One of the barriers to overcoming this issue is the lack of access to STEM programs for underrepresented and disadvantaged populations. The L.A.B.S. program is helping to overcome this barrier by offering a no-cost, immersive STEM program for high school students, particularly those with limited access. This chapter introduces the first two groups in this study and discusses their survey and focus group results.

4.2 Demographics

Group 1 began the L.A.B.S. program in Fall of 2019 with 15 students. This group included one 9th grader, four 10th graders, five 11th graders, and five 12th graders. They participated in a virtual Summer session in 2020 due to the COVID-19 pandemic. Only ten of the original 15 students were able to come back and take part in the in-person Summer 2021 session. Of those 10, only six could fully participate in the study, complete all surveys, and participate in the focus group. Demographic data for the students in Group 1 is seen in the figures below.
Figure 4.1: Student Gender Data at the start of L.A.B.S. for Group 1
This figure shows the self-reported gender data for the 15 students in group 1 selected and participated in the L.A.B.S. program starting in Fall 2019.

Figure 4.2: Student Race Data at the start of L.A.B.S. for Group 1
This figure shows the self-reported race data for the 15 students in group 1 selected and participating in the L.A.B.S. program starting in Fall 2019.
Figure 4.3: Student Income Data at the start of L.A.B.S. for Group 1
This figure shows the self-reported income data for the 15 students in group 1 selected and participated in the L.A.B.S. program starting in Fall 2019.

Figure 4.4: Student Gender Data for Group 1 Study Participants
This figure shows the self-reported gender data for the six students in group 1 that participated in this study during the Summer of 2021.
Figure 4.5: Student Race Data for Group 1 Study Participants
This figure shows the self-reported race data for the six students in group 1 that participated in this study during the Summer of 2021.

Figure 4.6: Student Income Data for Group 1 Study Participants
This figure shows the self-reported income data for the six students in group 1 that participated in this study during the Summer of 2021.
All but one student in Group 1 fit into at least one of the underrepresented and disadvantaged demographics of the L.A.B.S. program. 47% of the students fit into two or more demographics. Of the students included in this study, 66% fit into two or more of the demographics.

Group 2 began the L.A.B.S. program in Fall 2020 with 16 students. This group included five 9th graders, three 10th graders, seven 11th graders, and one 12th grader. Only 15 could fully participate in the study, complete all surveys, and participate in the focus group. Demographic data for the students in group 2 is seen in the figures below.

Figure 4.7: Student Gender Data at the start of L.A.B.S. for Group 2
This figure shows the self-reported gender data for the 16 students in group 2 selected and participated in the L.A.B.S. program starting in Fall 2020.
Figure 4.8: Student Race Data at the start of L.A.B.S. for Group 2
This figure shows the self-reported race data for the 16 students in group 2 selected and participated in the L.A.B.S. program starting in Fall 2020.

Figure 4.9: Student Income Data at the start of L.A.B.S. for Group 2
This figure shows the self-reported income data for the 16 students in group 2 selected and participating in the L.A.B.S. program starting in Fall 2020.
Figure 4.10: Student Gender Data for Group 2 Study Participants
This figure shows the self-reported gender data for the 15 students in group 2 that participated in this study during the Summer of 2021.

Figure 4.11: Student Race Data for Group 2 Study Participants
This figure shows the self-reported race data for the 15 students in group 2 that participated in this study during the Summer of 2021.
Figure 4.12: Student Income Data for Group 2 Study Participants
This figure shows the self-reported income data for the 15 students in group 2 that participated in this study during the Summer of 2021.

All but one student in Group 2 fit into at least one of the underrepresented and disadvantaged demographics of the L.A.B.S. program. 69% of the students fit into two or more demographics. Of the students included in this study, 67% fit into two of the demographics and 40% fit into all three demographics.

4.3 Results
This section contains the results of the three validated instruments: the SIC-STEM survey, the Science Anxiety survey, and the STEM Semantics survey given at the end of the L.A.B.S. program. The results of the focus group discussions and the CRISPR subject matter pre- and post-test are also discussed. These surveys, discussions, and tests were used to answer the research questions described in the following sub-sections for Groups 1 and 2.
Since these Groups 1 and 2 did not participate in pre-surveys for the validated instruments, their results were compared against the pre-survey results for Group 3. The justification for this is that all three groups were treated the same and should have identical results. To ensure this was a reasonable assumption, the Mann-Whitney U test was employed to ascertain that the post-survey results of all three groups were identical[115]. When assessing the results of a Mann-Whitney U test, whenever the actual U-value is greater than the critical value of U at \( p < 0.05 \) and the Z-score is between -1.96 and 1.96, the null hypothesis is confirmed, and the groups are considered to be identical. As long as the groups are considered equivalent, the post-survey results for Groups 1 and 2 can be compared to the pre-survey results for Group 3 to look for a change over time.

When comparing the results of the post-surveys of the SIC-STEM survey, the U-value between Group 1 and Group 3 was 16.5. The critical value of U at \( p < 0.05 \) was 17. Since the actual U-value was lower than the critical value, the two groups were not considered identical. The Z-Score was -2.06; since this was less than -1.96, the null hypothesis was rejected, and these two groups were not regarded as identical. Therefore, it was not reasonable to compare the post-survey results of Group 1 to the pre-survey results of Group 3 for the SIC-STEM survey.

When comparing the results of the post-surveys of the SIC-STEM survey, the U-value between Group 2 and Group 3 was 99. The critical value of U at \( p < 0.05 \) was 59. Since the actual U-value was higher than the critical value and the Z-score of -0.24 was between -1.96 and 1.96, the two groups were considered equivalent. It was
reasonable to compare the SIC-STEM post-survey results of Group 2 to the SIC-STEM pre-survey results of Group 3, as the two groups were identical.

When comparing the results of the post-surveys of the Science Anxiety survey, the $U$-value between Group 1 and Group 3 was 34. The critical value of $U$ at $p < 0.05$ was 17, and the Z-score was 0.62. The $U$-value between Group 2 and Group 3 was 100.5. The critical value of $U$ at $p < 0.05$ was 59, and the Z-score was 0.17. Therefore, comparing the post-survey results of Group 1 and Group 2 to the pre-survey results of Group 3 for the Science Anxiety survey was reasonable.

When comparing the results of the post-surveys of the STEM Semantics survey, it was found that the $U$-value between Group 1 and Group 3 was 27.5. The critical value of $U$ at $p < 0.05$ was 1.7, and the Z-score was 1.15. The $U$-value between Group 2 and Group 3 was 81.5. The critical value of $U$ at $p < 0.05$ was 59, and the Z-score was 1.00. Comparing the post-survey results of Group 1 and Group 2 to the pre-survey results of Group 3 for the STEM Semantics survey was reasonable.

<table>
<thead>
<tr>
<th>Survey</th>
<th>Group Being Compared</th>
<th>$U$-Value</th>
<th>Critical value of $U$ at $p &lt; 0.05$</th>
<th>Z-score</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIC-STEM</td>
<td>1 to 3</td>
<td>16.5</td>
<td>17</td>
<td>-2.06</td>
<td>Significant</td>
</tr>
<tr>
<td></td>
<td>2 to 3</td>
<td>99</td>
<td>59</td>
<td>-0.24</td>
<td>Not significant</td>
</tr>
<tr>
<td>Science Anxiety</td>
<td>1 to 3</td>
<td>34</td>
<td>17</td>
<td>0.62</td>
<td>Not significant</td>
</tr>
<tr>
<td></td>
<td>2 to 3</td>
<td>100.5</td>
<td>59</td>
<td>0.17</td>
<td>Not significant</td>
</tr>
<tr>
<td>STEM Semantics</td>
<td>1 to 3</td>
<td>27.5</td>
<td>1.7</td>
<td>1.15</td>
<td>Not significant</td>
</tr>
<tr>
<td></td>
<td>2 to 3</td>
<td>81.5</td>
<td>59</td>
<td>1.00</td>
<td>Not significant</td>
</tr>
</tbody>
</table>

If results are not significant, groups are comparable.
4.3.1 Does participation in the L.A.B.S. program affect students' self-efficacy and outcome expectations and influence students' interest in STEM-based careers?

Since Group 1’s SIC-STEM post-survey results weren’t similar enough to be compared to the pre-survey results of Group 3, their actual data is presented here. All six of these students enjoy doing science and experiments in science. They all believe they can get good grades and are confident in science classes. They want to have careers in science, think they can get a good job, and choose courses to help them achieve that goal.

Figure 4.13: SIC-STEM Interests for Group 1 Study Participants
This figure shows how interested the Group 1 study participants are in Science, as reported on the SIC-STEM survey.
Figure 4.14: SIC-STEM Self-efficacy for Group 1 Study Participants
This figure shows how the Group 1 study participants reported their self-efficacy on the SIC-STEM survey.

Figure 4.15: SIC-STEM Outcome expectations for Group 1 Study Participants
This figure shows how the Group 1 study participants reported their outcome expectations on the SIC-STEM survey.
Figure 4.16: SIC-STEM Choice goals for Group 1 Study Participants
This figure shows how the Group 1 study participants reported their choices for utilizing Science in their future career goals on the SIC-STEM survey.

Figure 4.17: SIC-STEM Choice actions for Group 1 Study Participants
This figure shows how the Group 1 study participants reported their actions in high school and how that pertains to their future career goals on the SIC-STEM survey.

Based on these results, the Group 1 students enjoy science, want to pursue a career in science, and take action to make that happen. However, no conclusion can be
drawn as to the effects of the L.A.B.S. program on those constructs based on the SIC-STEM survey.

The results of the 15 participants of Group 2's SIC-STEM surveys show more variability in their interest in science and their confidence when doing experiments and in their science classes. Approximately 25% do not feel confident in science. Most of them think they can still get a good job in science, but 25% do not believe the courses they are taking will help them obtain a good job in science. Approximately half of the students do not take additional science courses, do projects, or attempt to get good grades in order to pursue a career in science (Appendix F).

There was no significant difference in the student responses for the SIC-STEM survey in pre-test Group 3 ($M = 63.29$, $SD = 5.46$) and post-test Group 2 ($M = 61.4$, $SD = 10.48$); $t = 0.6148$, $p = 0.5387$ (Table 4.2 & 4.3)[116].

<p>| Table 4.2 | L.A.B.S. SIC-STEM Pre-survey Group 3 and Post-survey Group 2 Statistics |
|-----------|---------------------------|----------------|--------------|--------------------------|--------------------------|</p>
<table>
<thead>
<tr>
<th></th>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>Median</th>
<th>Mode</th>
<th>Standard Deviation</th>
<th>Standard Error Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 3 Pre-test</td>
<td>14</td>
<td>63.29</td>
<td>64.5</td>
<td>67</td>
<td>5.46</td>
<td>1.46</td>
<td></td>
</tr>
<tr>
<td>Group 2 Post-test</td>
<td>15</td>
<td>61.4</td>
<td>61.4</td>
<td>66</td>
<td>10.48</td>
<td>2.71</td>
<td></td>
</tr>
</tbody>
</table>
Table 4.3
L.A.B.S. SIC-STEM Pre-survey Group 3 and Post-survey Group 2 t-test

<table>
<thead>
<tr>
<th>Equal variance assumed</th>
<th>t</th>
<th>df</th>
<th>Sig. (2-tailed)</th>
<th>Mean Difference</th>
<th>Std. Error Difference</th>
<th>95% Confidence Interval of the Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.6148</td>
<td>14.5086</td>
<td>0.5387</td>
<td>1.8900</td>
<td>3.0743</td>
<td>-4.6614 8.4414</td>
</tr>
</tbody>
</table>

Based on these results, it is assumed that the Group 2 students are not statistically different at the end of the L.A.B.S. program regarding their confidence or interest in science and ways to achieve a career in science.

4.3.2 Does participation in the L.A.B.S. program affect the persistence of science anxiety?

The results of the Science Anxiety survey for the six Group 1 students show a fairly low to slightly moderate level of science anxiety. The maximum score is 200, which correlates to extreme science anxiety. The minimum score is 40, which correlates to no science anxiety. Group 1 students had a low of 58 and a high of 99 (Figure 4.18). However, there is no significant difference in the student responses for the Science Anxiety survey in pre-test Group 3 ($M = 85.29, SD = 26.91$) and post-test Group 1 ($M = 79, SD = 14.49$); $t = 0.6755, p = 0.9988$ (Table 4.4 & 4.5).
This figure shows how the Group 1 study participants scored on the Science Anxiety survey.

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>Median</th>
<th>Mode</th>
<th>Standard Deviation</th>
<th>Standard Error Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 3 Pre-test</td>
<td>14</td>
<td>85.29</td>
<td>92</td>
<td>107</td>
<td>26.91</td>
<td>7.19</td>
</tr>
<tr>
<td>Group 1 Post-test</td>
<td>6</td>
<td>79</td>
<td>80.5</td>
<td>N/A</td>
<td>14.49</td>
<td>5.92</td>
</tr>
</tbody>
</table>
Table 4.5
L.A.B.S. Science Anxiety Pre-survey Group 3 and Post-survey Group 1 t-test

<table>
<thead>
<tr>
<th>Equal variance assumed</th>
<th>t</th>
<th>df</th>
<th>Sig. (2-tailed)</th>
<th>Mean Difference</th>
<th>Std. Error Difference</th>
<th>95% Confidence Interval of the Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.6755</td>
<td>10.7703</td>
<td>0.9988</td>
<td>6.2900</td>
<td>9.3123</td>
<td>-14.2063 to 26.7863</td>
</tr>
</tbody>
</table>

Based on these results, it is assumed that the Group 1 students are not statistically different at the end of the L.A.B.S. program regarding their science anxiety.

The results of the Science Anxiety survey for the fifteen students in Group 2 show a wider range of science anxiety than Group 1. Group 2 students had a low of 60 and a high of 143 (Figure 4.19). There is no significant difference in the student responses for the Science Anxiety survey in pre-test Group 3 ($M = 85.29$, $SD = 26.91$) and post-test Group 2 ($M = 84.64$, $SD = 26.93$); $t = 0.5406$, $p = 0.5888$ (Table 4.6 & 4.7).
Figure 4.19: Science Anxiety Scores for Group 2 Study Participants
This figure shows how the Group 2 study participants scored on the Science Anxiety survey.

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>Median</th>
<th>Mode</th>
<th>Standard Deviation</th>
<th>Standard Error Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 3 Pre-test</td>
<td>14</td>
<td>85.29</td>
<td>92</td>
<td>107</td>
<td>26.91</td>
<td>7.19</td>
</tr>
<tr>
<td>Group 2 Post-test</td>
<td>15</td>
<td>90.33</td>
<td>91</td>
<td>102</td>
<td>22.98</td>
<td>5.93</td>
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### Table 4.7
L.A.B.S. Science Anxiety Pre-survey Group 3 and Post-survey Group 2 t-test

<table>
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<th>df</th>
<th>Sig. (2-tailed)</th>
<th>Mean Difference</th>
<th>Std. Error Difference</th>
<th>95% Confidence Interval of the Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>t</td>
<td>df</td>
<td>Sig. (2-tailed)</td>
<td>Mean Difference</td>
<td>Std. Error Difference</td>
<td>95% Confidence Interval of the Difference</td>
</tr>
<tr>
<td>Equal variance assumed</td>
<td>0.5406</td>
<td>14.5086</td>
<td>0.5888</td>
<td>-5.0400</td>
<td>9.3236</td>
<td>-24.9087 - 14.8287</td>
</tr>
</tbody>
</table>

#### 4.3.3 Does participation in the L.A.B.S. program affect students' interest in science, interest in technology, interest in engineering, interest in mathematics, and pursuing a career in a STEM field?

The results of the STEM Semantics survey for the six Group 1 students show an extremely high interest in the STEM fields and pursuing a career in STEM. The maximum score for each area is 35, which correlates to extremely high interest. The minimum score is 7, which correlates to no interest. Group 1 students had a low of 33 and a high of 35 in science, a low of 29 and a high of 35 in technology, a low of 21 and a high of 31 in engineering, a low of 19 and a high of 35 in math, and a low of 33 and a high of 35 in a STEM career (Figure 4.20). There is no significant difference in the student responses for the STEM Semantics survey in pre-test Group 3 ($M = 150.57$, $SD = 13.11$) and post-test Group 1 ($M = 154.67$, $SD = 10.48$); $t = 0.7414$, $p = 0.9169$ (Table 4.8 & 4.9).
Figure 4.20: STEM Semantics Post-Survey Scores for Group 1 Study Participants
This figure shows the post-survey scores for the STEM Semantics survey for Group 1.

Table 4.8
L.A.B.S. STEM Semantics Pre-survey Group 3 and Post-survey Group 1 Statistics

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>Median</th>
<th>Mode</th>
<th>Standard Deviation</th>
<th>Standard Error Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 3 Pre-test</td>
<td>14</td>
<td>150.57</td>
<td>151</td>
<td>N/A</td>
<td>13.11</td>
<td>3.5</td>
</tr>
<tr>
<td>Group 1 Post-test</td>
<td>6</td>
<td>154.67</td>
<td>156.5</td>
<td>N/A</td>
<td>10.48</td>
<td>4.28</td>
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</table>

Table 4.9
L.A.B.S. STEM Semantics Pre-survey Group 3 and Post-survey Group 1 t-test

<table>
<thead>
<tr>
<th></th>
<th>t</th>
<th>df</th>
<th>Sig. (2-tailed)</th>
<th>Mean Difference</th>
<th>Std. Error Difference</th>
<th>95% Confidence Interval of the Difference</th>
</tr>
</thead>
<tbody>
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<td></td>
<td></td>
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<td>Lower</td>
</tr>
<tr>
<td>Equal variance assumed</td>
<td>0.7414</td>
<td>10.7703</td>
<td>0.9169</td>
<td>4.1000</td>
<td>5.5301</td>
<td>-8.0717</td>
</tr>
</tbody>
</table>
Based on these results, it is assumed that the Group 1 students are not statistically different at the end of the L.A.B.S. program regarding their interest in the STEM fields and pursuing a career in STEM than at the program's onset.

The results of the STEM Semantics survey for the 15 Group 2 students show a wide range of interest in the various STEM fields while maintaining a fairly high interest in pursuing a career in STEM. Group 2 students had a low of 14 and a high of 35 in science, a low of 22 and a high of 35 in technology, a low of 5 and a high of 35 in engineering, a low of 10 and a high of 32 in math, and a low of 18 and a high of 35 in STEM overall (Figure 4.21). There is a significant difference in the student responses for the STEM Semantics survey in pre-test Group 3 ($M = 150.57, SD = 13.11$) and post-test Group 2 ($M = 133.6, SD = 19.6$); $t = 2.7570, p = 0.0117$ (Table 4.10 & 4.11).

**Figure 4.21: STEM Semantics Post-Survey Scores for Group 2 Study Participants**
This figure shows the post-survey scores for the STEM Semantics survey for Group 2.
Table 4.10
L.A.B.S. STEM Semantics Pre-survey Group 3 and Post-survey Group 2 Statistics

<table>
<thead>
<tr>
<th>Group</th>
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<th>Mean</th>
<th>Median</th>
<th>Mode</th>
<th>Standard Deviation</th>
<th>Standard Error Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 3 Pre-test</td>
<td>14</td>
<td>150.57</td>
<td>151</td>
<td>N/A</td>
<td>13.11</td>
<td>3.5</td>
</tr>
<tr>
<td>Group 2 Post-test</td>
<td>15</td>
<td>133.6</td>
<td>137</td>
<td>114</td>
<td>19.6</td>
<td>5.06</td>
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</table>

Table 4.11
L.A.B.S. STEM Semantics Pre-survey Group 3 and Post-survey Group 2 t-test

<table>
<thead>
<tr>
<th></th>
<th>t-test for equality of means</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>t</td>
</tr>
<tr>
<td>Equal variance assumed</td>
<td>2.7570</td>
</tr>
</tbody>
</table>

Based on these results, it is assumed that the Group 2 students are statistically different at the end of the L.A.B.S. program regarding their interest in the STEM fields and pursuing a career in STEM than at the program's onset. However, these results show students had less interest than they had at the beginning of the L.A.B.S. program.
4.3.4 Does the L.A.B.S. program help alleviate barriers for underrepresented and disadvantaged students?

The data for all the validated instruments were segregated to examine any differences based on gender, race, grade level, and income. No significant differences were found between the groups when comparing pre-survey results to post-survey results.

Focus group transcripts were analyzed by looking at each question, and the results for groups 1 and 2 are as follows.

Focus Group Question 1: Do you feel that L.A.B.S. has helped you understand concepts that you had/have learned in your science classes at school, and if so, how?

Most respondents reported that L.A.B.S. enabled them to fill gaps and obtain more in-depth knowledge about subjects they covered in school. Students stated that hands-on experiments make it easier to understand concepts and topics and remember things when tested on them later. One student commented, "it is easier to learn when you see what you're doing when you're doing it."

Focus Group Question 2: Has your participation in L.A.B.S. changed the way you feel when taking science tests in school, and if so, how?

Students overwhelmingly agreed that they understood concepts more instead of just memorizing things to take tests. While not all students thought L.A.B.S. helped with specific tests, multiple students agreed that it improved their critical thinking skills, which allowed them to improve on tests. One student commented, "it helps you visualize what we are learning, and I don't know why – this is probably just me, but I feel I'm a lot more comfortable asking questions now."
Focus Group Question 3: How has L.A.B.S affected your confidence in performing laboratory experiments in the future, if it affected it at all?

Students reported feeling much more comfortable working with lab equipment and in a lab setting. They also said they had increased confidence when they had to perform labs in school and gained the ability to do experiments confidently by themselves. One student discussed the length of time of the L.A.B.S. program and how "when you get that much lab experience, you are bound to feel more confident doing future experiments and stuff. It definitely helped how comfortable I am and confident when it comes to experiments in the lab."

Focus Group Question 4: Unlike other experiments performed in L.A.B.S., CRISPR is a new technique that is still experimental and not completely understood. How do you feel about getting to perform CRISPR in L.A.B.S.?

Students felt "really good" about using cutting-edge technology and thought it was a cool opportunity to do CRISPR as high schoolers. One student stated, "A couple of years ago, I would never have imagined that I myself would actually be doing CRISPR in a lab, and being exposed to very new types of lab work really improves my confidence and helps me see myself in a STEM profession in the future."

Focus Group Question 5: How has L.A.B.S. increased or decreased your interest in STEM or science, if it has at all?

Students reported that "interest has exponentially gone up," "increased my interest," "drastically increased," "changed my viewpoint on science as a whole," and "was definitely eye-opening." One student commented, "L.A.B.S. has really opened my mind to working as a researcher in science or genetics or biotech and not just medicine."
Focus Group Question 6: How have the CRISPR experiments increased or decreased your interest in STEM/science, if they have at all?

Students reported a piqued interest in CRISPR and wanted to pay more attention to stories about gene editing. Students reported gaining a better understanding of the concept, "so, when I read all these scary news articles, I have a better grasp - what is science fact and what is science fiction -- there is still a lot of potential for its applications in the future." Students didn't think the CRISPR experiments changed their interest in STEM/science but thought, "it was eye-opening because I never had thought about gene editing tools."

Focus Group Question 7: You participated in numerous experiments in L.A.B.S. during your first two semesters. Do you feel that performing these experiments helped you complete the CRISPR experiment, and if so, how and why?

Group 1 and 2 students overwhelmingly believed that the skills learned during the first two semesters aided them in successfully completing and understanding the CRISPR experiment. One student reported that they thought, "the labs that we have done before have been setting us up for [the CRISPR experiment] because a bunch of things we did with CRISPR involved a lot of techniques that we did in other labs."

Focus Group Question 8: Has attending L.A.B.S. and performing CRISPR influenced your plans to pursue a STEM/science degree in college and/or pursue a career in STEM/science? If so, how?

Students not only stated that L.A.B.S. influenced their career plans but that it also gave them more information about all of the career possibilities in STEM. Multiple students discussed being focused on medicine as a career path but now know they have
other options. At least three students found they had a passion for lab work they didn't realize before by sharing that "I really especially love lab work" and recognizing that "I am much more suited to actually do lab work and just be in the laboratory setting."

Another student discussed "switching from field research to being more interested in lab work."

Focus group facilitators asked a couple of the groups if anyone had become less interested in science, and everyone asked either said no or shook their heads no. The facilitators also asked if anyone had additional comments. One student discussed how they enjoyed L.A.B.S. because "this is the kind of experience that you never get in high school -- possibly in college. I'm glad we have it now because we can -- we have a perspective on what we want to do because if it was years [later] and you're in college, and you finally get to do lab and work with these things, and then you realize you have a love for it. I feel like you have an opportunity before all of that to really get your interest [nailed] down."

The answers to the focus group questions were separated into gender, race, grade level, and income and re-analyzed. Females overwhelmingly stated an increased interest in science and wanting to pursue a career in STEM. Females also discussed now having many more options as to what jobs they might want to pursue. Several female students also stated they were looking for even more opportunities similar to L.A.B.S. to participate in before college. There were a couple of students in 9th grade saying that their career aspirations hadn't changed because they didn't really have any coming into the program and still don't. There were no real insights based on race or income level.
4.3.5 Is the CRISPR project being taught in a manner that allows for student comprehension and understanding?

CRISPR pre-and post-test data were compared utilizing the t-test to determine if the data had changed. Average scores and percent increases between the pre-and post-tests were also determined. The results for groups 1 and 2 are presented below.

The average score on the pre-test for Group 1 was 52.22, while the average score on the post-test was 74.44. This resulted in a 22.22 score increase and a 69% improvement in test scores for Group 1 for the CRISPR subject matter tests. There was a significant difference between the pre-test group \((M = 52.22, \ SD = 22.08)\) and the post-test group \((M = 74.44, \ SD = 9.81)\); \(t = 2.9882, \ p = 0.0056\) (Table 4.12 & 4.13).

<table>
<thead>
<tr>
<th>Table 4.12</th>
<th>L.A.B.S. Group 1 CRISPR Pre-survey and Post-survey Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Group</td>
</tr>
<tr>
<td>------------</td>
<td>------------------------------------</td>
</tr>
<tr>
<td></td>
<td>Group 1 Pre-test</td>
</tr>
<tr>
<td></td>
<td>Group 1 Post-test</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 4.13</th>
<th>L.A.B.S. Group 1 CRISPR Pre-survey and Post-survey t-test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>t-test for equality of means</td>
</tr>
<tr>
<td></td>
<td>t</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Equal variance assumed</td>
<td>2.9882</td>
</tr>
</tbody>
</table>
The average score on the pre-test for Group 2 was 48.44, while the average score on the post-test was 77.78. This resulted in a 29.33 score increase and a 75% improvement in test scores for Group 2 for the CRISPR subject matter tests. There was a significant difference between the pre-test group ($M = 48.44, SD = 14.36$) and the post-test group ($M = 77.78, SD = 10.89$); $t = 6.2651, p = 0.000021$ (Table 4.14 & 4.15).

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>Median</th>
<th>Mode</th>
<th>Standard Deviation</th>
<th>Standard Error Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 2 Pre-test</td>
<td>15</td>
<td>48.44</td>
<td>46.67</td>
<td>53.33</td>
<td>14.36</td>
<td>3.71</td>
</tr>
<tr>
<td>Group 2 Post-test</td>
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<td>77.78</td>
<td>80.00</td>
<td>86.67</td>
<td>10.89</td>
<td>2.81</td>
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Table 4.15
L.A.B.S. Group 2 CRISPR Pre-survey and Post-survey t-test

<table>
<thead>
<tr>
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<th>t</th>
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<th>Sig. (2-tailed)</th>
<th>Mean Difference</th>
<th>Std. Error Difference</th>
<th>95% Confidence Interval of the Difference</th>
</tr>
</thead>
</table>

The results show that Groups 1 and 2 increased their scores on the CRISPR subject matter test between the beginning and the end of the CRISPR project. These
results indicate that the students gained a better understanding and comprehension of the subject, and effective teaching measures were undertaken.
CHAPTER 5

GROUP: DATA & ANALYSIS

5.1 Introduction

Group 3 participants in this study could take the validated instrument surveys at the beginning and end of the L.A.B.S. program. This allowed for a more meaningful comparison of their attitudes pertaining to science anxiety, self-efficacy, and career interests and how they might have changed throughout the L.A.B.S. program. This chapter introduces the third group in this study and discusses their survey and focus group results.

5.2 Demographics

Group 3 began the L.A.B.S. program in Fall 2020 with 16 students. This group included three 9th graders, five 10th graders, two 11th graders, and six 12th graders. Only 14 could fully participate in the study, complete all surveys, and participate in the focus group. Demographic data for the students in group 3 is shown in the figures below.
**Figure 5.1: Student Gender Data at the start of L.A.B.S. for Group 3**
This figure shows the self-reported gender data for the 16 students in group 3 selected and participating in the L.A.B.S. program starting in Fall 2021.

![Group 3 Student Gender Data at the start of L.A.B.S.](image)

**Figure 5.2: Student Race Data at the start of L.A.B.S. for Group 3**
This figure shows the self-reported race data for the 16 students in group 3 selected and participating in the L.A.B.S. program starting in Fall 2021.

![Group 3 Student Race Data at the start of L.A.B.S.](image)
Figure 5.3: Student Income Data at the start of L.A.B.S. for Group 3
This figure shows the self-reported income data for the 16 students in group 3 selected and participating in the L.A.B.S. program starting in Fall 2021.

Figure 5.4: Student Gender Data for Group 3 Study Participants
This figure shows the self-reported gender data for the 14 students in group 3 that participated in this study during the Summer of 2022.
Figure 5.5: Student Race Data for Group 3 Study Participants
This figure shows the self-reported gender data for the 14 students in group 3 that participated in this study during the Summer of 2022.

Figure 5.6: Student Income Data for Group 3 Study Participants
This figure shows the self-reported income data for the 14 students in group 3 that participated in this study during the Summer of 2022.
All but one student in Group 3 fit into at least one of the targeted groups of the L.A.B.S. program. 50% of the students fit into two or more targeted groups. Of the students included in this study, 50% fit into two or more of the targeted groups.

5.3 Results

This section contains the results of the three validated instruments: the SIC-STEM survey, the Science Anxiety survey, and the STEM Semantics survey given at the beginning and the end of the L.A.B.S. program. The results of the focus group discussions and the CRISPR subject matter pre- and post-test are also discussed. These surveys, discussions, and tests were used to answer the research questions described in the following sub-sections for Group 3.

5.3.1 Does participation in the L.A.B.S. program affect students' self-efficacy and outcome expectations and influence students' interest in STEM-based careers?

Totals for the SIC-STEM instrument post-surveys vary more than the pre-survey totals. The post-survey had a low of 39, while the pre-surveys lowest score was 54. The highest score for the post-survey was 75, up just 3 points from the pre-survey. Pre-and post-survey data for the SIC-STEM instrument for Group 3 were compared utilizing the t-test to determine if the data had changed following participation in the L.A.B.S. program. There was no significant difference in the student responses for the SIC-STEM instrument in the pre-survey \( (M = 63.29, SD = 5.46) \) and post-survey \( (M = 61.57, SD = 9.94) \); \( t = 0.8204, p = 0.8240 \) (Table 5.1 & 5.2).
Based on these results, it is assumed that the Group 3 students are not statistically different at the end of the L.A.B.S. program regarding their confidence or interest in science and ways to achieve a career in science.

5.3.2 Does participation in the L.A.B.S. program affect the persistence of science anxiety?

The results of the Science Anxiety survey for the fourteen Group 3 students show a wide range of science anxiety in both the pre-survey and post-survey totals. Group 3 students had a low of 40 and a high of 134 on the pre-survey. Group 3 students had a low of 47 and a high of 125 (Figure 5.7) on the post-survey. There is no significant
difference in the student responses for the Science Anxiety survey completed before 

\( (M = 85.29, \ SD = 26.91) \) and after L.A.B.S. \( (M = 84.64, \ SD = 26.93) \); \( t = 0.5406, \ p = 0.5888 \) (Table 5.3 & 5.4).

![Science Anxiety Group 3](image)

**Figure 5.7: Science Anxiety Scores for Group 3 Study Participants**

This figure shows how the Group 3 study participants scored on the Science Anxiety survey.

**Table 5.3**

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>Median</th>
<th>Mode</th>
<th>Standard Deviation</th>
<th>Standard Error Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 3 Pre-survey</td>
<td>14</td>
<td>85.29</td>
<td>92</td>
<td>107</td>
<td>26.91</td>
<td>7.19</td>
</tr>
<tr>
<td>Group 3 Post-survey</td>
<td>14</td>
<td>84.64</td>
<td>94.5</td>
<td>N/A</td>
<td>29.63</td>
<td>7.92</td>
</tr>
</tbody>
</table>
Table 5.4
L.A.B.S. Science Anxiety Group 3 Pre-and Post-Survey t-test

<table>
<thead>
<tr>
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<th>t</th>
<th>df</th>
<th>Sig. (2-tailed)</th>
<th>Mean Difference</th>
<th>Std. Error Difference</th>
<th>95% Confidence Interval of the Difference</th>
</tr>
</thead>
<tbody>
<tr>
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<td>0.6429</td>
<td>4.1952</td>
<td>-8.4189 to 9.7046</td>
</tr>
</tbody>
</table>

Based on these results, it is assumed that the Group 3 students are not statistically different at the end of the L.A.B.S. program regarding their science anxiety.

5.3.3 Does participation in the L.A.B.S. program affect students' interest in science, interest in technology, interest in engineering, interest in mathematics, and pursuing a career in a STEM field?

The results of the STEM Semantics survey for the fourteen students in Group 3 show an extremely high interest in the STEM fields and pursuing a career in STEM. The maximum score for each area is 35, which correlates to extremely high interest. The minimum score is 7, which correlates to no interest. At least one student ranked their interest at 35 in every area in both pre-and post-surveys. Group 3 students had only slight changes in the minimum score for each area between the pre-and post-surveys except Math, which had decreased from 17 to 8 (Figure 5.8). There is no significant difference in the student responses for the STEM Semantics survey in pre-program
Group 3 ($M = 150.57, SD = 13.11$) and post-program Group 3 ($M = 143.86, SD = 20.82$); $t = 2.8162, p = 0.0576$ (Table 5.5 & 5.6).

Figure 5.8: STEM Semantics Math Scores for Group 3 Study Participants
This figure shows how the Group 3 study participants scored on the STEM Semantics Math survey.

Table 5.5
L.A.B.S. STEM Semantics Group 3 Pre- and post-survey Statistics

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>Median</th>
<th>Mode</th>
<th>Standard Deviation</th>
<th>Standard Error Mean</th>
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</thead>
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<tr>
<td>Group 3 Pre-survey</td>
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<td>150.57</td>
<td>151</td>
<td>N/A</td>
<td>13.11</td>
<td>3.5</td>
</tr>
<tr>
<td>Group 3 Post-survey</td>
<td>14</td>
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<td>142</td>
<td>173</td>
<td>20.82</td>
<td>5.56</td>
</tr>
</tbody>
</table>
Based on these results, there was no significant difference in STEM interest and STEM career interest throughout the L.A.B.S. program for students in Group 3.

5.3.4 Does the L.A.B.S. program help alleviate barriers for underrepresented and disadvantaged students?

The data for all the validated instruments were segregated to examine any differences based on gender, race, grade level, and income. No significant differences were found between the groups when comparing pre-survey results to post-survey results.

Focus group transcripts were analyzed by looking at each question, and the results for Group 3 are as follows.

Focus Group Question 1: Do you feel that L.A.B.S. has helped you understand concepts that you had/have learned in your science classes at school, and if so, how?

As with the first two groups, respondents of Group 3 reported that L.A.B.S. enabled them fully understand concepts and subjects they covered in school. Students stated that hands-on experiments were crucial to facilitate this deeper understanding.
One student commented, "this program showed a lot of lab techniques that were mentioned or introduced in school but not done."

Focus Group Question 2: Has your participation in L.A.B.S. changed the way you feel when taking science tests in school, and if so, how?

Nearly half of the students in Group 3 thought L.A.B.S. changed their feelings about school tests. Some thought L.A.B.S. made taking tests easier, while others thought it only helped when the topics on their school tests and in L.A.B.S. overlapped.

Focus Group Question 3: How has L.A.B.S affected your confidence in performing laboratory experiments in the future, if it affected it at all?

All students in Group 3 stated that their confidence was "boosted" or that their confidence "increased." One student described the effect L.A.B.S. had, saying, "It has definitely increased my confidence because I was exposed to more advanced -- like machinery and lab techniques -- that I would not have gotten in my school, and it has given me the ability to be confident in my ability to work independently."

Focus Group Question 4: Unlike other experiments performed in L.A.B.S., CRISPR is a new technique that is still experimental and not completely understood. How do you feel about getting to perform CRISPR in L.A.B.S.?

Group 3 students were very excited about getting to perform CRISPR because they felt like it was such a new technology, and they wouldn't usually have access to that type of technology. One student said they "liked it [because] we got to actually do it instead of just reading about it. It was complicated, and we still did it.

Focus Group Question 5: How has L.A.B.S. increased or decreased your interest in STEM or science, if it has at all?
Like the results seen in groups 1 and 2, Group 3 overwhelmingly stated that L.A.B.S. increased their interest in science and opened their eyes to other possibilities for STEM careers. One student commented, "I don't think I ever realized how deep the subject is and just how much there is to know." At least three students expressed that L.A.B.S. had helped them figure out which STEM area they wanted to focus.

Focus Group Question 6: How have the CRISPR experiments increased or decreased your interest in STEM/science, if they have at all?

Most Group 3 students said the CRISPR experiments did increase their interest in STEM/science. A couple of the students stated that their interests in science hadn't changed due to the CRISPR experiment. However, they became aware of additional ethical issues they hadn't considered before. One student, in particular, said, "I think the introduction that we did and the discussion that we had increased my interest in the ethical part of CRISPR."

Focus Group Question 7: You participated in numerous experiments in L.A.B.S. during your first two semesters. Do you feel that performing these experiments helped you complete the CRISPR experiment, and if so, how and why?

Most students agreed that the first two semesters were good preparation for the CRISPR experiment. One student stated the previous lab work "helped me build a strong foundation to ultimately do the CRISPR experiment." Another student said, "So, I feel like if we had went straight into CRISPR and didn't have those small things to build on I probably would have been totally lost."
Focus Group Question 8: Has attending L.A.B.S. and performing CRISPR influenced your plans to pursue a STEM/science degree in college and/or pursue a career in STEM/science? If so, how?

Group 3 students expressed that the L.A.B.S. program increased their interest in pursuing a career and gave them knowledge of the vastness of available STEM careers. A couple of students discussed that L.A.B.S. has helped prepare them for college and the lab courses they will take during their college careers.

The answers to the focus group questions were separated into gender, race, grade level, and income and re-analyzed. Females, once again, were overwhelmingly positive when describing their increased interest in science and wanting to pursue a career in STEM. There were no real insights based on race, grade level, or income level.

5.3.5 Is the CRISPR project being taught in a manner that allows for student comprehension and understanding?

CRISPR pre-and post-test data were compared utilizing the t-test to determine if the data had changed from the beginning of the CRISPR project to the end of the CRISPR project. Average scores and percent increases between the pre-and post-tests were also determined. The average score on the pre-test for Group 3 was 46.19, while the average score on the post-test was 71.43. This resulted in a 25.14 score increase and a 71% improvement in test scores for Group 3 on the CRISPR subject matter tests. There was a significant difference between the pre-test group (\( M = 46.19, SD = 20.33 \)) and the post-test group (\( M = 71.43, SD = 11.82 \)); \( t = 5.4332, p = 0.00011 \) (Table 5.7 & 5.8).
### Table 5.7
L.A.B.S. Group 3 CRISPR Pre-survey and Post-survey Statistics

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>Median</th>
<th>Mode</th>
<th>Standard Deviation</th>
<th>Standard Error Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 3 Pre-test</td>
<td>14</td>
<td>46.19</td>
<td>43.33</td>
<td>33.33</td>
<td>20.33</td>
<td>5.43</td>
</tr>
<tr>
<td>Group 3 Post-test</td>
<td>14</td>
<td>71.43</td>
<td>73.33</td>
<td>73.33</td>
<td>11.82</td>
<td>3.16</td>
</tr>
</tbody>
</table>

### Table 5.8
L.A.B.S. Group 3 CRISPR Pre-survey and Post-survey t-test

<table>
<thead>
<tr>
<th>Equal variance assumed</th>
<th>t</th>
<th>df</th>
<th>Sig. (2-tailed)</th>
<th>Mean Difference</th>
<th>Std. Error Difference</th>
<th>95% Confidence Interval of the Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>t</td>
<td>df</td>
<td></td>
<td></td>
<td></td>
<td>Lower</td>
</tr>
<tr>
<td></td>
<td>5.4332</td>
<td>13.0000</td>
<td>0.00011</td>
<td>-25.2386</td>
<td>4.6452</td>
<td>-35.2723</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Upper</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-15.2049</td>
</tr>
</tbody>
</table>

The results show that Group 3 increased their scores on the CRISPR subject matter test between the beginning and the end of the CRISPR project. These results indicate that the students gained a better understanding and comprehension of the subject, and effective teaching measures were undertaken.
CHAPTER 6

CONCLUSION

6.1 Introduction

L.A.B.S. is an immersive, after-school STEM program that targets applicants from traditionally underrepresented or disadvantaged groups in STEM. This study aimed to determine if high school students who complete L.A.B.S. have higher interest levels in science, technology, engineering, and mathematics and are more likely to pursue a degree or career in STEM. This study examined an overall interest in STEM and a career in STEM, as well as an interest in the individual fields of science, technology, engineering, and mathematics. This study was also designed to determine if students who have completed the course have increased self-efficacy and less science anxiety. L.A.B.S. culminates with students learning about and performing a bona fide CRISPR experiment. The study also determined if taking part in cutting-edge technology, like using the gene-editing tool CRISPR, influenced any of these ideas and if the students could understand CRISPR adequately.

The lack of cultural minority and female representation in STEM fields has long been an issue many institutions have tried to address[117]. Since the participants of the L.A.B.S. program are often underrepresented and disadvantaged in STEM fields, this study also attempted to ascertain if these populations were affected more or less than their
represented counterparts. According to historical evidence and current literature, female students are significantly less likely to pursue STEM careers[118]. Black, Hispanic, and American Indian populations are underrepresented in STEM and less likely to pursue STEM careers[119]. Lower-income students also face barriers to accessing programs and experiences that can help lead them to STEM careers. This study examined these populations within the L.A.B.S. program and their effect on STEM subjects, career interests, self-efficacy, and science anxiety.

6.2 Study Design

This mixed-methods study used quantitative and qualitative methods to obtain and analyze the data. Three validated instruments were used and served as the quantitative measures for the study. The SIC-STEM survey was used to examine how self-efficacy and outcome expectations influence students' interest in STEM-based careers. The Science Anxiety survey was used to determine if participation in the L.A.B.S. program alleviated science anxiety. The STEM Semantics survey was used to measure student interest in science, technology, engineering, and mathematics, as well as interest in STEM careers. These three instruments were taken by Group 3 participants at the beginning of the L.A.B.S. program and by all participants at the conclusion of their respective L.A.B.S. program. A subject matter survey was used to determine if the CRISPR project was taught in a manner that allowed for student comprehension and understanding. All participants took this survey at the beginning and end of the summer session.
Focus groups served as the qualitative measures for the study. The focus group questions were designed to assess the students' feelings about how the L.A.B.S. program affected their STEM interests, if it did at all. The questions also inquired about the activities performed during L.A.B.S. and what the students gained from those experiences, if anything. Other questions tried to determine if the student's interests in a STEM career had changed following participation in the program. Overall, the focus group setting allowed the students to expand on their feelings without constraint, in contrast to the surveys that allowed only specific answers. The group setting also promoted the free flow of conversation between students and facilitators. The transcripts from these end-of-program focus groups were used to assess the data for all participants.

6.3 Review of the findings

6.3.1 Research Question 1: Does participation in the L.A.B.S. program affect students' self-efficacy and outcome expectations and influence students' interest in STEM-based careers?

The results of the SIC-STEM survey showed no statistical difference between pre-and post-surveys for Group 3. Group 2 post-survey data was compared to Group 3 pre-survey data and also showed no statistical difference. Group 1 post-survey data was too different from Group 3 pre-survey data to be compared. Ultimately, according to the SIC-STEM study results, there was no evidence to suggest that the L.A.B.S. program affected students' self-efficacy, outcome expectations, or interest in STEM careers. This study is one of the first instances where the SIC-STEM survey has been used, making it impossible to compare results from previous studies that utilized the same survey.
6.3.2 Research Question 2: Does participation in the L.A.B.S. program affect the persistence of science anxiety?

The results of the Science Anxiety survey showed no statistical difference between pre-and post-surveys for any of the groups. There is no evidence that the L.A.B.S. program affected students' science anxiety. The lack of a decrease in science anxiety is not surprising. The Science Anxiety survey is set up in a way that addresses broad situations in science that students might encounter. Since the L.A.B.S. program focuses on biology lab skills and concepts, it’s not surprising that there is no decrease in students’ anxiety over Physics or music, etc. Numerous other Science Anxiety survey studies have had similar results[120]–[124].

6.3.3 Research Question 3: Does participation in the L.A.B.S. program affect students' interest in science, interest in technology, interest in engineering, interest in mathematics, and pursuing a career in a STEM field?

The results of the STEM Semantics survey showed no statistical difference between pre-and post-surveys for any of the groups. There is no evidence that the L.A.B.S. program affected students' interest in STEM fields or pursuing STEM careers. Numerous studies have utilized the STEM Semantics survey when looking for changes in student interest in STEM fields. The results varied depending on the program the survey evaluated [125]–[128].
6.3.4 Research Question 4: Does the L.A.B.S. program help alleviate barriers for underrepresented and disadvantaged students?

Focus group data showed students overwhelmingly agreed that L.A.B.S. helped them form a deeper understanding and more in-depth knowledge of topics and subjects covered in their science classes at school due to their participation in the program. About 50% of students also said that the knowledge they learned in L.A.B.S. did make taking tests in school easier. The other 50% of students who didn't think the knowledge learned in L.A.B.S. pertained to taking tests in school did feel that L.A.B.S. increased their critical thinking ability, which helped them when taking tests in school.

All but one student in the focus groups communicated that their confidence in a lab setting, utilizing lab equipment, and working independently in a lab all increased due to participating in L.A.B.S. Even though the SIC-STEM survey didn’t show an increase in self-efficacy, the focus groups showed an increase in confidence. This contrasting data is most likely due to student interpretation of the statements on the SIC-STEM survey. The three statements that attempt to assess self-efficacy focus on a student's feelings about getting a good grade and doing well in science. The last statement directly considers a student’s confidence. Of the six students that marked that they agreed or strongly agreed that they were not confident in science, none of them felt like they weren’t able to do well or get a good grade in science. The benefit of the focus group was to allow expansion on what they actually felt confident about in science.

According to the focus group responses, the CRISPR project allowed students to learn about and understand this gene-editing technology. Numerous students thought it was a great project and were excited to be able to do such a cutting-edge technique.
Students enjoyed learning about and discussing the ethical aspects of using CRISPR for human gene editing. Although the students enjoyed the CRISPR experiment, it primarily only increased their interest in CRISPR and not necessarily other STEM fields. Overall, the students stated their interest in STEM/science and pursuing a career in STEM had increased due to participating in the L.A.B.S. program, even though the results of the STEM Semantics survey did not show a change.

Students agreed that the first two semesters of L.A.B.S. allowed them to gain the skills and knowledge that helped them complete the CRISPR project successfully. Multiple students discussed the fact that L.A.B.S. opened their eyes to many careers in STEM that they were unaware of before and helped them decide to go on and pursue a degree in STEM.

A small number of student focus group responses stated that while they enjoyed L.A.B.S. and all of the experiments and activities they could do, it hadn’t changed their opinions on STEM or pursuing a career in STEM. They all said they had already wanted to pursue STEM careers when they applied to L.A.B.S. If anything, it just helped confirm their decisions. The demographics of these students were Asian and Caucasian males. The demographics of students that stated L.A.B.S. increased their interest in STEM and pursuing a career in STEM were overwhelmingly female.

The increase in interest in pursuing a STEM career stated by female L.A.B.S. participants does show a positive effect of the program. This positive effect also speaks to overcoming one of the issues in the lack of diversity in STEM fields. Since women are far more historically likely not to pursue a STEM career, giving these students the
opportunity and their positive reaction should help increase their persistence in a STEM career as their ultimate goal.

6.3.5 **Research Question 5: Is the CRISPR project being taught in a manner that allows for student comprehension and understanding?**

All three groups showed significant improvements in the pre-and post-subject matter surveys related to CRISPR, confirming that it was being taught in a manner that allowed for student understanding and comprehension. This indicates the CRISPR project is an appropriate culminating project for this program and can be used for subsequent cohorts.

The results of this study didn’t lessen science anxiety in students or increase interest in STEM fields and careers in all underrepresented and disadvantaged populations. However, it did increase female interest in pursuing a career in STEM. This study also exposed students to cutting-edge technology that they most likely wouldn’t see anywhere else during their high school years.

6.4 **Social Cognitive Career Theory Model**

This study considered the relationships in the SCCT model and the interplay between self-efficacy, outcome expectations, and STEM career goals based on STEM-related activities in which students participate. Even though the results of this study did not show significant changes in the students’ self-efficacy, science anxiety, and STEM career interest throughout the L.A.B.S. program, correlations between SCCT model variables can be made. Utilizing the results of the SIC-STEM survey, it is apparent that
students who have stated an interest in pursuing a STEM career choose to participate in programs and take classes in school that will help them achieve their goals. These students also believe they can do well and are confident in science. These results indicate that the SCCT Interest and Choice model variables are related in the expected way and provide support for the model’s validity.

6.5 Other Findings of the Study

The focus groups allowed students to expand on their feelings about the L.A.B.S. program beyond the research questions. During the week-long summer experience, students were given a tour of the HudsonAlpha facility and saw several of the research labs. The students indicated that they would have liked to hear from the scientists and representatives of the labs themselves. One student said, “On the tour, we passed by many labs – we could see people working – we got a brief description of it – but getting to hear from the people that work there would be a nice touch.”

Four students from Group 2 also expressed that they did not always clearly understand the results of some of the experiments. They stated that they had a clear understanding when there was a physical result to an experiment, like a picture of an agarose gel. However, they would have liked more time to sit and think when the results were numerical or more ambiguous. The students also stated that they sometimes felt rushed and that working on more than one experiment at a time became even more confusing.
6.6 Pitfalls of the Study

Small sample size and the impacts of COVID were both pitfalls of this study. Group 1 ended up with only six students that completed all surveys and participated in the focus group. These students were highly invested in the L.A.B.S. program and STEM simply because they stuck with the program through a shift to a virtual Summer session in 2020 and returned for a make-up in-person Summer session in 2021. The type of student willing to continue with a program for this length of time most likely has a high interest in STEM and pursuing a STEM career. This type of student also likely has less science anxiety and higher self-efficacy than their peers.

One of the ways discussed earlier to alleviate science anxiety and increase self-efficacy is by utilizing active learning. While the L.A.B.S. program implements active learning, one of its main aspects was diminished. That aspect is that peer-to-peer engagement fosters active learning[129]. Due to COVID restrictions of masking and social distancing, students in the L.A.B.S. program had less interaction with each other, which could have led to less beneficial outcomes of active learning.

The lack of a control group and pre-surveys for two of the study groups were also pitfalls of this study. Without a control group, confirmation of the study results being due to the study’s independent variables rather than extraneous variables cannot be made. The missing pre-surveys also do not allow direct measurement of the changes the students in Groups 1 and 2 had over the course of the L.A.B.S. program for the three validated instrument surveys.
6.7 Future Research

The next step of this research is identifying ways to increase interest in STEM fields for various underrepresented and disadvantaged groups, particularly Black, Hispanic, and American Indian males. Attracting these populations of students to STEM will help lead to a more diverse STEM workforce.

One of the easiest ways to attract more diverse students to STEM is to identify role models with whom the students can relate. Invited guest speakers to the L.A.B.S. program should come from similar demographics of the students. When students see someone like them in a particular career field, they tend to believe they can also succeed in a similar career. When students hear how others like them have overcome barriers, they are more likely to persevere to break down barriers they might face.

Future research can also include a longitudinal study. Keeping in touch with the students participating in the L.A.B.S. program can elucidate more information about its impact. Following these students once they graduate high school, continue in college, and then into their careers can provide data on whether or not they persisted in STEM and the choices they made that influenced their careers.

Implementing the theory of a growth mindset in L.A.B.S. can also help increase self-efficacy and lessen science anxiety[130]. The growth mindset is a set of beliefs that focus on the concept that intelligence and talents can be developed and are not fixed. This mindset views failures as an opportunity to learn and believes mistakes are essential to learning. The growth mindset also embraces challenges and views others’ success as inspirational. The setting of the L.A.B.S. program is the perfect place to harbor the growth mindset. Students will definitely be challenged and will most certainly fail at
times. Many chances to celebrate the success of their peers and themselves are possible with the program's curriculum.
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APPENDIX A

Validated Instrument Surveys, Subject Matter Survey, and Focus Group Questions
SIC STEM Survey 2.0

For each of the following statements, please indicate the degree to which you agree or disagree. Even though some statements are very similar, please answer each statement. There are no "right" or "wrong" answers. The only correct responses are those that are true for you. Whenever possible, let the things that have happened to you help make your choice.

SCIENCE

Directions: Please respond to these questions regarding your feelings about science.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly Agree</th>
<th>Disagree</th>
<th>Neither Agree nor Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>I enjoy doing science work.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>I can get a good grade in science.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>I can earn money by knowing science.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>I want to choose a job in science.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>I do projects because I want a job in science.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>I do not like science.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>I can do well in science.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>I can get a good job by learning science.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>I want to use science after I finish high school.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>I try to get good grades because I want a job in science.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>I like doing experiments.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>I am not confident in science.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>The science I do in school will not help me in the real world.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>I want to use science in my job.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>I take more science classes because I want a job in science.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>
Science Anxiety Questionnaire

The items in the questionnaire refer to things and experiences that may cause fear or apprehension. For each item, place a check mark on the line under the column that describes how much YOU ARE FRIGHTENED BY IT NOWADAYS.

<table>
<thead>
<tr>
<th>Item</th>
<th>Not at all</th>
<th>A little</th>
<th>A fair amount</th>
<th>Much</th>
<th>Very Much</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learning how to convert Celsius to Fahrenheit degrees as you travel to Canada</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In a Philosophy discussion group, reading a chapter on the Categorical Imperative and being asked to answer questions</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asking a question in science class</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Converting kilometers to miles</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Studying for a midterm exam in Chemistry, Physics, or Biology</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Planning a well-balanced diet</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Converting American dollars to English pounds as you travel in the British Isles</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cooling down a hot tub of water to an appropriate temperature for a bath</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Planning the electrical circuit or pathway for a simple “light bulb” experiment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Changing the eyepiece on a microscope</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Using a thermometer in order to record the boiling point of a heating solution</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>You want to vote on an upcoming referendum on student activities fees, and you are reading about it so that you might make an informed decision</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Having a fellow student watch you perform an experiment in the lab</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visiting the Museum of Science and Industry and being asked to explain atomic energy to a 12-year-old</td>
<td></td>
<td></td>
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<td>Tuning your guitar to a piano or some other musical instrument</td>
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<td>-Replacing a bulb on a movie projector.</td>
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<td>-Focusing the lens on your camera.</td>
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<td>Asking a question in an English Literature class</td>
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STEM Semantics Survey

This five-part questionnaire is designed to assess your perceptions of scientific disciplines. It should require about 5 minutes of your time. Usually it is best to respond with your first impression, without giving a question much thought. Your answers will remain confidential.

Instructions: Choose one circle between each adjective pair to indicate how you feel about the object.

To me, SCIENCE is:

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To me, TECHNOLOGY is:

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To me, a CAREER in science, technology, engineering, or mathematics (is):

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CRISPR Subject Matter Survey

1. What does the technique commonly referred to as CRISPR do?
   a) It transcribes DNA into mRNA
   b) It is a gene-editing tool
   c) It translates mRNA into protein
   d) It is a gene expression regulator

2. Which option most closely relates to how CRISPR works?
   a) “measure and cut”
   b) “seek and destroy”
   c) “cut and paste”
   d) “trash and burn”

3. What enzyme is most commonly used in CRISPR gene editing?
   a) Cre3
   b) Rna5
   c) Cas9
   d) Cpr9

4. What is the role of guide RNA?
   a) Helps the cell recognize that DNA is damaged and tries to repair it
   b) Uses the DNA repair machinery to introduce changes to one or more genes
   c) Ensures that an enzyme cuts at the right point in the genome
   d) Makes a cut across both strands of double-stranded DNA

5. What was the original function of the CRISPR system?
   a) Defending bacteria from viral infections
   b) Defending leukocytes from viruses
   c) Defending bacteriophages from bacteria
   d) Defending multicellular organisms from bacteria

6. A PAM is
   a) A 15-20 bp viral sequence embedded in the host genome
   b) A polymerized adenosine monomer
   c) A 3-5 bp sequence adjacent to viral DNA in a CRISPR array
   d) A target sequence of a CRISPR enzyme
7. What does CRISPR stand for?
   
a) Clustered International Societies for Progressive Research  
b) It doesn’t stand for anything, it’s a technique used in gene editing  
c) Clustered Regularly Interspaced Short Palindromic Repeats  
d) Controlled Regulation In Short Phenotypic Regions  

8. Which option correctly describes all of the components required for a CRISPR reaction?
   
a) mRNA, DNA, ribosomes  
b) Viral proteins, mitochondria, tRNA  
c) Cre enzymes, CRISPR array, DNA  
d) sgRNA, DNA, Cas enzymes  

9. In what type of organisms can the CRISPR system be found naturally?
   
a) Eukaryotes  
b) Prokaryotes  
c) Archaea  
d) Viruses  

10. The enzymes used in the CRISPR system can best be compared to which of the following:
   
a) An anchor  
b) Scissors  
c) Glue  
d) Stapler  

11. Where does gene editing occur?
   
a) Anywhere in the genome, as long as the sgRNA binds upstream of a PAM sequence  
b) Anywhere in the genome, as long as the sgRNA binds downstream of a PAM sequence  

12. What does sgRNA stand for and why?
   
a) Short guide RNA, because it isn’t more than 100 bp  
b) Simple guide RNA, because it makes gene editing simple  
c) Short genomic RNA, because it binds genomic DNA  
d) Single guide RNA, because it is a fusion of crRNA and tracrRNA
13. HDR is less efficient than NHEJ because

   a) HDR is inherently mutagenic and bad for the host
   b) HDR relies on endogenous cellular proteins involved in homologous recombination
   c) HDR relies on particular sequence-specific motifs that reduce its frequency, whereas NHEJ does not
   d) None of the above, HDR is more efficient than NHEJ

14. What is NOT one of the three basic steps of CRISPR?
   a) Adaptation
   b) Integration
   c) Production of CRISPR RNA
   d) Targeting

15. Off-target mutations are a result of

   a) Mutant nuclease variants that randomly cut and mutate the genome
   b) Nontargeted sites that share sequence homology with the targeted locus
   c) Flawed sgRNA design, which hyperactivates nuclease activity to randomly cut and mutate nontargeted sites
   d) Errors that occur during DNA repair via HDR or NHEJ
Focus Group Questions for L.A.B.S. Students

1. Do you feel L.A.B.S. helped you understand concepts you had/have learned in your science classes at school? If so, how?
2. Has your participation in L.A.B.S. changed the way you feel when taking science tests in school? If so, how?
3. How has L.A.B.S. affected your confidence in performing laboratory experiments in the future, if it affected it at all?
4. Unlike other experiments performed in L.A.B.S., CRISPR is a new technique that is still experimental and not completely understood. How do you feel about getting to perform CRISPR in L.A.B.S.?
5. How has L.A.B.S. increased or decreased your interest in STEM/science, if it has at all?
6. How have the CRISPR experiments increased or decreased your interest in STEM/science, if they have at all?
7. You participated in numerous experiments in L.A.B.S. during the first two semesters. Do you feel performing these experiments helped you to complete the CRISPR experiment? If so, how and why?
8. Has attending L.A.B.S. and performing CRISPR influenced your plans to pursue a STEM/science degree in college and/or to pursue a career in STEM/science? If so, how?
APPENDIX B

IRB Approval Letter
The UAH Institutional Review Board of Human Subjects Committee has reviewed your proposal titled: Development of a CRISPR Lab for Underrepresented and Disadvantaged High School Students as a Tool to Increase Diversity and Retention in STEM Majors and the STEM Workforce and found it meets the necessary criteria for approval. Your proposal seems to be in compliance with these institutions Federal Wide Assurance (FWA) 00019998 and the DHHS Regulations for the Protection of Human Subjects (45 CFR 46).

Please note that this approval is good for one year from the date on this letter. If data collection continues past this period, you are responsible for processing a renewal application a minimum of 60 days prior to the expiration date.

No changes are to be made to the approved protocol without prior review and approval from the UAH IRB. All changes (e.g. a change in procedure, number of subjects, personnel, study locations, new recruitment materials, study instruments, etc) must be prospectively reviewed and approved by the IRB before they are implemented. You should report any unanticipated problems involving risks to the participants or others to the IRB Chair.

If you have any questions regarding the IRB’s decision, please contact me.

Sincerely,

Ann L. Bianchi
IRB Chair
Associate Professor, College of Nursing
Expedited: form 2

☐ Clinical studies of drugs and medical devices only when condition (a) or (b) is met. (a) Research on drugs for which an investigational new drug application (21 CFR Part 312) is not required. (Note: Research on marketed drugs that significantly increases the risks or decreases the acceptability of the risks associated with the use of the product is not eligible for expedited review. (b) Research on medical devices for which (i) an investigational device exemption application (21 CFR Part 812) is not required; or (ii) the medical device is cleared/approved for marketing and the medical device is being used in accordance with its cleared/approved labeling.

☐ Collection of blood samples by finger stick, heel stick, ear stick, or venipuncture as follows: (a) from healthy, nonpregnant adults who weigh at least 110 pounds. For these subjects, the amounts drawn may not exceed 550 ml in an 8 week period and collection may not occur more frequently than 2 times per week; or (b) from other adults and children, considering the age, weight, and health of the subjects, the collection procedure, the amount of blood to be collected, and the frequency with which it will be collected. For these subjects, the amount drawn may not exceed the lesser of 50 ml or 3 ml per kg in an 8 week period and collection may not occur more frequently than 2 times per week.

☐ Prospective collection of biological specimens for research purposes by noninvasive means. Examples: (a) hair and nail clippings in a nondisfiguring manner; (b) deciduous teeth at time of exfoliation or if routine patient care indicates a need for extraction; (c) permanent teeth if routine patient care indicates a need for extraction; (d) excreta and external secretions (including sweat); (e) uncannulated saliva collected either in an unstimulated fashion or stimulated by chewing gumbase or wax or by applying a dilute citric solution to the tongue; (f) placenta removed at delivery; (g) amniotic fluid obtained at the time of rupture of the membrane prior to or during labor; (h) supra- and subgingival dental plaque and calculus, provided the collection procedure is not more invasive than routine prophylactic scaling of the teeth and the process is accomplished in accordance with accepted prophylactic techniques; (i) mucosal and skin cells collected by buccal scraping or swab, skin swab, or mouth washings; (j) sputum collected after saline mist nebulization.

☐ Collection of data through noninvasive procedures (not involving general anesthesia or sedation) routinely employed in clinical practice, excluding procedures involving x-rays or microwaves. Where medical devices are employed, they must be cleared/approved for marketing. (Studies intended to evaluate the safety and effectiveness of the medical device are not generally eligible for expedited review, including studies of cleared medical devices for new indications).

☐ Research involving materials (data, documents, records, or specimens) that have been collected, or will be collected solely for nonresearch purposes (such as medical treatment or diagnosis).

☐ Collection of data from voice, video, digital, or image recordings made for research purposes.

☒ Research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies.
Exempt form 3:

☐ Research conducted in established or commonly accepted educational settings, involving normal educational practices, such as (a) research on regular and special education instructional strategies, or (b) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods. The research is not FDA regulated and does not involve prisoners as participants.

☐ Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interviews, or observation of public behavior in which information is obtained in a manner that human subjects cannot be identified directly or through identifiers linked to the subjects and any disclosure of the human subject’s responses outside the research would NOT place the subjects at risk of criminal or civil liability or be damaging to the subject’s financial standing, employability, or reputation. The research is not FDA regulated and does not involve prisoners as participants.

☐ Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement) survey procedures, interview procedures, or observation of public behavior if (a) the human subjects are elected or appointed public officials or candidates for public office, or (b) Federal statute(s) require(s) without exception that the confidentiality of the personally identifiable information will be maintained throughout the research and thereafter. The research is not FDA regulated and does not involve prisoners as participants.

☐ Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available or if the information is recorded by the investigator in such a manner that subjects cannot be identified, directly or through identifiers linked to the subjects. The research is not FDA regulated and does not involve prisoners as participants.

☐ Research and demonstration projects which are conducted by or subject to the approval of department or agency heads, and which are designed to study, evaluate, or otherwise examine: (i) public benefit or service programs; (ii) procedures for obtaining benefits or services under those programs; (iii) possible changes in or alternatives to those programs or procedures; or (iv) possible changes in methods or levels of payment for benefits or services under those programs. The protocol will be conducted pursuant to specific federal statutory authority; has no statutory requirement for IRB review; does not involve significant physical invasions or intrusions upon the privacy interests of the participant; has authorization or concurrent by the funding agency and does not involve prisoners as participants.

☐ Taste and food quality evaluation and consumer acceptance studies, (i) if wholesome foods without additives are consumed or (ii) if a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the Food and Drug Administration or approved by the Environmental Protection Agency or the Food Safety and Inspection Service of the U.S. Department of Agriculture. The research does not involve prisoners as participants.

1 Surveys, interviews, or observation of public behavior involving children cannot be exempt.
APPENDIX C

IDT Spec Sheets for sgRNA’s 1 - 4
## Oligonucleotide Specification Sheet

**TARA BREWER**

**HudsonAlpha Institute for Biotechnology**
601 Genome Way
Huntsville, AL 35806-2908
2563270439

**Duplex Sequences**

5’-5Phos/ATAGCAATTTGTGATAGA-3’
5’-5Phos/AAACTGAAATCAAAGATTTG-3’

5’ - ATAGCAATTTGTGATAGA -3’
3’ - GGTAAAACAGTTAATCTCAAA -5’

**Duplex Oligonucleotide Information**

<table>
<thead>
<tr>
<th>Reference #</th>
<th>297182265</th>
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<tbody>
<tr>
<td>Duplex Name</td>
<td>deGFp-gRNA 1</td>
</tr>
<tr>
<td>Product</td>
<td>100 nmole Duplex</td>
</tr>
</tbody>
</table>

**Purification:** Standard Desalting

**Amount of Duplex:** 90.1 nmole

**MW of Duplex:** 14,878.7

**Duplex Oligo 1 - deGFp-gRNA 1_Sense**

- Mfg ID: M421234672
- Molecular Weight: 7,445.8
- Extinction Coefficient: 241,500 L/(mole cm)
- GC Content: 29.2

**Duplex Oligo 2 - deGFp-gRNA 1_AntiSense**

- Mfg ID: M421234672
- Molecular Weight: 7,432.9
- Extinction Coefficient: 246,600 L/(mole cm)
- GC Content: 29.2

### Duplex Oligo 1 - Modifications & Services

<table>
<thead>
<tr>
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<tr>
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### Duplex Oligo 2 - Modifications & Services

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</tbody>
</table>

### Disclaimer

*Lyophilized contents may appear as either a translucent film or a white powder. This variance does not affect the quality of the oligo.*

*Please centrifuge tubes prior to opening. Some of the product may have been dislodged during shipping.*

---

**Instructions**

1. Lyophilized contents may appear as either a translucent film or a white powder. This variance does not affect the quality of the oligo.
2. Please centrifuge tubes prior to opening. Some of the product may have been dislodged during shipping.
TARA BREWER
HUDSONALPHA INSTITUTE FOR BIOTECHNOLOGY
601 GENOME WAY
HUNTSVILLE, AL 35806-2908
2563270439

Duplex Sequences
5’- 5Phos/ATAGAAAGGAGAAGAATTTTCAC-3’
5’- 5Phos/AAACGTTAAGAGTTCTCTCTTT-3’
3’ - ATAGAAAGGAGAAGAATTTTCAC - 5’

Purification: Standard Desalting
Amount of Duplex: 97.7 n mole
MW of Duplex: 14,879.7

Duplex Oligonucleotide Information
Reference #: 298390648
Duplex Name: deGFP-gRNA 2
Product: 100 n mole Duplex

Duplex Oligo 1 - deGFP-gRNA 2_Sense
Mfg ID: M425236090
Molecular Weight: 7,407.9
Extinction Coefficient: 253,800 L/(mole cm)
GC Content: 33.3

Duplex Oligo 2 - deGFP-gRNA 2_AntiSense
Mfg ID: M425236089
Molecular Weight: 7,381.8
Extinction Coefficient: 227,900 L/(mole cm)
GC Content: 33.3

Duplex Oligo 1 - Modifications & Services
Item | Qty
--- | ---
5’ Phosphorylation | 1
DNA Bases | 24

Duplex Oligo 2 - Modifications & Services
Item | Qty
--- | ---
5’ Phosphorylation | 1
DNA Bases | 24

Disclaimer

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OLIGONUCLEOTIDE SPECIFICATION SHEET

TARA BREWER
HUDSONALPHA INSTITUTE FOR BIOTECHNOLOGY
601 GENOME WAY
HUNTSVILLE, AL 35806-2908
2563270439

Duplex Sequences
5'-5'Phos/ATAGCTGAAAACCTACTGTCCA-3'
5'-5'Phos/AAACTGGAACAGGATTTCTCCAG-3'

3'- ATAGCTGAAAACCTACTGTCCA -5'

Duplex Oligonucleotide Information

Reference #: 298390651
Duplex Name: deGFP-gRNA 3
Product: 100 n mole Duplex

Purification: Standard Desalting
Amount of Duplex: 76.5 n mole
MW of Duplex: 14,881.6

Duplex Oligo 1 - deGFP-gRNA 3_Sense
Mfg ID: M425236902
Molecular Weight: 7,400.8
Extinction Coefficient: 235.600 L/( mole cm)
GC Content: 41.7

Duplex Oligo 2 - deGFP-gRNA 3_AntiSense
Mfg ID: M425236901
Molecular Weight: 7,480.8
Extinction Coefficient: 242.100 L/(mole cm)
GC Content: 41.7

Item 1 - Modifications & Services

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<td>24</td>
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Disclaimer

INSTRUCTIONS

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- Please centrifuge tubes prior to opening. Some of the product may have been dislodged during shipping.
TARA BREWER
HUDBONALPHA INSTITUTE FOR BIOTECHNOLOGY
601 GENOME WAY
HUNTSVILLE, AL 35806-2908
2563270439

Duplex Sequences

5'-5Phos/ATAGGAATTAGATGGATGTTAA-3'
5'-5Phos/AACCTTAACATCACATCTAATT-3'

5' - ATAGGAAATTAGATGGATGTTAA - 3'
3' - CTAAAATACCTACACTACATCTCAA - 5'

Duplex Oligonucleotide Information

Reference #: 298390654
Duplex Name: deGFP-gRNA 4
Product: 100 nmole Duplex

Purification: Standard Desalting
Amount of Duplex: 96.7 nmole
MW of Duplex: 14,878.7

Duplex Oligo 1 - deGFP-gRNA 4_Sense
Mfg ID: M425236004
Molecular Weight: 7,574.9
Extinction Coefficient: 257.700 L/(mole cm)
GC Content: 29.2

Duplex Oligo 2 - deGFP-gRNA 4_AntiSense
Mfg ID: M425236003
Molecular Weight: 7,303.8
Extinction Coefficient: 235.300 L/(mole cm)
GC Content: 29.2

Duplex Oligo 1 - Modifications & Services

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Duplex Oligo 2 - Modifications & Services

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<td>DNA Bases</td>
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Disclaimer

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APPENDIX D

Sequences of plasmids constructed with sgRNA’s 1 - 4
>cNM002_sgRNA 1 (1122 bp)
NNNNNNNNNNNACAGNAGCGANGCACAAGTGAAACGCAGCCGCTTAATGCTTAAGTGAAACAGGCTACTCCGTATACAAGTAAACGCTGTCAAAACACCCGTACACGATGAAACGCTGTCAAAACACCCGTACACGATGAAACGCTGTCAAAACACCCGTACACGATGAAACGCTGTCAAAACACCCGTACACGATGAAACGCTGTCAAAACACCCGTACACGATGAAACGCTGTCAAAACACCCGTACACGATGAAACGCTGTCAAAACACCCGTACACGATGAAACGCTGTCAAAACACCCGTACACGATGAAACGCTGTCAAAACACCCGTACACGATGAAACGCTGTCAAAACACCCGTACACGATGAAACGCTGTCAAAACACCCGTACACGATGAAACGCTGTCAAAACACCCGTACACGATGAAACGCTGTCAAAACACCCGTACACGATGAAACGCTGTCAAAACACCCGTACACGATGAAACGCTGTCAAAACACCCGTACACGATGAAACGCTGTCAAAACACCCGTACACGATGAAACGCTGTCAAAACACCCGTACACGATGAAACGCT

>cNM006_sgRNA 2 (1089 bp)
NNNNNNNNNTTACAGGAGNCANGNCAGANGCACAAGTGAAACGCAGCCGCTTAATGCTTAAGTGAAACAGGCTACTCCGTATACAAGTAAACGCTGTCAAAACACCCGTACACGATGAAACGCTGTCAAAACACCCGTACACGATGAAACGCTGTCAAAACACCCGTACACGATGAAACGCTGTCAAAACACCCGTACACGATGAAACGCTGTCAAAACACCCGTACACGATGAAACGCTGTCAAAACACCCGTACACGATGAAACGCTGTCAAAACACCCGTACACGATGAAACGCTGTCAAAACACCCGTACACGATGAAACGCTGTCAAAACACCCGTACACGATGAAACGCTGTCAAAACACCCGTACACGATGAAACGCTGTCAAAACACCCGTACACG

125
>cNM011_sgRNA 3 (1124 bp)
NNNNNNNNNNNNNNNNNNTNANNNANAGNGANGACATGAAGCGGCCGCCGATA
ATGCTTAAGTGCAACAGAAAGAATATCGTATTTGTAACACGGCCGCATAATCGAAA
ATTATACGACTCACTATAGTGGAATAACTACCTGTTCCAGTTTATGAGCTAG
AAATAGCAGAATTTAAGGAGCTCCGCTTATCACAATCTGAAAAGGACAGGACAG
CGAGTCCGAGTCTCGCAGCAGAAACTAGCATAACCCCTTGGGGCCTCTAAACGGGTCTTGAGGGGTTTTTTGCTGAAACCTCAGGCATTTGAGAAGCACACGGTCACACTGCTTCCGGTAGTCAATAAACCGGTAAACCAGCAATAGACATAAGCGGCTATTTAACGACCCTGCCCTGAACCGACGACCGGGTCGAATTTGCTTTCGAA
TTTCTGCCATTCATCCGCTTATTATCACTTATTCAGGCGTAGCAACCAGC
GTTTAAGGGCACACAACTATGCTTCTTCTGAATATACTGTAGAAACTGCAAAAACTACCCAGGATTGGCTGAGACGAAACATATTCTCAATAAACCCTTTANGGAAATAGGCCAGGTTTTCACCGTAAACACGCCACATCTTGCGAATATATGTGTAGAAACTGCCGGAAATCGTCGTGGTATTCACTCCAGAGCGATGAAAACGTTTCAGTTTGCTCATGGAAAACGGTGTAACAANGGGTGAAACACTATCCCATATCACCAGCTCACCCGTC TTTCATTGC
CATAACGGGGNCTNCNGGATGAGCATTCATCAGGCGGGNAGAATGTGAATAAANGCCNGNNAACCTGNGCTNTTTTCTTTTANGCATTAAAAANNNGTANNTCCAGNCNTGACGNCTGNNTNNNTNNNAACATTNCCANNNNNNCTNNNNNCNNNNAAAANNNNNNNNNNNNNNNNNNN

> cNM016_sgRNA 4 (1118 bp)
NNNNNNNNNNNNNNNNNNTNANNNANAGNGANGACATGAAGCGGCCGCCGATA
ATGCTTAAGTGCAACAGAAAGAATATCGTATTTGTAACACGGCCGCATAATCGAAA
ATTATACGACTCACTATAGTGGAATAACTACCTGTTCCAGTTTATGAGCTAG
AAATAGCAGAATTTAAGGAGCTCCGCTTATCACAATCTGAAAAGGACAGGACAG
CGAGTCCGAGTCTCGCAGCAGAAACTAGCATAACCCCTTGGGGCCTCTAAACGGGTCTTGAGGGGTTTTTTGCTGAAACCTCAGGCATTTGAGAAGCACACGGTCACACTGCTTCCGGTAGTCAATAAACCGGTAAACCAGCAATAGACATAAGCGGCTATTTAACGACCCTGCCCTGAACCGACGACCGGGTCGAATTTGCTTTCGAA
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GTTTAAGGGCACACAACTATGCTTCTTCTGAATATACTGTAGAAACTGCAAAAACTACCCAGGATTGGCTGAGACGAAACATATTCTCAATAAACCCTTTANGGAAATAGGCCAGGTTTTCACCGTAAACACGCCACATCTTGCGAATATATGTGTAGAAACTGCCGGAAATCGTCGTGGTATTCACTCCAGAGCGATGAAAACGTTTCAGTTTGCTCATGGAAAACGGTGTAACAANGGGTGAAACACTATCCCATATCACCAGCTCACCCGTC TTTCATTGC
CATAACGGGGNCTNCNGGATGAGCATTCATCAGGCGGGNAGAATGTGAATAAANGCCNGNNAACCTGNGCTNTTTTCTTTTANGCATTAAAAANNNGTANNTCCAGNCNTGACGNCTGNNTNNNTNNNAACATTNCCANNNNNNCTNNNNNCNNNNAAAANNNNNNNNNNNNNNNNNNN

126
ACNAGGGAACACTATCCCATATCACCAGCTACCGTCTTTTCATTGNCCATA
CNGNAACTCCGGATGAGCATTTTCATCNNNNNGGGNNAGAAATGTGAATAAANG
CCNGGANAACACTTNGCNNNNTTTTTTTCTTTTANNNNNNTNAAANNNNNNTAANA
TCNAGCANTNANNNGNNTNNNNNNNNNNNNANNATNNNNNNNNNNNNCTNNNNNN
NNNNNNNNNNNNNNNNNNNTNCNANNNN
TARA BREWER

HUDDSONALPHA INSTITUTE FOR BIOTECHNOLOGY
601 GENOME WAY
HUNTSVILLE, AL 35806-2908
2563270439

Duplex Sequences
5’-3’ Phos/ATACTATTGGATCATATGAAA-3’
5’-3’ Phos/AACTTTTCATAGATCCGGATAGCA-3’
3’- ATAGGTACACCATGATATGAA -3’

Duplex Oligonucleotide Information
Reference #: 328922484
Duplex Name: deGFP-gRNA5
Product: 100 nmole Duplex

Purification: Standard Desalting
Amount of Duplex: 72.5 nmole
MW of Duplex: 14,879.7

Duplex Oligo 1 - deGFP-gRNA5_Sense
Mfg ID: M464704302
Molecular Weight: 7,479.9
Extinction Coefficient: 251.200 L/(mole cm)
GC Content: 33.3

Duplex Oligo 2 - deGFP-gRNA5_AntiSense
Mfg ID: M464704303
Molecular Weight: 7,399.8
Extinction Coefficient: 240.400 L/(mole cm)
GC Content: 33.3

Duplex Oligo 1 - Modifications & Services
Item
3’ Phosphorylation
DNA Bases
Qty
1
24

Duplex Oligo 2 - Modifications & Services
Item
3’ Phosphorylation
DNA Bases
Qty
1
24

Disclaimer

INSTRUCTIONS
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OLIGONUCLEOTIDE SPECIFICATION SHEET

TARA BREWER

HUDSONALPHA INSTITUTE FOR BIOTECHNOLOGY
601 GENOME WAY
HUNTSVILLE, AL 35806-2908
2563270439

Sales Order #: 18411650
Reference #: 328922487

Order Date: 24-Mar-2022
End User #: 143619
P.O. #: PO032702

Duplex Sequences
5' - 5'Phos/ATAGCGTGCTGAAGTCAAGTTGA-3'
5' - 5'Phos/AAACTCAACTTGAATGCACCG-3'

5' - ATAGCGCTGCTGAAGTCAAGTTGA - 3'
3' - GCACGACTTCTGATCCTCACAAA - 5'

Duplex Oligonucleotide Information

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Duplex Oligo 1 - Modifications & Services

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Duplex Oligo 2 - Modifications & Services

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TARA BREWER
HUDSONALPHA INSTITUTE FOR BIOTECHNOLOGY
601 GENOME WAY
HUNTSVILLE, AL 35806-2908
2563270439

Duplex Sequences
5’-5’PhosATAAGCTCACAGAATGATACATCA-3’
5’-5’PhosAAACTGATGTATACAGTTGCTGAG-3’
5’- ATAGCTCACAGAATGATACATCA -3’
3’- GAGTGTGTTACATATGATGCTAAA -5’

Duplex Oligonucleotide Information

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I N S T R U C T I O N S

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TARA BREWER

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601 GENOME WAY
HUNTSVILLE, AL 35806-2908
2563270439

Order Date : 24-Mar-2022
End User #: 143619
P.O. #: PO0032702

Sales Order #: 18411650
Reference #: 328922493

Duplex Sequences
5'-5'Phos/ATAGTATCAACAAAAATACTCCAAT-3'
5'-5'Phos/AAACATGGGATTTTGTGATA-3'

5' - ATAGTATCAACAAAAATACTCCAAT
3' - ATAGTATCAACAAAAATACTCCAAT

Duplex Oligonucleotide Information

Reference #: 328922493
Duplex Name: deGFP-gRNA8
Product: 100 n mole Duplex

Purification: Standard Desalting
Amount of Duplex: 62.7 n mole
MW of Duplex: 14,877.7

Molecular Weight: 7,376.8
Extinction Coefficient: 250,200 L/(mole cm)
GC Content: 25.0

Duplex Oligo 1 - deGFP-gRNA8_Sense Mfg ID: M464704308

Duplex Oligo 2 - deGFP-gRNA8_AntiSense Mfg ID: M464704309

Molecular Weight: 7,500.9
Extinction Coefficient: 246,100 L/(mole cm)
GC Content: 25.0

Item 1 - Modifications & Services

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Item 2 - Modifications & Services

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</tbody>
</table>

I N S T R U C T I O N S

*Lyophilized contents may appear as either a translucent film or a white powder. This variance does not affect the quality of the oligo.

*Please centrifuge tubes prior to opening. Some of the product may have been dislodged during shipping.
TARA BREWER

HUDSONALPHA INSTITUTE FOR BIOTECHNOLOGY
601 GENOME WAY
HUNTSVILLE, AL 35806-2908
2563270439

Duplex Sequences
5’-5Phos/ATAGCAACGAAAACGTCACCAC-3’
5’-5Phos/AACAGCTGTTCACCCGCTGG-3’
5’- ATAGCAACGAAAACGTCACCAC -3’
3’ - GGGCTTTTGGGACTGTCACAA -5’

Duplex Oligonucleotide Information
Reference #: 328922496
Purification: Standard Desalting
Duplex Name: deGFP-gRNA9
Amount of Duplex: 70.5 nmole
Product: 100 nmole Duplex
MW of Duplex: 14,882.6

Molecular Weight: 7,429.8
Extinction Coefficient: 221,600 L/(mole cm)
GC Content: 45.8

Duplex Oligo 1 - deGFP-gRNA9_Sense Mfg ID: M464704310

Molecular Weight: 7,452.9
Extinction Coefficient: 250,300 L/(mole cm)
GC Content: 45.8

Duplex Oligo 2 - deGFP-gRNA9_AntiSense Mfg ID: M464704311

Molecular Weight: 7,429.8
Extinction Coefficient: 221,600 L/(mole cm)
GC Content: 45.8

Duplex Oligo 1 - Modifications & Services

Item                           Qty
3’ Phosphorylation             1
DNA Bases                      24

Duplex Oligo 2 - Modifications & Services

Item                           Qty
3’ Phosphorylation             1
DNA Bases                      24

Disclaimer

INSTRUCTIONS
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**TARA BREWER**

**HUDSONALPHA INSTITUTE FOR BIOTECHNOLOGY**
601 GENOME WAY
HUNTSVILLE, AL 35806-2908
2563270439

**Sales Order #:** 18411650  
**Reference #:** 328922499

**Order Date:** 24-Mar-2022  
**End User #:** 143619  
**P.O. #:** PO032702

**Duplex Sequences**

5'-'5'Phos/ATAGTGCTGGGATTACACATGGCA-3'
5'-'5'Phos/AAACTGCCATGTTAATCCAGGGCA-3'
5'-' ATAGTGCTGGGATTACACATGGCA -3'  
3'-' ACGACCTTAATGTGTACCAGTCAA -5'

**Duplex Oligonucleotide Information**

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<tr>
<td>Product: 100 nmole Duplex</td>
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<td>Molecular Weight: 7,385.8</td>
<td>Extinction Coefficient: 234,700 L/(mole cm)</td>
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<td>GC Content: 45.8</td>
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**Item** | **Qty**
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5' Phosphorylation | 1
DNA Bases | 24

**Duplex Oligo 2 - Modifications & Services**

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<tr>
<td>DNA Bases</td>
<td>24</td>
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APPENDIX F

SIC-STEM Charts for Group 2
**Figure A.1: SIC-STEM Interests for Group 2 Study Participants**
This figure shows how interested the Group 2 study participants are in Science, as reported on the SIC-STEM survey.

**Figure A.2: SIC-STEM Self-efficacy for Group 2 Study Participants**
This figure shows how the Group 2 study participants reported their self-efficacy on the SIC-STEM survey.
Figure A.3: SIC-STEM Outcome expectations for Group 2 Study Participants
This figure shows how the Group 2 study participants reported their outcome expectations on the SIC-STEM survey.

Figure A.4: SIC-STEM Choice goals for Group 2 Study Participants
This figure shows how the Group 2 study participants reported their choices for utilizing Science in their future career goals on the SIC-STEM survey.
Figure A.5: SIC-STEM Choice actions for Group 2 Study Participants
This figure shows how the Group 2 study participants reported their actions in high school and how that pertains to their future career goals on the SIC-STEM survey.