Demystifying STEM with an Authentic Research Experience

A Major Qualifying Project Report

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Abstract

STEM fields that are not related to life or social sciences are dominated by men, reflecting a gender gap in STEM higher education. Combating the gender gap will start with purposeful policies and opportunities aimed at elementary and secondary school aged girls. The author designed a week-long, low pressure authentic biology research experience for high school aged girls. The experience emphasizes the importance of all STEM fields and the value of each student's background and culture in diversifying the greater STEM community. The hypothesis is that this and similar programs will increase positive associations with STEM and demystify potential STEM careers for women, which will be essential in encouraging girls to choose careers in STEM and closing the workforce gender gap.

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1.0 Background and Introduction:

1.1 Women in STEM workforce

There remains a large gender gap in STEM fields. This is a problem seen across the developed world. [1] Despite efforts to close the gender gap, it still remains quite significant, especially in highly technical, or engineering heavy fields. In 2018, women made up 13.9% of the civil engineering workforce, and 18.7% of the software engineering workforce in the US. In addition, even among the women in the workforce there is a distinct lack of women of color. In 2017, only 11.5% of all engineering employees in the US were women of color. [1]

Table 1: Summary of Female Population in STEM Workforce

STEM Field	Percent of workforce that identify as female
Life and Social Sciences	49.4
Biological Sciences	47.7
Computer and Mathematical Sciences	25.8
Software Developers	18.7
Architecture and Engineering Occupations	15.7
Civil Engineers	13.9

Bureau of Labor Statistics, "Table 11: Employed Persons by Detailed Occupation, Sex, Race, and Hispanic or Latino Ethnicity," Current Population Survey, Household Data Annual Averages 2019 (2020).

The effects of this lack of diversity go far beyond the surface level social implications. A lack of diversity in the STEM workforce comes at a detriment to the field itself. [6,7] Studies have shown that having a more diverse group benefits not only the overall productivity of the group, but diversity also allows each member to grow personally and professionally. [6] Heterogeneous groups of people have been shown to be more innovative than homogeneous groups. [6] In addition, there is no evidence to suggest that innate scientific talent differs between genders, or between races, so a lack of diversity in the STEM work force represents significant amounts of missed talent. [7] Finally, historically male-dominated fields have been known to incorporate their implicit biases into their work, resulting in a detriment to the overall field. An example of this is still being experienced in the medical field, wherein the male pioneers of the field conducted many fundamental studies using only white males, then extrapolated the data to include other genders and races. [8] Now, with a modern understanding of biological and medical research, researchers are finding that these original conclusions should not have been as broadly applied as they were. [8] Moving forward, it is important that all STEM fields have heterogenous research teams, so that the public is better represented and thus served by these fields.

Solving the problem of the gender gap does not start and end with simply hiring more women on the professional level, or giving women more opportunities for advancement through the ranks of institutions. In addition to the efforts of employers, there needs to be a systemic push starting earlier in a woman's life.

1.2 Women in STEM Higher Education

The problems facing women in higher education have some overlap and some differences from those facing women in the STEM workforce. To begin, the gender gap persists among college students. The National Center for Education Statistics reports that in the 2017-18 school year, biological and biomedical sciences had the highest percentage of female students, the populations of female students being 54-61% women depending on degree.[1] In contrast, other STEM fields such as engineering heavy fields and computer information sciences have a more significant gender gap, their populations being 21-26% and 20-32% women, respectively.

Table 2: Summary of female population in STEM Higher Education in 2018-19

STEM field	Percent of student population that identify as female		
	Bachelor's	Master's	PhD's
Biological and Biomedical Sciences	62.2	59.1	53.4
Mathematics and Statistics	42.4	42.9	28
Physical Sciences and Science Technologies	40	37.6	34.1
Engineering and Engineering Technologies	21.0	26.0	24.5
Computer and Information Sciences and Support Services	20.0	32.4	21.7
All STEM Fields	36.1	34.0	34.6

National Center for Education Statistics, "Table 318.30: Bachelor's, Master's, and Doctor's Degrees Conferred by Postsecondary Institutions, By Sex of Student and Discipline Division: 2017-18," Digest of Education Statistics: 2019 Tables and Figures (2019).
National Center for Education Statistics, "Table 318.45: Number and Percentage Distribution of Science, Technology, Engineering, and Mathematics (STEM) Degrees/Certificates Conferred by Postsecondary Institutions, by Race/Ethnicity, Level of Degree/Certificate, and Sex of Student: 2008-09 through 2017-18," Digest of Education Statistics: 2019 Tables and Figures (2019).

The numbers above represent the percent of women who *graduate* with degrees in STEM, however, it has been shown that keeping girls enrolled in STEM programs is a challenge in itself. Female students, especially female students of color, have reported feeling under supported while earning STEM degrees. [4] Studies have also shown that female students feel an increase in internal motivation when they can identify with their professors and mentors, and significant discouragement when this is not the case.[4] Further, some female college students have attributed their change out of a STEM major to feeling un-included among their fellow male STEM students. [4] However, at universities where female students feel supported by friends, family, staff, and student organizations, they are more likely to graduate with their initial STEM degree. [4]

Another component of the gender gap in STEM is persuading women to enter the STEM field at all. Much work has been done on understanding why high school students chose the major they do. The main factors that seem to influence women in their choice are: their ability to see how this field can help others [9]; their ability to personally identify with the stereotypes related to that major [2]; the proximity of their parents to the STEM field [9]; and gender socialization regarding STEM courses [2]. Let's take a closer look at each of these factors.

The data shows that if a high school aged girl can clearly see how this major will allow her to help others, then she is much more likely to choose it.[9] This does help explain why social sciences, health sciences, and biology are some of the majors with the highest female populations. Unfortunately, often young women make this assessment without proper exposure to all STEM majors, so they fail to see how majors such as mathematics, computer science, or engineering can also be used to help others. [9]

An additional factor in a high school aged girl's choice of major has to do with their ability to identify with the profession. [2] For example, a stereotypical nurse, or health care professional, is a kind, friendly, helpful woman. Young women can easily see themselves as this person, and thus can justify majoring in life sciences. In contrast, the stereotypical computer scientist or engineer is depicted as a socially awkward, introverted individual, and young women often cannot see themselves aligning with this image. Whether or not these stereotypes are accurate, they are very present in the media, and may be the only point of reference a high schooler has. [2] These stereotypes are so prevalent that a students' interest or talent in a specific STEM field may be negated by them, discouraging them to consider a career in those fields. [2]

The third factor, the parent's proximity to the STEM field fits with other research regarding parent's education and children's education level. [10] There exists a well-established connection between a higher level of parental education and the final education level reached by their children [10], so it makes sense that this connection also applies to STEM degrees. In addition, it is possible that having a parent in STEM can help counteract the factor above, allowing female students to have a more rounded understanding of STEM careers. If one's mother is a computer scientist, then it is much easier for a young woman to see herself as one also.

The fourth factor effecting a female student's willingness to go into STEM has bigger societal implications. Researchers believe that the verbal and nonverbal messages sent to women about their math and science abilities influence them as they pick college majors. [2] Studies have also shown that women tend to judge themselves harder when it comes to stumbles or failures in math or science classes while in middle or high school, feeling as if they need to exceed expectations to respected by instructors or peers. [2] Finally, historically, men have been socialized to have confidence in their inherent intelligence, where women often have not been. [2] These elements combine to leave women discouraged in STEM classes, and thus less likely to pursue STEM in higher education.

The four factors that influence a high school aged girl's desire to study STEM do not have an easy fix and interact with each other to create new dynamics and effects. However, trends released by the Digest of Education Statistics show that the number of women earning STEM degrees and entering the STEM workforce is increasing yearly. [11] This progress should not be discounted, as it represents positive trends of change.

However, of note is the positive trend seen in the past ten years in regards to the number of STEM degrees awarded to women. Data shows a steady increase in total STEM degrees awarded to women within the past ten years, indicating that current programs and supports are beneficial, and should be expanded upon. See Figure 1 below for details.

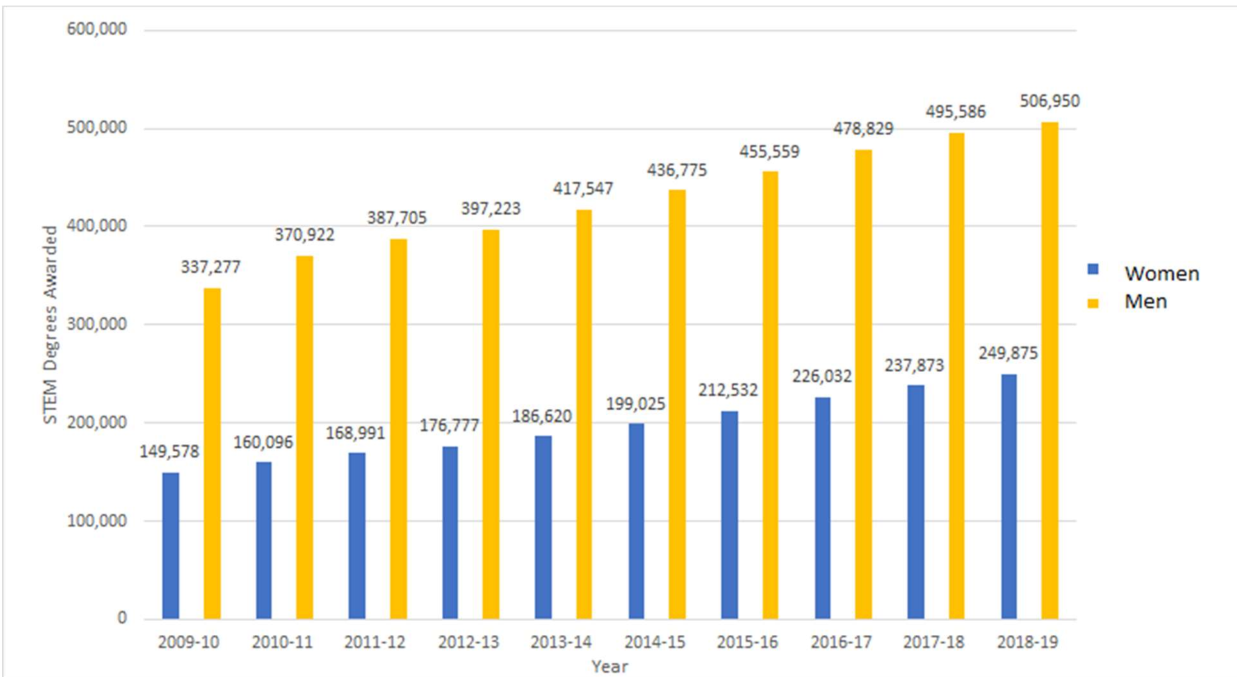

Figure 1: Total STEM Degrees Awarded to Women and Men, 2009-2019

Digest of Education Statistics, 2019
Note: the author was unable to find data regarding the STEM degrees awarded to trans, nonbinary, and gender nonconforming individuals

Further work still needs to be done to close the gender gap in STEM education and workforce populations. In response to the gender gap, there have been a large increase in extracurricular STEM opportunities presented to male and female students. There are programs that serve almost every age of student, from elementary school to high school.

1.3 Need for extracurricular STEM opportunities

Extracurricular STEM opportunities solve many of the problems keeping young women from pursing STEM careers. The nature of these experiences such as camps or extracurricular programs can allow for girls to experience STEM concepts in a grade free environment,[2] hopefully encouraging them to be more willing to experiment with the material. In addition, programs can allow a community of just girls to bond and encourage each other, eliminating the fear of being ridiculed by male peers, and creating a supportive network between the girls, and around the STEM material. [2] In addition, research has shown that when girls are allowed to freely experiment with the material in a hands-on environment, they are much more likely to identify with the STEM field, than if they were simply taught the material. [2] Of course, hands-on experimentation could benefit all students, but often time and resource restrictions felt by the public education system prevent it. Finally, attending a camp or an afterschool program carries a great amount of excitement, and positive emotions, so simply attending one can create a positive association with STEM for the girls. Girls with positive feelings towards STEM are more likely to pursue STEM careers. [2]

In general, published literature shows that there are several essential elements to extracurricular STEM programs that result in an increased level of STEM interested from the student. These include free and open environments, where students feel comfortable experimenting [2]; dynamic hands-on experiences that engage the students on many levels [15]; elements of mentoring, where students can begin to identify with instructors or professionals in STEM fields [16]; and some element that connects their activities to careers and STEM majors [16].

1.4 Existing extracurricular STEM opportunities

There are numerous extracurricular STEM opportunities for girls nation-wide. For this project, the author chose to look extensively at opportunities offered by Worcester Polytechnic Institute (WPI). WPI is an engineering college with a focus on integrating both theory and practice into a project-based STEM education. The extracurricular STEM programs at WPI had the same budget and intended audience as the author's program, and thus served as a good model.

Camp Reach is an extracurricular STEM program offered by WPI during the summer. It is open to female identifying students who are at least 11 years old and are entering 8^{th} grade in the fall. [12] The girls must live in Massachusetts, Connecticut, or Providence County, Rhode Island to attend. [12] The camp is staffed entirely by females including high school aged mentors, undergraduate women enrolled at WPI, and WPI faculty. [13] While at Camp Reach, the girls work in teams of 10 to tackle an engineering project proposed by a sponsor from the WPI community. [13] Emphasis is placed on the Engineering Design Cycle and problem-solving skills, rather than learning content. At the end of the two weeks, the girls present their solutions to the sponsors and to parents and family. [13]

Camp Reach has girls working on hands-on projects for 2 ½ hour sections of time, with breaks and meals interspersed. [13] The camp also builds time into the schedule for smaller projects and activities, as well as opportunities for the girls to bond and explore their possible career interests. [13]

Another extracurricular STEM program offered by WPI is Launch. Launch is open to both girls and boys in grades 9-10. [14] While at Launch, students decide which program they take part in, with the options raging across many different STEM majors. [14] During this week-long program, the students spend up to 7 hours a day with WPI staff learning concepts and content, and then applying the knowledge to hands-on activities. [13] Launch is staffed by WPI faulty members and students. [13] At Launch, emphasis is placed on sparking the student's interest in STEM fields, and encouraging their progression through the so-called STEM pipeline, wherein high school aged students who are exposed to STEM programs are more likely to enter STEM higher education, and eventually the workforce. [13]

1.5 Value of this project

Two vital factors that inform a young woman's choice to enter the field of STEM are: their ability to see how this field can help others [9] and their ability to personally identify with the STEM field [2]. The author of this project used these four factors to inform the program and evaluate its effectiveness.

The first factor, the ability to see how STEM can help others, and the second one, the ability to personally identify with the field, is addressed within the experience through an activity focused on STEM career awareness. In this activity, the participants are given a quick overview of common STEM majors, with emphasis placed on the essential questions and actions taken by each branch, not on the stereotypical jobs found in each branch of STEM. By introducing STEM fields via the essential questions of each field, the author is attempting to circumvent the stereotypes within STEM and allow the students to realize that their interests align with the fields. The students are then asked to sort a list of job titles into the four main branches of STEM, expanding their understanding of what each field comprises. The goal of this activity is to show the students that there are interesting jobs through which they can help people that fall under the umbrella of STEM in a wide variety of fields. Students should walk away from this activity with a deeper understanding and a more complete picture of STEM careers, and the benefits each of them brings to society.

Another factor that influences a young woman's choice to enter the field of STEM is the ability of the students to feel a connection to a STEM major. As stated before, women often see themselves depicted in the healthcare field, but rarely see themselves depicted in highly technical engineering fields. This project addresses this factor in two ways. The first way is an inherent feature of hosting the experience at WPI. WPI is fortunate enough to employ a faculty that has over 150 female faculty members across various fields of STEM.[17] Hosting the experience in this environment allows for the students to see strong, intelligent women across the fields of STEM, and will help reshape the student's internal image of individuals in STEM. The other way this factor is addressed is through the content of the experience itself. The author included several activities such as the use of micropipettes and proper use and understanding of PPE which are intended to be exciting and novel for the students. After completing these activities, the intention is that the students will be more likely to see themselves in a technical STEM field, as they now understand what such a field would entail.

Of note is the biology theme chosen by the author. As shown in Tables 1 and 2, female students tend to enter fields related to life sciences. By choosing to center the program around an authentic biology research experience, the author is hoping to capitalize on this trend towards life sciences to interest students, then display the parallels between biology and other branches of STEM. The intention is that when the students participate in activities and practices that are highly reminiscent of authentic biology research, they will be excited and positively engaged with the program. Once attending the camp, the hope is that this excitement will expand beyond the field of biology, and the students will gain excitement for STEM in general.

2.0 Materials and Methods:

2.1 External Sources Referenced

In order to fully understand the structure and content of currently existing successful STEM camps, the author searched for previously published studies. The data referenced in this paper explicitly along with other data consulted in the process of searching were a product of these searches. The author largely consulted the Google Scholar database, along with JSTOR, and ERIC databases, with access provided by WPI. The author focused the search by using terms such as “women in STEM”, “girls in STEM”, “STEM camps”, “High school STEM opportunity”.

2.2 Studies Conducted by the Author

2.2.1 Lab Skills Survey

One of the goals of this camp is to provide the students with an authentic research experience that allowed them to develop essential laboratory skills. To achieve this goal, the author of this project presented a survey to WPI Bio/Biotech (BBT) staff about the relative importance of specific biology and general STEM skills. The author generated this list of skills using her own experience both as a student in a BBT program, and her experience teaching high school students. The survey was designed so that the faculty were asked to rate 10 skills on a scale of 1-10 in terms of importance. The survey was sent via email to all faculty listed on WPI’s BBT faculty website. The author received 7 responses from the 19 professors that were contacted. The author then calculated the average score each skill received. See Table 3 below for details on the skills assessed and the average scores they were awarded.

Table 3: Skills assessed in the survey and the average importance score (out of 10)

#	Survey Question	Score
1	**On a scale from 1-10 please rate the importance of the following STEM skill:** Ability to cooperate within group	8
2	**On a scale from 1-10 please rate the importance of the following STEM skill:** Ability to keep a lab notebook	8.28
3	**On a scale from 1-10 please rate the importance of the following STEM skill:** Ability to judge the reliability of literature	8.7
4	**On a scale from 1-10 please rate the importance of the following STEM skill:** Ability to extract important information from literature	8.7
5	**On a scale from 1-10 please rate the importance of the following STEM skill:** Ability to form a hypothesis based on prior research	8.3
6	**On a scale from 1-10 please rate the importance of the following STEM skill:** Ability to design an experiment around desired data	8
7	**On a scale from 1-10 please rate the importance of the following Biology skill:** Practice of sterile/aseptic technique	7.2
8	**On a scale from 1-10 please rate the importance of the following Biology skill:** Understanding of PPE and the reasoning behind PPE	7.5
9	**On a scale from 1-10 please rate the importance of the following Biology skill:** Understanding of proper lab behavior, manners, and best practices	7.7
10	**On a scale from 1-10 please rate the importance of the following Biology skill:** Ability to use micropipettes	7

The survey was conducted to inform the author on which skills teaching professors see as most important, and to help prioritize the skills incorporated into the experience. As seen in Table 3 above, all of the 10 skills were rated between 7 and 8 on a 1-10 scale. This was interpreted by the author to mean that all of the listed skills were moderately important, and to fit as many of them as possible into the camp design. If one skill had been unanimously rated very low or very high by the BBT faculty, then the author would have adjusted the activities of the camp accordingly.

2.2.2 Lab Skills Survey Analysis

The 1st skill included on the survey was the ability to cooperate within a group. This question was added to the survey because the author had experienced significant cooperation within her STEM training, and wanted a measure of how important WPI professors felt it to be. Their rating of 8/10 affirmed the author's perception that collaboration is an important element of STEM. Some STEM fields are stereotyped as being uncollaborative, which could result in high school students, particularly girls, being discouraged to join said field. By requiring collaboration from participants in this program, the author intends to re-shape misconceptions about STEM held by some students. This skill is applicable to those in Biology and those in any other STEM field. Please see Table 4 below for specific activities within the program that emphasize this skill.

Table 4: Skill 1 Activity Matrix

Activity	Day				
	1	2	3	4	5

1					
2		X	X	X	X
3			X	X	
4	X	X	X	X	
5	X		X	X	
6	X		X		X
7					
8				X	-
9	-		-	-	-

Table 4: Skill 1 Activity Matrix. See Appendixes 5.3-5.8 for a description of activities. A blank space indicates that the activity does not apply to the skill, an "X" indicates that the activity does apply to the skill, and a dash indicates that there was not an activity with that number on that day. Ex: Activity 4 on Day 1 is applicable to practicing the skill, Activity 5 on Day 2 is not applicable, and there is not an Activity 9 on Day 4.

The 2nd skill addressed by the survey is the ability of the students to keep a lab notebook. This question was added to the survey because although the author understands the importance of a lab notebook in genuine research settings, she was unsure if the professors would consider it to be an important aspect when learning about STEM. As it was rated 8.28/10, the author included several activities in which the participants will practice maintaining a lab notebook. A benefit of introducing this skill into the program is that it contributes to the authentic research experience that the author is intending to create. This skill is applicable both to those in biology and those in any other STEM field. Please see Table 5 below for specific activities within the program that emphasize this skill.

Table 5: Skill 2 Activity Matrix

Activity	Day				
	1	2	3	4	5

1					
2			X	X	
3					
4	X	X	X		
5			X	X	
6	X		X		
7					
8		X		X	-
9	-		-	-	-

Table 5: Skill 2 Activity Matrix. See Appendixes 5.3-5.8 for a description of activities. A blank space indicates that the activity does not apply to the skill, an X indicates that the activity does apply to the skill, and a dash indicates that there was not an activity with that number on that day. Ex: Activity 4 on Day 1 is applicable to practicing the skill, Activity 5 on Day 2 is not applicable, and there is not an Activity 9 on Day 4.

The 3rd skill addressed by the survey was the ability to judge the reliability of literature. This skill was added to the survey to assess if professors felt judging the reliability of research was an important element to teach beginners in STEM. The professors rated it 8.7/10, indicating that they considered it to be a very important skill when teaching STEM. Across all fields of STEM, researchers build on the work of others, so the collection and evaluation of scientific literature is a vital step moving forward. By introducing this skill in the context of a summer camp program the author is hoping to build positive associations around this skill for the participants. Often judging the reliability of literature is considered to be an uninteresting and challenging task by high school students, but practicing the skill in positive environments should help the students break down the wall between themselves and the task. Please see Table 6 below for specific activities within the program that emphasize this skill.

Table 6: Skill 3 Activity Matrix

Activity	Day				
	1	2	3	4	5

1					
2		X			
3					
4					
5			X		
6	X				
7					
8					-
9	-		-	-	-

Table 6: Skill 3 Activity Matrix. See Appendixes 5.3-5.8 for a description of activities. A blank space indicates that the activity does not apply to the skill, an X indicates that the activity does apply to the skill, and a dash indicates that there was not an activity with that number on that day. Ex: Activity 6 on Day 1 is applicable to practicing the skill, Activity 5 on Day 2 is not applicable, and there is not an Activity 9 on Day 4

The 4th skill addressed on the survey was the ability to extract important information from literature. This skill is very closely related to skill 3. According to the results of the survey, the professors determined that it was equally as important that the students judge the reliability of literature and extract meaningful information from said literature. As such, the author incorporated several activities which allow the students to practice the extraction of information from literature. Please see Table 7 below for specific activities within the program that emphasize this skill.

Table 7: Skill 4 Activity Matrix

Activity	Day				
	1	2	3	4	5

1					
2		X			
3					
4					
5			X		
6	X				
7					
8					-
9	-		-	-	-

Table 7: Skill 4 Activity Matrix. See Appendixes 5.3-5.8 for a description of activities. A blank space indicates that the activity does not apply to the skill, an X indicates that the activity does apply to the skill, and a dash indicates that there was not an activity with that number on that day. Ex: Activity 6 on Day 1 is applicable to practicing the skill, Activity 5 on Day 2 is not applicable, and there is not an Activity 9 on Day 4

The 5th skill addressed on the survey was the ability to form a hypothesis based on prior research. This skill was added to the survey to assess the degree to which professors found generation of hypotheses as an important aspect when learning STEM. The rating this skill received was 8.3/10, indicating a high importance. The ability to gather new information, organize it, and then use it to form a hypothesis is a skill generally unpracticed in elementary and secondary STEM Education, but is the foundation of genuine STEM research and innovation. The desire to improve upon or expand current information is a driving force among those who practice STEM, and by incorporating it into this program, the author is hoping to appeal to the participants who share that desire. This skill is applicable across all fields of STEM. Please see Table 8 below for specific activities within the program that emphasize this skill.

Table 8: Skill 5 Activity Matrix

Activity	Day				
	1	2	3	4	5

1					
2	X		X	X	
3					
4		X			
5			X	X	
6			X		
7			X		
8				X	-
9	-		-	-	-

Table 8: Skill 5 Activity Matrix. See Appendixes 5.3-5.8 for a description of activities. A blank space indicates that the activity does not apply to the skill, an X indicates that the activity does apply to the skill, and a dash indicates that there was not an activity with that number on that day. Ex: Activity 2 on Day 1 is applicable to practicing the skill, Activity 4 on Day 2 is not applicable, and there is not an Activity 9 on Day 4.

The 6th skill addressed on the survey was the ability to design an experiment around desired data types. This skill is very closely related to Skill 5, and received a similarly high rating of 8/10. The ability to not only make a hypothesis, but to then design an experiment that accurately tests that hypothesis, then results in data that is clear and reliable can often be intimidating to students. By practicing this skill, participants will "think like scientists", further contributing to the authentic research experience. Please see Table 9 below for specific activities in which the participants practice this skill.

Table 9: Skill 6 Activity Matrix

Activity	Day				
	1	2	3	4	5

1					
2	X				
3		X		X	
4		X	X	X	X
5				X	
6			X		
7			X		
8		X		X	-
9	-		-	-	-

Table 9: Skill 6 Activity Matrix. See Appendixes 5.3-5.8 for a description of activities. A blank space indicates that the activity does not apply to the skill, an X indicates that the activity does apply to the skill, and a dash indicates that there was not an activity with that number on that day. Ex: Activity 2 on Day 1 is applicable to practicing the skill, Activity 5 on Day 2 is not applicable, and there is not an Activity 9 on Day 4

The 7th skill addressed on the survey was the practice of sterile technique. This question was included on the survey given to professors to discern if they think explicit instruction of sterile technique is valuable in an educational STEM context. Their rating of 7.2/10 indicates that they consider it to be moderately important. As such, it was explicitly taught in one activity (2.6) and referenced in several others. By explicitly teaching and then referencing sterile technique within the program, the author is intending to create an authentic research experience for the participants. Giving the students an experience that they feel is genuine can help them build confidence in themselves and in the program, which should contribute to their overall positive impression of the experience. Please see Table 10 below for specific activities in which the participants practice this skill.

Table 10: Skill 7 Activity Matrix

Activity	Day				
	1	2	3	4	5

1					
2			X	X	
3					
4					
5					
6		X	X		
7		X			
8		X			-
9	-		-	-	-

Table 10: Skill 7 Activity Matrix. See Appendixes 5.3-5.8 for a description of activities. A blank space indicates that the activity does not apply to the skill, an X indicates that the activity does apply to the skill, and a dash indicates that there was not an activity with that number on that day. Ex: Activity 2 on Day 3 is applicable to practicing the skill, Activity 5 on Day 2 is not applicable, and there is not an Activity 9 on Day 4

The 8th skill addressed on the survey was understanding of Personal Protective Equipment (PPE). This skill was rated 7.5/10 by the professors polled. The understanding of PPE is a skill very relevant to biology research, but not applicable to all fields of STEM. This skill is similar to Skill 7, as both of these skills contribute to creating an authentic research experience. Due to the a rating of 7.5/10, the author chose to incorporate one activity in which PPE was explicitly taught (2.5), and then several other activities in which PPE was simply employed by the students. Please see Table 11 below for specific activities in which the participants practice this skill.

Table 11: Skill 8 Activity Matrix

Activity	Day				
	1	2	3	4	5

1					
2			X	X	
3					
4					
5					
6		X	X		
7		X			
8		X			-
9	-		-	-	-

Table 11: Skill 8 Activity Matrix. See Appendixes 5.3-5.8 for a description of activities. A blank space indicates that the activity does not apply to the skill, an X indicates that the activity does apply to the skill, and a dash indicates that there was not an activity with that number on that day. Ex: Activity 2 on Day 3 is applicable to practicing the skill, Activity 5 on Day 2 is not applicable, and there is not an Activity 9 on Day 4

The 9th skill addressed on the survey is the understanding of proper lab behavior, manners, and best practices. This skill was rated to 7.7/10 by the professors surveyed. This skill, although not essential to *learning* about biology research, is essential for *doing* biology research, and thus was included within the program. Since one of the aims of the program is to give the participants a genuine biology research experience, the students should be shown the mannerisms and activities consistent with genuine biology research. It is the intention of the author to allow the participants to feel as though they are treated as "real scientists" throughout the program. This should increase the degree to which the program empowers and validates the participants as members of the STEM community. Please see Table 12 below for specific activities that allow the students to practice this skill.

Table 12: Skill 9 Activity Matrix

Activity	Day				
	1	2	3	4	5

1					
2			X	X	
3					
4					
5		X			
6		X	X	X	
7		X			
8		X	X		
9	-	X	-	-	-

Table 12: Skill 9 Activity Matrix. See Appendixes 5.3-5.8 for a description of activities. A blank space indicates that the activity does not apply to the skill, an X indicates that the activity does apply to the skill, and a dash indicates that there was not an activity with that number on that day. Ex: Activity 2 on Day 3 is applicable to practicing the skill, Activity 4 on Day 2 is not applicable, and there is not an Activity 9 on Day 4

The 10th skill addressed by the survey was the ability to use micropipettes. This skill was rated 7/10 by the professors surveyed, indicating that the professors surveyed found this skill to be relatively non-essential in STEM education. This skill is only applicable to a small range of STEM fields, however it functions much like Skill 9 in it's seemingly technical and thus exciting nature. The intention of the author when including this skill is to increase the excitement and novelty felt by the students towards the program. Please see Table 13 below for specific activities in which the students practiced this skill.

Table 13: Skill 10 Activity Matrix

Table 13: Skill 10 Activity Matrix

Activity	Day				
	1	2	3	4	5

1					
2					
3					
4					
5					
6			X		
7		X			
8		X			
9	-		-	-	-

Table 13: Skill 10 Activity Matrix. See Appendixes 5.3-5.8 for a description of activities. A blank space indicates that the activity does not apply to the skill, an X indicates that the activity does apply to the skill, and a dash indicates that there was not an activity with that number on that day. Ex: Activity 6 on Day 3 is applicable to practicing the skill, Activity 4 on Day 2 is not applicable, and there is not an Activity 9 on Day 4

2.2.3 Review of Curriculum given to In-Service Teachers

A survey was distributed to seven in service high school STEM teachers in early March. The teachers selected all work in public Massachusetts high schools, and have participated in curriculum development through WPI before.

The aim of this survey was two-fold. First, the author wanted to assess the clarity of the curriculum and teacher's resources. One of the goals of this project is to produce a completed set of resources that are self-explanatory and usable by another instructor. To assess the clarity of the program materials, the author included questions in the survey about lab protocols, activity descriptions, and teachers notes (see Table 14 below for more details). The second aim of the survey was to assess the level and content of the curriculum as appropriate for high school aged students. To assess the level of the curriculum, the author included questions in the survey about the language used in the PowerPoints, the protocols, and the discussions included in the program (see Table 14 below for more details).

Table 14: Data from Curriculum Review Survey

Question	Rating
Please rate the level of the sources provided here. 5 being appropriate, 0 being too low, and 10 being too complex for high school students	**5**
Please rate the clarity of the protocols located here. 0 being unclear and 10 being clear	**9.6**
Please rate the level to which you feel the lesson summaries communicate the goals and actions of each activity. You can access them here. 0 being not well communicated, and 10 being well communicated	**9.6**
Please rate the discussion prompts included in the lesson summaries. You can access them in context of the lessons here, and complied into a separate list here. 0 being too low or engaging, 5 being appropriate, and 10 being too complicated	**5**
Please rate the language used in the Power Point slides provided here. 5 being appropriate, 0 being too simple, and 10 being too complex for high school students	**5**
Any other comments or feedback would be greatly appreciated	**- "My one constructive criticism is to consider adding pictures to the lab protocols for students who don't necessarily know the names of all of the tools."**

	- "My only suggestion may be to vary the methods of discussion to keep it lively, dynamic and engaging. Keep the structure as is but incorporate "think-pair-share", games, activities that help students think and share collectively. Especially if this is a summer camp, lesson the lecture style and get them laughing, moving, making noise. Really great job though, I like the format, the content, the self inquiry" **-**

The results of this survey will inform the author on adjustments that need to be made in order to maximize the clarity and effectiveness of the curriculum.

2.3 Determination of Success of Program

The success of this project will not be determined before the end of the 2020-2021 school year. Due to COVID restrictions, the author was unable to run the program. Instead, the expected success of the program will be explored in the following sections.

The goal of the project is to provide high school aged young women with an authentic biology research experience, which will correlate with an increased interest in STEM careers. In order to assess this goal, data needs to be gathered on the enjoyment of the students during the program, and on the attitudes of the students before and after.

2.4 Informal Data Collection

The majority of the results from this program will be informally gathered and qualitative. Informal results are considered by this author to be data points and feedback gathered from students in every setting but a survey. This data would include the demeanor of students, the level of participation, enthusiasm among the students, the level of collaboration between and among groups, and the ability of the students to connect to the content throughout the program on a daily basis. An important outcome of the program is the students feeling welcome and positive in the scientific environment, and the best indicator is the day-to-day actions and attitudes of the students.

2.5 Formal Data Collection via Pre-and Post- Survey

Formal data collection is considered by this author to be the results of the pre-and post-surveys given to students on Day 1 (Appendix 6.3) and Day 5 (Appendix 6.7). The surveys will provide quantifiable data indicating the change in the knowledge and attitudes of the students after their experience with the program. The survey will focus on increasing young women's awareness of STEM career options, as well as on shifting their perception of the role of women in said STEM fields.

To determine the success of the program, the author drew from already established surveys to design the formal pre- and post- survey. Largely, the author referenced the Friday Institute for Educational Innovation's Student Attitudes toward STEM Survey, intended for Middle and High School Students [19]. This survey is designed to "…measure changes in students' confidence and efficacy in STEM subjects, 21st century learning skills, and interest in STEM careers"[19]. See Appendix 5.9 for the entire survey. It is the intention of the author that this program and experience will result in an increase in positive associations with STEM (see Table 15), an increase in interest STEM careers (see Table 16), an increase in confidence with STEM content (see Table 17), and an overall increase in confidence with STEM skills (see Table 18).

Table 15: Questions in Pre- and Post- Survey that Assess Positive Associations with STEM

Question	**Part**								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**

1	X			X		X	-	-	-	-
2	X			X		-	-	-	-	-
3	X	X	X	X	-	-	-	-	-	-
4			X	-	-	-	-	-	-	-
5										

Table 15: Questions in Survey that Assess Positive Associations with STEM. The table should be read as follows: Question 1.1 applies to the assessment of positive associations with STEM, Question 2.5 does not, and there is not a Question 4.4.

Table 16: Questions in Pre- and Post- Survey that Assess Interest in STEM Careers

Question	Part								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1		X			X		-	-	-
2		X				-	-	-	-
3			X		-	-	-	-	-
4				-	-	-	-	-	-
5	X	X	X	X	X	X	X	X	X

Table 16: Questions in the Survey that Assess Interest in STEM careers. Table should be read in the same manner as Table 15.

Table 17: Questions in Pre- and Post- Survey that Assess Confidence in STEM Content

Question	Part								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1	X			X		X	-	-	-
2	X	X	X	X		-	-	-	-
3		X	X	X	-	-	-	-	-
4		X	X	-	-	-	-	-	-
5									

Table 17: Questions in the Survey that Assess Confidence in STEM content. Table should be read in the same manner as Table 15.

Table 18: Questions in Pre- and Post- Survey that Assess Confidence in STEM Skills

Question	Part								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1	X					X	-	-	-
2	X		X	X		-	-	-	-
3			X		-	-	-	-	-
4	X	X		-	-	-	-	-	-
5									

Table 18: Questions in the Survey that Assess Confidence in STEM skills. Table should be read in the same manner as Table 15.

3.0 Results and Discussion

It has been demonstrated that the most influential factors informing a young woman's choice of career are the ability to identify with the career choice, [16] the level to which the student can see the career as beneficial and helpful to society, [16] and previous hands-on experience with the field. [15] This program was designed to satisfy all three of these factors.

The activities within the program were designed to inspire a sense of ownership and responsibility over the experiment performed. This is expected to translate into a high level of self-identification with the content. All discussions are structured around encouraging the students to draw on their own prior knowledge, or the results they generated themselves (Appendix 6.2-6.7). By structuring discussions in this way, the students' personal experiences and identities are shown to be valuable. Further, the premise for the program, connecting the wide range of spices used around the world to antibiotic properties, allows students to speak and think about their culture, heritage, or simply just their favorite foods. Allowing the students to pick which spice(s) they test allows them to see themselves and their culture as relevant in a scientific context. It is hoped that by allowing the students to connect to and draw upon their identities, the degree to which they see themselves as a valid and valued member of the STEM community will increase.

In order to address the second factor, the degree to which students consider the field to be beneficial, the Career Day Activity of day 4 was added (Appendix 6.6). This activity has several goals, one of which is to show the benefit provided to society by all fields of STEM. Often Biology in general, but Health Care specifically is considered by students to be the most beneficial to society, and this activity aims to expand this perception by explaining and exploring the careers available in each STEM field. The second goal of this activity is to demystify fields of STEM that may not be familiar to the students, and provide concrete examples of what professionals in each field do. The activity also aims to connect professional level jobs with initial STEM degrees that someone might earn as they work towards the job. Again, demystification of STEM and STEM career pathways is the goal. Often first-generation college students are unaware of the wide range of STEM degrees available, and what career path said degrees can provide. Providing this information to the students in a welcoming, low-pressure environment is intended to inspire students to further consider and explore careers in STEM.

Finally, exposure to hands-on experience in a low-pressure environment has been shown to increase a young woman's likelihood to choose a career in STEM. Every day of the program students participate in hands-on activities related to designing, conducting, or analyzing an experiment. The students work in groups and are encouraged both directly and indirectly to collaborate within and between groups, hopefully resulting in a positive supportive environment among the students. Forming bonds and positive memories between students is a major goal of the program, as research as shown that a positive memory of a STEM experience will last longer and be more influential than a neutral but highly informative memory of a STEM experience.[2]

Going forward, the author believes that this curriculum could be adapted to serve several underrepresented populations in STEM, including students of color, English language learners, first generation college students, and students with disabilities [20]. Further, the author intends to modulate the curriculum into 50-minute-long lessons that could be executed within a STEM high school classroom. These modules will be published as a unit on to several websites which allow high school teachers to trade curriculum and resources without cost.

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5.0 Appendices

5.1 Appendix 1: Daily Program Schedule

	Monday	Tuesday	Wednesday	Thursday	Friday
9:00 AM	Get settled in, introductions, ice breakers, form groups	Get settled in	Get settled in, dawn PPE	Get settled in, dawn PPE	Get settled in
9:30 AM		Group work: answer questions	Look at plates; interprate results within groups	Look at plates; interprate results within groups	Group work: Finish poster
10:00 AM	Introduce goal of program	share out questions and answers	Class discussion: what happened? What does it mean?	Class discussion: what happened? What does it mean?	
10:30 AM	Introduce spice world concept	Modeling how to design an experiment			Q and A for any remaining questions about STEM
11:00 AM	Take pre-test on scientific method, and basic BB concepts	Group work: design experiment	Groups decide: do you want to re-plate? Why or why not?	Group work: what conclusions can we draw? Why can we draw them	
11:30 AM	Start to brainstorm what we would need to deisgn an experiment like this		What do you need to know for round two? Group discussion	Class discussion: why can we draw these conclusions?	Take post-test on scientific method, and basic BB concepts
12:00 PM		Design our own labcoats and maks (with sharpie)	Gather materials, do more research	Wind down, clean up	Class discussion: what did we learn this week?
12:30 PM	Lunch (12:30-1:30) Morgan Dining Hall	Lunch (12:30-1:30) Morgan Dining Hall	Lunch (12:30-1:30) Morgan Dining Hall	Lunch (12:30-1:30) Morgan Dining Hall	Lunch (12:30-1:30) Morgan Dining Hall
1:00 PM					
1:30 PM	Settle in, re-connect with group, finalize list of requirements	PPE talk	Grind spices, replate bacteria	Career Day activity	Robotics Competition (1:30-4:00) / Practice poster presenting
2:00 PM	Class discussion: scientific method,research steps, requirement for this experiment	Model how to grind spices and plate bacteria			
2:30 PM		Groups grind spices and plate bacteria	Class discssion: scientific method; why it works	Discussion: what makes a good poster? And why do we make them?	Good-byes
3:00 PM	Group work: prior research questions				Academic Showcase All Programs (3:00 - 3:45)
3:30 PM		Wind down, clean up	Wind down, clean up	Wind down, clean up	Closing Remarks (3:45-4:00)

5.2 Appendix 2: Learning Objectives for Each Day

Day	**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**
Objectives-(Students Will Be Able To)	-Begin to *create bonds* with staff and other students -*Determine* personal goals for the week -*Generate list* of information needed before beginning an experiment -*Communicate effectively* with peers and instructors	-*Understand* what PPE is required for the lab -*Demonstrate* the reasoning behind PPE -*Perform* bacterial plating and spice grinding after it is modeled -*Communicate effectively* with peers and instructors	-*Analyze* data gathered -*Asses* the success of their experiment -*Apply* scientific method to determine how they wish to continue -*Communicate effectively* with peers and instructors	-*Analyze* data gathered -*Draw conclusions* from collected and analyzed data -*Communicate effectively* with peers and instructors -Demonstrate an understanding of the range of careers available in STEM	-*Communicate effectively* with peers, instructors, and parents -*Create* a posterboard that communicates their experiment and their findings

5.3 Appendix 3: Day 1 Lesson Summary, Associated Presentation, and Skills Matrix

Presentation

Activities:

1. **9:00am-10:00am: Ice Breakers and introductions.** Instructor will lead students through activities that introduce the students to each other and to the instructor. Goal is to get the students comfortable with being with each other and being in the lab space. Instructor should try to establish a casual and welcoming tone where students feel empowered and confident with themselves.

2. **10:00-11:00am: Introduce program**. Instructor will share with students the goal of the program. (To inspire an interest in biology or STEM in general in the students, and to show that STEM has room for everyone. Program hopes to see an increase in awareness and interest in a variety of STEM careers from the students). Instructor will also share the basis of the experience. Students should leave discussion with an understanding of the correlation between spice use around the world and climate. The students will use this correlation as a basis for an antimicrobial assay using common spices. When experiments are finished, students should be able to make conclusions about the antimicrobial properties of spices, and correlate this back to the distribution of spice use around the world.

Practice 1. Asking Questions and Defining Problems

3. **11:00-11:30am: Initial survey**. Goal of survey is to assess the technical skills, critical thinking skills, ability to plan experiment, and interest in STEM careers of the students before the program.
4. **11:30am-12:00pm and 1:30pm-2:00pm: Prior research question brainstorm.** Students will work in groups to generate questions or knowledge needed before planning and conducting experiment. Goal is to have students think about what knowledge needs to exist before new knowledge can be generated. Conversations should revolve around understanding materials, bacteria, spices, they wish to use. Instructor should circulate room and prompt students when needed, but conversation should be largely student led within groups. Students should leave brainstorm session with an ownership of the experiment, and an introduction to the importance of prior research before conducting an experiment.

Practice 1. Asking Questions and Defining Problems

5. **2:00pm-3:00pm: Class Discussion of prior research questions.** Instructor will lead students through an introduction of the scientific method, with emphasis on how the students are going to use it in the coming days. Goal is to remind (or introduce) the scientific method to the students in an interactive and accessible way. Discussion should be student led, allowing them to see value in their past experiences and knowledge. The second half of the conversation will be focused around the prior research questions generated by the students. Sharing among the whole class should be encouraged and become common place. Students are encouraged to learn from each other, and use ideas or questions generated by other groups. Emphasis should be placed on the collaborative nature of STEM when students are sharing.

Practice 3. Planning and Carrying Out Investigations

6. **3:00pm-4:00pm: Research.** Students should use resources provided (or find their own depending on level of class and resources available) to answer the questions they generated. Emphasis should be placed on intra-and inter-group collaboration while researching. Goal is not to simply answer the questions they generated, rather the goal is to fully understand the systems they will be using, in order to conduct the most successful and telling experiment they can.

Practice 8. Obtaining, Evaluating, and Communicating Information

	Skill (as numbered in Table 3)									
Activity	1	2	3	4	5	6	7	8	9	10
1										
2					X	X				
3										
4	X	X								
5	X									
6	X	X	X	X						

5.4 Appendix 4: Day 2 Lesson Summary, Associated Presentation, and Skills Matrix

Presentation

Activities:

1. **9:00-9:30am: Get settled in.** First half hour of all classes from here on will be reserved for students to enter the room, get settled, and redirect their headspace. Quite chatting among students should be allowed. Goal is to allow students to build connections with other students, and become comfortable within the lab space.

2. **9:30-10:30am: Share out questions and answers.** Groups will share out the questions they researched the previous day, along with the answers they found. Emphasis should be placed on understanding the systems they will be using. Groups should be encouraged to share any question they had, even if an answer was not found or was found to be nonapplicable. As many students as possible should share and contribute. Groups should be encouraged to help other groups answer questions or add to presented answers. Tone should be informal and inviting. Instructor should prompt students if they feel an element of the experiment has not been discussed or researched. By the end of the conversation, students should have enough information to plan their experiment.

Practice 8. Obtaining, Evaluating, and Communicating Information

3. **10:30-11:00am: Model of experiment design.** Instructor should walk students through the steps of planning an experiment. Extensive details can be found on Day 2 powerpoint. Activity should not be a lecture, but an interactive conversation in which students are being introduced to the steps, then immediately applying them to their own experiment. Discussion among and between groups should be encouraged.

Practice 2. Developing and Using Models

4. **11:00-12:00pm: Experimental design**. Using the information they just gained, the students should design their experiments. Discussions should be mainly small group focused and student led. Instructor should circulate the room and answer questions. If instructor weighs in on the experimental design, comment should be asked as a question. Goal is to lead students to a well designed experiment while letting them feel ownership and excitement towards design. If groups happen to be testing the same subjects and treatments, instructor should lead an inter-group discussion wherein the importance of duplicates and redundancies in science should be emphasized. If no two groups test the same subjects and treatments, instructor should lead a full class discussion about the value of having several scientists work on the same problem. Neither should be encouraged over the other, but both should be addressed if they occur.

Practice 2. Developing and Using Models

5. **12:00-12:30pm: Design Lab Coats**. Students will have the time between the end of experimental design and lunch to design their lab coats. Goal is to allow students to express themselves and take ownership over their lab coats. Inter-and intra-group conversation should be allowed.

6. **1:30-2:00pm: PPE introduction**. Instructor will model a purposefully flawed experiment for the students. Students should be encouraged to exploit faults in methods.

When faults are pointed out by students, instructor should correct the method, and then connect it to a best practice actually used in lab. Tone should be fun and informal (competitive if group dynamics allow)

7. **2:00-2:30pm: Modeling of grinding and plating technique.** Instructor will show videos of grinding and plating technique. Students should be encouraged to ask questions. Emphasis should be placed on using best lab practices, and being consistent throughout experiment. Videos will probably need to be shown twice each.

8. **2:30pm-3:30pm: Grinding spices and plating bacteria**. Students will plate and grind their own spices. Instructor should circulate room and encourage aseptic technique. Emphasis should be placed on proper plate handling and labeling. Conversations among the students should be encouraged, as bonding among students is important.

Practice 3. Planning and Carrying Out Investigations

9. **3:30-4:00pm: Students should clean up their stations,** return all materials to the correct location. Emphasis should be placed on ownership and respect of lab materials

	Skill (as numbered in Table 3)									
Activity	1	2	3	4	5	6	7	8	9	10
1										
2	X		X	X	X					
3						X				
4	X	X				X				
5									X	
6							X	X	X	
7							X	X	X	
8		X				X	X	X	X	
9									X	

5.5 Appendix 5: Day 3 Lesson Summary, Associated Presentation, and Skills Matrix

Presentation

Activities:

1. **9:00-9:30am: Get settled in.** First half hour of all classes from here on will be reserved for students to enter the room, get settled, and redirect their headspace. Quite chatting among students should be allowed. Goal is to allow students to build connections with other students, and become comfortable within the lab space.

2. **9:30-10:00am: Look at plates**. Students should look at their plates and record results. Emphasis is on proper and accurate recording of their results. Student should make hypothesis before looking at results, then use results to comment on it. Groups should discuss among themselves what results could mean, both in the context of the hypothesis and in the context of lab technique.

Practice 4. Analyzing and Interpreting Data

3. **10:00-11:00am: Class discussion of results**. Students will share out their results using sentence structure provided in Day 3 powerpoint. Emphasis is placed on validating and understanding every piece of data. Instructor should stress that no information is bad information, and every piece of data gathered helps the class understand either the over arching question, or helps the class understand lab technique. Each student should be encouraged to share and participate. Inter-group collaboration should be encouraged. If two groups tested similar conditions their results should be discussed. Trends within class data should be noted. Emphasis should be placed on the collaborative nature of science, instructor should note how much more information was gained by having several groups test the same question.

Practice 4. Analyzing and Interpreting Data

4. **11:00-11:30am: Replating conversation**. Using the knowledge gained in last conversation, groups should decide among themselves what they want to plate in round 2. Instructor should circulate the room and help guide student's decisions. Every group should replate. (if resources are tight, each group being able to replate at least one more plate should be prioritized over testing more samples the first time). Depending on situation within group, instructor should encourage students to either re-test a condition that didn't work (no growth on control, no growth over all, no inhibition over all) or encourage students to test new combinations based off their results (did one bacteria seem particularly hard to kill? Did one spice seem particularly deadly?)

Practice 3. Planning and Carrying Out Investigations

5. **11:30-12:30pm: Prior research questions again**. Within groups, students should decide what else they need to know, if anything, in order to design a second experiment. Time could also be used to re-investigate information that students used for round 1. If groups experienced a systemic failure (contamination, no growth at all) time should be spend researching why. (Sources provided may not have information needed to do so.) When finished, students should gather materials that can be left out during lunch, and begin to record new experiment in their notebooks.

Practice 8. Obtaining, Evaluating, and Communicating Information

6. **1:30pm-2:30pm: Grinding spices and plating bacteria**. Students should work within their groups to set up second experiment. Instructor should circulate room and encourage aseptic technique. Emphasis should be placed on proper plate handling and labeling. Conversations among the students should be encouraged, as bonding among students is important. Students may wish to watch videos from Day 2 again, so they have been copied into this powerpoint as well.

7. **2:30-3:30pm: Class discussion; How do we know the scientific method works?** Instructor will lead students through a discussion of the scientific method again. Emphasis this time should be placed on where we currently are in the process, and how we used round 1 to inform the actions of round 2. Students should leave conversation with an understanding of the cyclical, hence reliable nature of scientific inquiry. Value of re-testing and confirming data should be noted, as well as the value of having several people test the same question.

Practice 6. Constructing Explanations and Designing Solutions

8. **3:30-4:00pm: Students should clean up their stations,** return all materials to the correct location. Emphasis should be placed on ownership and respect of lab materials

	Skill (as numbered in Table 3)									
Activity	1	2	3	4	5	6	7	8	9	10
1										
2	X	X			X			X	X	
3	X						X			
4	X	X			X	X				
5	X	X	X	X	X					
6	X	X			X	X	X	X	X	
7					X	X				
8									X	

5.6 Appendix 6: Day 4 Lesson Summary, Associated Presentation, and Skills Matrix

Presentation

Activities:

1. **9:00-9:30am: Get settled in.** First half hour of all classes from here on will be reserved for students to enter the room, get settled, and redirect their headspace. Quite chatting among students should be allowed. Goal is to allow students to build connections with other students, and become comfortable within the lab space.

2. **9:30-10:00am: Look at plates**. Students should look at their plates and record results. Emphasis is on proper and accurate recording of their results. Student should make hypothesis before looking at results, then use results to comment on it. Groups should discuss among themselves what results could mean, both in the context of the hypothesis and in the context of lab technique.

Practice 4. Analyzing and Interpreting Data

3. **10:00-11:00am: Class Discussion of results.** Instructor will lead class through a discussion of results from round 2 of plating. Emphasis should be placed on what was learned from previous day, and how that helped inform the set up of this experiment. Every student should be encouraged to share. Inter-group conversations are encouraged. If groups have corroborating or conflicting results they should be noted and further discussed. Goal of the conversation is not to draw conclusions, rather to fully understand the trends in data. Emphasis is placed on validating and understanding every piece of data. Instructor should stress that no information is bad information, and every piece of data gathered helps the class understand either the overarching question, or helps the class understand lab technique.

Practice 4. Analyzing and Interpreting Data

4. **11:00-11:30am: Group Discussion of conclusions**. Students should work within their groups to draw conclusion based on their data and the class data. Student conversations should focus on WHAT conclusions can be drawn and WHY they can be drawn. Students should be reminded of overarching question, and asked to relate their results back to it.

5. **11:30-12:00pm: Class Discussion of results**. Groups should share out their conclusions to the class. If every group reaches similar conclusions, emphasis should be placed on what we all did that was similar and led us to the same conclusion. Students should be prompted to think about what else they still need to know, and if that new information would change their conclusion. If groups reach different conclusions, conversation should focus on what groups did differently to reach these different conclusions. Neither should be encouraged over the other, but both should be addressed when and if they arise. Conversation should then shift to understanding the validation of results. Students should be prompted about what they did within the course of their experiment that allows them to make a conclusion. Students should leave conversation understanding the correlation between controls, replicates, standard procedure, prior research and the validity of their results.

Practice 7. Engaging in Argument from Evidence

6. **12:00-12:30pm: Clean up and wind down**. Students should take ownership of properly disposing of their plates and materials. Students will also clean their lab stations. Extra time before lunch should be spent adding conclusions to lab notebooks. Quite chatting among students should be allowed. Goal is to allow students to build connections with other students, and become comfortable within the lab space.

7. **1:30pm-2:30pm: Career Activity.** Instructor will lead students through an exercise aimed at exposing students to the variety of STEM careers. See Day 4 Powerpoint for more details. Goal of activity is to introduce students to the wide range of careers within STEM, and allow students to see themselves in that career. Special attention should be given to connecting the concrete image of a career with the abstract name of the major. For example: students could likely explain what an astronaut or an app developer is, but they likely cant connect the job back to a degree in aerospace engineering or CS. Students should leave activity with an appreciation for the wide range of jobs that can arise from an undergraduate STEM degree. In addition, instructor should emphasize the "good" each major does, making the connection that one can help people in every STEM field, as this seems to be a driving force for young students when picking a career field.

8. **2:30-4:00: Poster discussion.** Whole group will have a discussion around what makes a good poster. Emphasis should be placed on making the poster clear, aesthetically pleasing, informative, uncluttered. Students will then generate a list of important information their posters should include. Students will be given the rest of the day to work on their posters. Inter- and intra- group discussions should be encouraged. If resources allow, posters can be digital and include images of their plates. Goal with posters is to effectively communicate what the students learned and did within the past week. There are no failures in science, so unexpected or contaminated data should be mentioned and discussed in a positive way.

Practice 7. Engaging in Argument from Evidence
Practice 8. Obtaining, Evaluating, and Communicating Information

	Skill (as numbered in Table 3)									
Activity	1	2	3	4	5	6	7	8	9	10
1										
2	X	X			X		X	X	X	
3	X					X				
4	X					X				
5	X	X			X	X				
6										
7										
8	X	X			X	X			X	

5.7 Appendix 7: Day 5 Lesson Summary, Associated Presentation, and Skills Matrix

Presentation

Activities:

1. **9:00-9:30am: Get settled in.** First half hour of all classes from here on will be reserved for students to enter the room, get settled, and redirect their headspace. Quite chatting among students should be allowed. Goal is to allow students to build connections with other students, and become comfortable within the lab space.

2. **9:30-11am: Group work: Finish poster.** Students will work within their groups to finish their poster designs. Instructor should circulate room and encourage making the poster clear, aesthetically pleasing, informative, uncluttered. Inter- and intra- group discussions should be encouraged. If resources allow, posters can be digital and include images of their plates. Goal with posters is to effectively communicate what the students learned and did within the past week. There are no failures in science, so unexpected or contaminated data should be mentioned and discussed in a positive way.

Practice 7. Engaging in Argument from Evidence
Practice 8. Obtaining, Evaluating, and Communicating Information

3. **11:00-11:30am: Q and A about STEM from students.** Students will be asked to reflect back on discussion about STEM careers from the previous day and time will be spent answering questions. Emphasis should be placed on de-stigmatizing STEM careers.

4. **11:30-12:00pm: Class Discussion: What did we learn this week?** Students will be asked to share one thing they learned from the program. Can be related to the content of the program, or related to STEM careers. Each student should share. Inter- and intra-group interactions should be encouraged. Conversation should have a positive and inviting tone.

5. **12:00-12:30pm: Post-survey.** Goal of survey is to assess the technical skills, critical thinking skills, ability to plan experiment, and interest in STEM careers of the students after the program. Same survey as the pre-survey

6. **1:30-2:30pm: Practice presenting posters.** Groups will display their poster and practice presenting to the rest of the groups. Emphasis should be placed on encouraging every student to feel comfortable with presenting, and confident in their science. After each presentation, other groups should give positive and constructive feedback.

Practice 7. Engaging in Argument from Evidence
Practice 8. Obtaining, Evaluating, and Communicating Information

7. **2:30pm- end of day: Launch Activities.** The rest of the day is occupied with whole-camp activities.

	Skill (as numbered in Table 3)									
Activity	1	2	3	4	5	6	7	8	9	10
1										
2	X									
3										
4						X				
5										
6	X									
7										

5.8 Appendix 8: Google Drive Folder with all Resources

The link to the Google Drive Folder with all resources can be found here. Link gives permission only to view, if commenting or editing permission is desired, please contact the author.