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After School Matters: Expanding the Time to Engage Minority Middle School Girls in STEM

Dr. Stephanie Luster-Teasley, North Carolina A&T State University

Dr. Stephanie Luster-Teasley is an Associate Professor with a joint appointment in the Departments of Civil, Architectural, and Environmental Engineering, and Chemical, Biological, and Bioengineering. Over the last ten years, Dr. Luster-Teasley has demonstrated excellence in teaching by using a variety of research-based, student-centered, pedagogical methods to increase diversity in STEM. Her teaching and engineering education work has resulted in her receiving the 2013 UNC Board of Governors Teaching Excellence Award, which is the highest teaching award conferred by the UNC system for faculty. In 2014, she was also the recipient of the ASEE Dupont Minorities in Engineering Award.

Dr. Radiah C. Minor, School of Agriculture and Envrinmental Sciences, North Carolina A&T State University
Prof. Vernal G. Alford III, North Carolina Agricultural and Technical State University

Vernal G. Alford III has worked at North Carolina A&T State University in various capacities since 1992. Mr. Alford has served as Assistant to the Dean of Engineering; Director of Outreach and Facilities Manager both for the College of Engineering; General Engineering Coordinator and Adjunct Associate Professor. Vernal Alford is a licensed Professional Engineer in the state of North Carolina.

Mr. Alford's outreach activities have included but are not limited to the following: • Judge Advisor (Head Judge) for 2007, 2009, 2010, 2011, 2012 Aggieland Competitions of the First Tech Challenge (FTC) and workshop presenter for the 2009, 2010, 2011 FTC Kick Off Event; • Judge Advisor (Head Judge) for 2011-2012 NC Region incl. 8 qualifying tournaments of the FIRST LEGO League(FLL); • Referee and Judge for FIRST Lego League Robotics competition of middle and high school students; • Director, 2010 Aggie Impact Scholars Program – a university wide six week summer program for up to seventy-five (75) incoming freshmen; • Coordinator of EMPACC and HOME Programs – six week programs for incoming freshmen to the College of Engineering; • Director of Engineer Starters Program – a two to three week program for middle and high school students; • Assisted with the planning and operations of Para-Researcher and Energy Engineer Starters Programs – two week programs for middle and high school students; • Coordinator of Para-Researcher Program 6 – a six week program for high school students taking a college course; • Conducted Save our Students outreach, in conjunction with the YWCA, during academic year to four area middle schools; • Served as a consultant to the Science Fair at Claxton Elementary School for two years and Erwin Montessori School including coordinating community service for engineering students. • Presenter for the Greensboro Area Mathematics and Science Education Center (GAMSEC) Summer Program • Speaker/presenter at various K-12 institutions.

Professor Alford currently teaches Introduction to Engineering Design and Ethics as well as Statics and Mechanics of Materials.

After School Matters: Expanding the time to engage Minority Middle School Girls in STEM through Informal learning outside of the classroom

An increase in the diversity of the U.S. pipeline for students entering STEM fields is significantly needed. This is especially true for minority and female students interested in pursuing opportunities in STEM careers. The North Carolina A&T State University (NCA&T) *Case Studies in Science and Engineering Enrichment Lab* program is an informal science and engineering education program in its third year of operation. It is a hands-on STEM program that uses guided inquiry and case studies to teach critical process skills for scientific inquiry for middle school female, minority students. The overarching goal is to identify how an all-female environment coupled with informal STEM learning experiences can build female learner's confidence in science and math. Hence, this intervention seeks to counteract negative gendered stereotypes and peer pressure that middle school girls experience in the 6^{th} – 8^{th} grade level. The program seeks to improve students' competence and self-efficacy in science and engineering, stimulate an interest in pursuing STEM-related careers, and provide engaging "hands-on/mind-on activities." The program is divided into two initiatives which include an academic year and weekend academy. A total of 45 middle school students have participated in a 1-week Girls in Science Lab Camp and five half-day Girls in Science and Engineering Weekend Academy activities. For the Girls in Science Lab program, the participants were divided into teams and assigned an environmental science and engineering themed case study to solve during guided laboratory experience. Students were taught how to collect and analyze water samples using university laboratory equipment and presented their findings at the end of the program. The Weekend Academy featured five hands-on, minds-on activities based on engineering and science. Program outcomes data suggests that student's self-efficacy and confidence in their ability to excel in engineering and science increased. This is especially true for students who participated in two or more STEM outreach activities. This paper will review the program implementation and program outcomes for outreach activities offered by the NCA&T *Case Studies in Science and Engineering Enrichment Lab* program.

Introduction

An increase in the diversity of the U.S. pipeline for students entering STEM fields is significantly needed. This is especially true for minority and female students interested in pursuing STEM careers [1]. Literature suggests that female students tend to lose interest in pursuing STEM classes and careers between the 6^{th} – 8^{th} grades.[2-4] This is attributed to a lack in role models, gender biases, and negative peer pressure suggesting female students are not good at science and math.[3, 5, 6]. The North Carolina A&T State University (NCA&T) *Case Studies in Science and Engineering Enrichment Lab* program is an informal science and engineering education program in its third year of operation. It is a hands-on STEM program designed to use guided inquiry and case studies to teach critical process skills for scientific inquiry. The overarching goal of the program was to identify how an all-female environment coupled with informal STEM learning experiences could build female learner's confidence in science and math. Research suggest effective strategies for influencing girls' self-confidence include persuasion, observing others, and emotional experiences that positive portray sciences significantly benefit female students.[3, 7] Hence, this intervention sought to counteract negative gendered stereotypes and peer pressure that middle school girls experience in the 6^{th} – 8^{th} grade level. The program focused on improving the girls' competence and self-efficacy in science and engineering, stimulate their interest in pursuing STEM-related careers, and provide engaging "hands-on/mind-on activities."

Funded since 2013 by the Burroughs-Wellcome Fund Student Science Enrichment Program (SSEP), the activities were strategically designed to: 1) Improve students' competence in science and engineering; 2) Nurture students' enthusiasm for science; and 3) Increase interest of students in research or other science-related careers. The *Case Studies in Science and Engineering Enrichment Lab* program interventions were divided into two program tracks. The first program track was the Girls in Science Lab Camp (GiSLC). The second program track was the Girls in Science Weekend Academy (GiSWA). For each of the program tracks, case stories were used to provide a relatable and realistic application of STEM concepts and to illustrate how science and engineering impact the participant's daily lives.

Implementation

Program track 1 - Girls in Science Lab Camp (GiSLC): The Girls in Science Lab Camp was a 1-week camp offered during the summer. It was designed to provide hands-on science experiences which teach the students about environmental science, water quality, and public health. The curriculum was based on the NC Science Essentials Standard 8.L.1 and 8.E.1.3 which is part of the Guilford County Public Schools' 8^{th} grade curriculum. During the camp, the participants learned lab skills, analyzed environmental samples using college level laboratory equipment, and gained invaluable confidence in their ability to become scientist. The targeted NC Science Essentials core competencies were:

- Understanding the hazards caused by agents of diseases that affect living organisms
- Ability to summarize the basic characteristics of viruses, bacteria, fungi and parasites relating to the spread, treatment and prevention of disease

- Ability to predict the safety and potability of water supplies in North Carolina based on physical and biological factors, including temperature, dissolved oxygen, pH, nitrates and phosphates, turbidity, and bio-indicators
- Ability to conclude that the good health of humans requires: Water quality standards, methods of water treatment, maintaining safe water quality, and stewardship

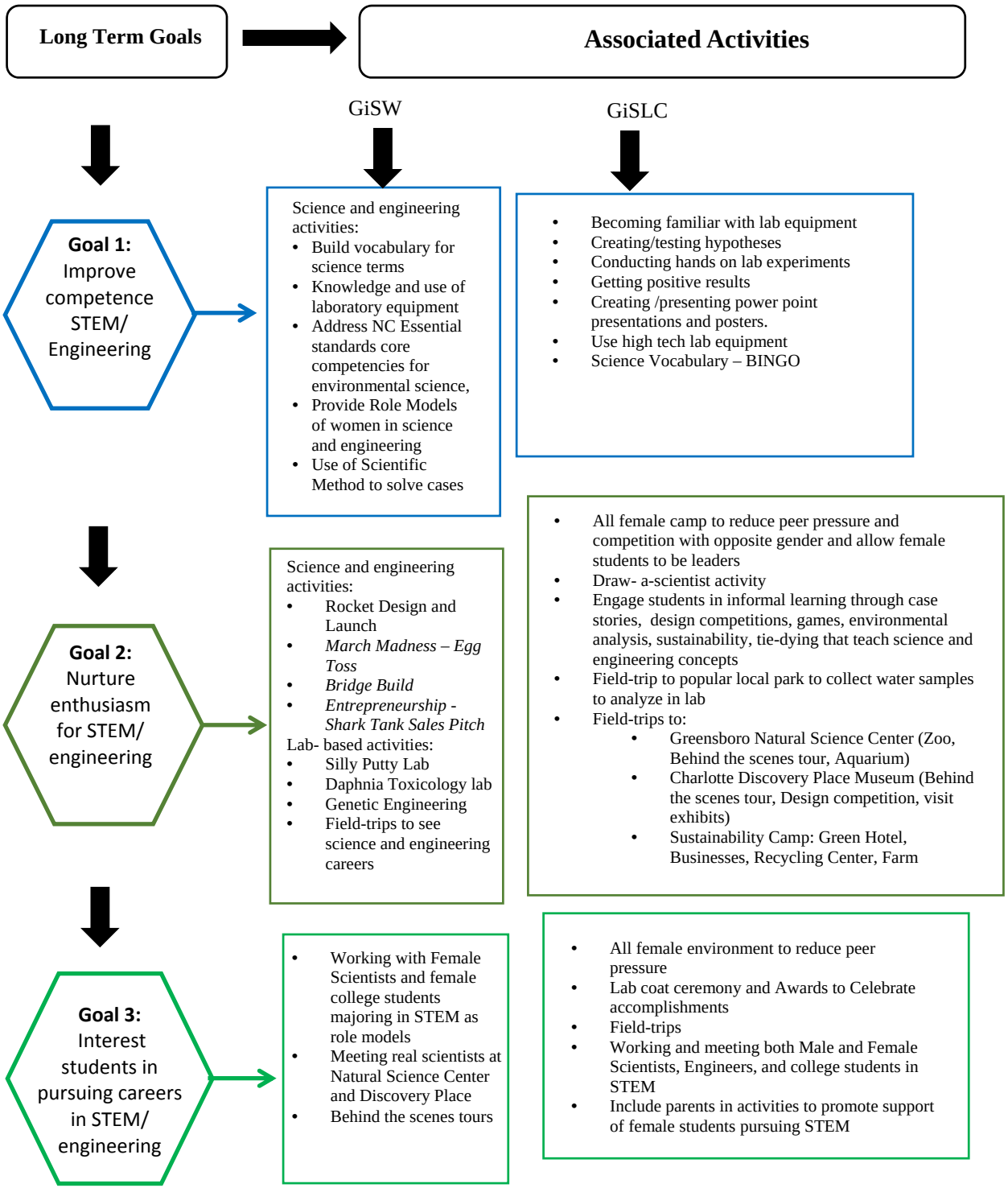
During the 1-week, summer program, students were engaged in activities each day for eight-hours. Camp activities involved learning and basic lab skills such as the proper use of laboratory instruments and tools such as pipettes, micropipettes, scales, how to correctly measure volumes, and handle chemicals and environmental samples safely. The girls were grouped into teams and each day a detailed schedule of events was presented to keep the young girls busy working in the lab and assure that each participant had the opportunity to participate in all of the hands-on science activities. The groups were assigned one of the three case studies that involved a community member or pet became sick due to an unknown microbial hazard. The groups were asked to think like scientists to solve the cases.

Program track 2 - Girls in Science Weekend Academy (GiSWA): For this activity, five half-day sessions were held during the academic year. The design for the GiSWA curriculum was to use cases linked to smaller hands-on science and engineering activities that could be accomplished within a few hours to engage the participants in math, science, and engineering. The activities were designed to be an informal continuation of the girls' summer GiSLC experience and to show the girls "everyday science and engineering" with practical applications. Each session included a case and theme to provide the girls with the opportunity to practice engineering design and science, be creative, and enjoy the learning experience in an informal environment. Activities occurred on Saturdays, once a month, for a duration of 4 hours and included lunch. The activities focused on design competitions, laboratory experiences, and behind the scenes tours at science museums. The half-day format for the GiSWA allowed us to introduce a variety of topics over several months to keep the girls interest and engagement. This format provided a "quick" and "fun" science experience that many participants do not have in their traditional public schools. The structure also kept the participants excited about the program and interested in coming back the next month for the GiSWA activity.

Student Participation

Students were recruited from the Guilford County area using the acronym removed Outreach Office website, our waiting list from the summer applications, and referrals from people who knew of the programs. Applicants and their parents were asked to complete an on-line application that collected demographic, school, and grade information. Student essays, parent essays, and a letter of recommendation from the applicant's science teacher were required for the GiSLC program, but not for the GiSWA. During the application review, we targeted minority students and students attending Title 1 government supported schools. During the selection process, rising 7^{th} and 8^{th} grades were the targeted grade levels, however, 9^{th} grade candidates who demonstrated a high level of interest in STEM and strong parent and teacher support letters were also selected. For GiSLC, 12 – 13 female students were selected to allow the camp leaders to provide focused attention on the participants. The GiSWA was open to 25 participants each academic year.

Figure 1. Logic Model for GiSLC and GiSWA



Program Implementation and Outcomes

The following discussion of the results will review the program implementation and program outcomes for the outreach activities based on the three SSEP goals of: 1) Improve students' competence in science and engineering; 2) Nurture students' enthusiasm for science; and 3) Increase interest of students for research or other science-related careers. A total of 45 female students have participated in the program since 2013. The participants included 42% 7th graders, 46% 8th graders, 14% 9th graders. African-American students represented 88%, 1% Caucasian, 11% Native American, 5% bi-racial, and 3% Asian.

Figure 2. Girls in the Weekend Academy at Discovery Place; Charlotte, NC.

Goal 1: Improving students' competence in science

The curriculum designed for the GiSLC and GiSWA was based on incorporating case "stories" into the science and engineering instruction. The "stories" were short narratives with fictional characters with a dilemma that could be solved by using a science or engineering solution. The use of the stories as the instructional tool was selected to make the concepts being taught relatable for the middle school participants in a societal context. This intervention and instructional model was based on literature, which supports the findings that active learning experiences that link to societal and social relevance are more impactful for learning among women and minorities.[8-10] For example, for the GiSLC program track, the students were asked to solve cases about mysterious illnesses that occur in three different case scenarios. Figure 4 provides images of the three cases used for the GiSLC program.

As the students read and discussed the cases during the GiSLC, they were asked to think critically about the symptoms and use clues to identify the source of contamination. Students learned and performed "diagnostic" Enzyme linked immunosorbent Assays (ELISA) to confirm that the patients in the cases were exposed to an infectious bacteria. Then the participants visited one of the public parks in Guilford County to sample water from the lakes discussed in the cases. Upon returning to the lab, the students used the scientific method to develop a hypothesis, learned hands-on lab skills to conduct experiments on the collected water samples, and reported their results. In the laboratory, they learned chemistry and biology lab skills, use of

micropipettes, how to culture common household bacteria, and they learned how to test water samples for bacterial contaminants.

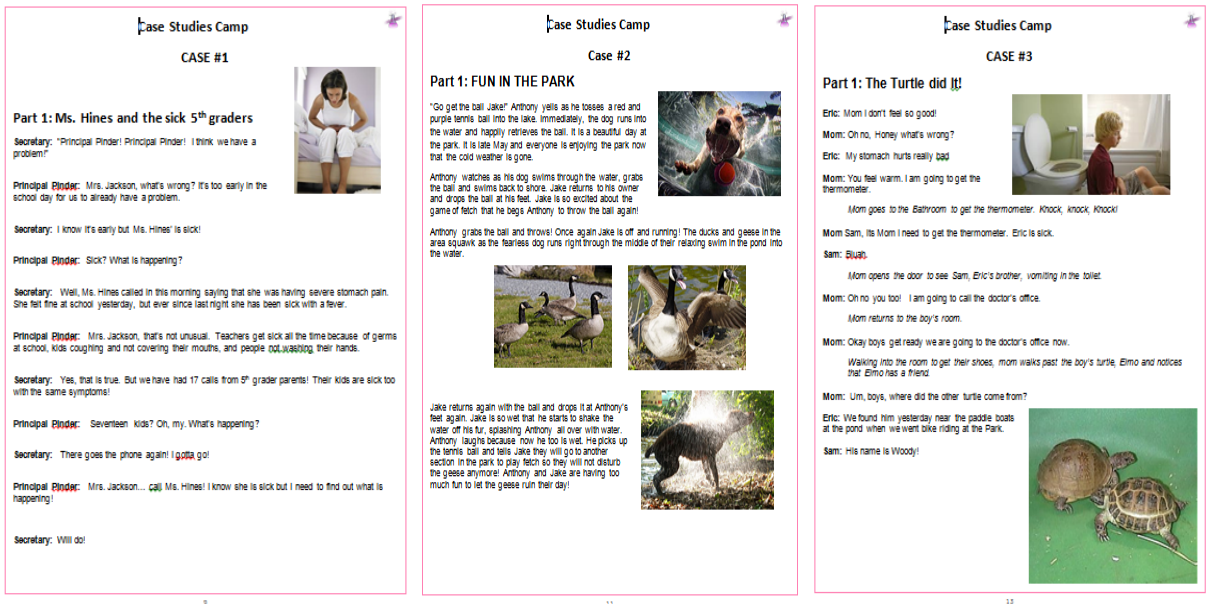


Figure 3. Samples of the Cases used for the student groups

Through the case, the girls learned about pathogens and got an overview of immune responses. The data they collected from the experiments was used directly to prove or disprove their case, hence, making their use of the scientific method more meaningful and relevant to real world applications. At the end of the camp, the girls produced a group poster, acted out the case study for their parents, and created PowerPoint presentations to present their results.

(a) (b) (c)

Figure 4. Girls in Science Lab Camp in laboratory

During the GiSWA program, the girls were challenged to conceive, engineer, and build creative solutions that addressed the theme for that week. Table 1 provides a summary of the activities during the GiSWA. The participants also learned about careers in STEM and during the tours they met women and men working in STEM.

Table 1. Schedule for the Weekend Academy Activities

Orientation	Parent/child Orientation
Competitions	Rocket Building Bridge Build with Straws Egg Drop Family March Madness – Egg Toss Competition
Laboratories	Daphnia Toxicology Lab Genetic Engineering of Bacteria Entrepreneurship and Innovation • Silly Putty – Designing your own Silly Putty formula and Shark Tank Company Pitch
Tours	Science Museum Tour Year 1: Greensboro Natural Science Center • Behind the scenes tours to learn about science careers • Aquarium • Zoo • Reptile house Year 2: Discovery Place Science Museum • Behind the Scenes tours to learn about science careers • Innovation and Engineering session • IMAX Movie: The unforeseen world Year 3: Greensboro Natural Science Center • Bodies Alive Exhibit

Science Notebooks

Notebooks were developed for the participants to provide a tangible document they could use during the programs and keep after the programs. The notebooks also served as a tool to help increase participant competence in science. Most of the students in Guilford County Public Schools do not have individual, student science textbooks and many school only have classroom sets of science textbooks. Therefore students, especially those in Title 1 schools, have limited access to science material that can be taken home on a regular basis. This means students must find their own resources outside of the classroom for science related content. The notebooks contained the science curriculum content, photos of equipment and tools that the girls would use during the program, and a list of relevant science and laboratory vocabulary that was consistent with the 7^{th} and 8^{th} grade science vocabulary lists. During the program, the leaders also required the participants to learn and use the terminology. The participants were tested on the vocabulary that they learned by daily playing vocabulary BINGO as one of their fun activities during their downtime and breaks.

Figure 5. GiSLC with their Notebooks

Laboratory Experiences

During the GiSLC program, the participants learned how to use laboratory equipment, analyzed environmental samples using college level laboratory equipment, and gained invaluable confidence in their ability to become future scientist. They practiced how to use the instruments and tools as well as how to safely handle and measure chemicals and environmental samples. To ensure each participant could gain confidence in their ability to become scientist, each student participated in the hands-on science activities that included extraction of DNA, Enzyme linked Immunosorbent Assay (ELISA), and quantification and identification of bacteria (*E. coli*). These activities helped directly build their competence in science and engineering and self-confidence in being able to use equipment used by scientists and engineers.

Figure 6. GiSLC performing DNA and PCR lab

Goal 2: Nurturing students' enthusiasm for science

Fun-Hands-on/Minds-On activities

The half-day format for the GiSWA allowed us to introduce a variety of topics over several months to nurture the students' enthusiasm for science. The use of household items to be creative during the activities helped to make the girls think of new ways to use everyday items. For example, the girls were challenged to build and launch a paper rockets, design and build a structure to protect a raw egg from cracking when thrown, to creatively make a free standing balloon tower in a tallest structure competition, and to make a wearable item using duct tape and cardboard. Thus, it allowed the girls to prove to themselves that they could have fun and be creative with everyday items to build and design projects that worked.

During the GiSWA, we were also intentional in engaging the families of the students. Parent support and influence can significantly impact their children's' self-confidence in STEM. [11, 12] This was done to increase the awareness in families for how to support their daughters in pursuing STEM courses in high school, college, and the future careers.

Figure 7. Families involved in designing egg protection vessel with their daughters

Role Play

Each year, our participants have been interested in acting out the case "stories" for their parents to help present the case their team solved. We have found that the use of role play helps increase their enthusiasm for the activity and reinforces the idea of incorporating the arts into the STEM curriculum also known by the acronym STEAM (Science, Technology, Engineering, Arts, and Mathematics).

Figure 8.Girls acting out skits and presenting their research

Goal 3: Increase Interest of students in research or other science-related careers.

Through the GiSLC and GiSWA, the participants were introduced to female and male role models in STEM. The camp leaders were female faculty and graduate students at NCA&T. During the tours, we were able to have the girls meet people working in STEM careers.

Figure 9. Girls meeting role models in STEM during tours

Program Evaluation

The surveys during the program evaluation were designed to assess the positive and negative benefits of the GiSLC and GiSWA program tracks. Question 1 provided a baseline for the participants' perception of herself as a science student. Table 2 presents the perception of the participants for their ability as a science student. As indicated in Table 2, less than half (35 – 45%) of the GiSWA and 20 – 54% of the GiSLC students classified themselves as very good science students. This suggested the potential for the programs to build their confidence in science was feasible.

Table 2. Girls' perception of themselves as a science student prior to the program

Q1. How would you describe yourself as a science student?	GiSWA 2013	GiSWA 2014	GiSLC 2104	GiSLC 2105	Totals Count and Percentage	
Very Good	4(36.4%)	11 (45.8%)	6 (54.5%)	3 (20.0%)	24	39.3%
Good	6 (54.5%)	13 (54.2%)	4 (36.4%)	9 (56.3%)	32	52.5%
Okay	1 (9.1%)	-	1 (9.1%)	3 (20.0%)	5	8.2%
Total	11 (100%)	24 (100%)	11 (100%)	15 (100%)	61	100.0%

Question 2 of the survey asked the participants to rate their interest in science before the program (Table 3). This data shows mixed responses in student interest in science prior to the programs. The majority of the student responses were in the middle range where they indicated they were "interested" or "sort of interested" categories.

Table 3. Girls' interest in science before the program

Q2. How would you describe your interest in science before this program	GiSWA 2013	GiSWA 2014	GiSLC 2014	GiSLC 2015	Totals Count and Percentage	
Very interested	3 (27.3%)	5 (20.8%)	1 (9.1%)	1 (6.6%)	10	16.4%
Interested	3 (27.3%)	10 (41.6%)	5 (45.5%)	5(33.3%)	23	37.7%
Sort of Interested	3 (27.2%)	7 (29.1%)	4 (36.4%)	6 (40%)	20	32.8%
A little interested	1 (9.1%)	2 (8.3%)	1 (9.1%)	3 (20%)	7	11.5%
Not interested at all	1 (9.1%)	0.10%	-	0.00%	1	1.6%
Total	11 (100%)	24 (100%)	11 (100%)	15 (100%)	61	100.0%

Table 4 summarizes data representing the participant's perception of how the programs helped build confidence in STEM. Questions 3 a - d for both the GiSWA and GiSLC suggest 55% strongly agreed and 41% agreed that the program helped them understand science better. There were no students that disagreed with the statement. The majority of the students (95%) either

agreed or strongly agreed that the program helped them feel better about being able to learn science (Q3.b) and three students (4.9%) were uncertain. Question 3c and d inquired about the students seeing the relevance in what they were learning for school and "everyday" living. Once again, we see the students responded positively to the potential for future application of the STEM skills learned. This is especially important since women and minorities tend to prefer to see societal links and application as motivation to pursue STEM fields.

Table 4. Girls' perception of their self-efficacy in science

Q3.a. This program helped me understand science better	GiSWA 2013	GiSWA 2014	GiSLC 2104	GiSLC 2105	Totals Count and Percentage	
Strongly agree	2 (18.2%)	12 (50.0%)	9 (81.8%)	11 (73.3%)	34	55.7%
Agree	9 (81.8%)	10 (41.7%)	2 (18.2%)	4 (26.7%)	25	41.0%
Uncertain	-	1 (4.2%)	-	-	1	1.6%
Disagree	-	1 (4.2%)	-	-	1	1.6%
Strongly Disagree	-	-	-	-	0	0.0%
No answer	-	-	-	-	0	0.0%
Total	11 (100%)	24 (100%)	11 (100%)	15 (100%)	61	100.0%
Q3.b. Because of this program, I feel better about being able to learn science	**GiSWA 2013**	**GiSWA 2014**	**GiSLC 2104**	**GiSLC 2105**	**Totals Count and Percentage**	
Strongly agree	4 (36.4%)	12 (50.0%)	9 (81.8%)	8 (53.3%)	33	54.1%
Agree	5 (45.5%_	11 (45.8%)	2 (18.2%)	7 (46.7%)	25	41.0%
Uncertain	2 (18.1%)	1 (4.2%)	-	-	3	4.9%
Disagree	-	-	-	-	0	0.0%
Strongly Disagree	-	-	-	-	0	0.0%
No answer	-	-	-	-	0	0.0%
Total	11 (100%)	24 (100%)	11 (100%)	15 (100%)	61	100.0%
Q3.c. I learned some things in this program that I can use in science class at school.	**GiSWA 2013**	**GiSWA 2014**	**GiSLC 2104**	**GiSLC 2105**	**Totals Count and Percentage**	
Strongly agree	6 (54.5%)	14 (58.3%)	11 (100%)	10 (66.7%)	41	67.2%
Agree	3 (27.3%)	6 (25.0%)	-	3 (20.0%)	12	19.7%
Uncertain	1 (9.1%)	3 (12.5%)	-	2 (13.3%)	6	9.8%
Disagree	1 (9.1%)	1 (4.2%)	-	-	2	3.3%
Strongly Disagree	-	-	-	-	0	0.0%
No answer	-	-	-	-	0	0.0%
Total	11 (100%)	24 (100%)	11 (100%)	15 (100%)	61	100.0%

Q 3.d. Because of this program, I think I am more aware of the importance of science in everyday living	GiSWA 2013	GiSWA 2014	GiSLC 2104	GiSLC 2105	Totals Count and Percentage	
Strongly agree	6 (54.5%)	8 (33.3%)	10 (90.9%)	8 (53.3%)	32	52.5%
Agree	5 (45.5%)	14 (58.3%)		6 (40.0%)	25	41.0%
Uncertain		1 (4.2%)	1 (9.1%)	1 (6.7%)	3	4.9%
Disagree		-		-	0	0.0%
Strongly Disagree		-		-	0	0.0%
No answer		1 (4.2%)		-	1	1.6%
Total	11 (100%)	24 (100%)	11 (100%)	15 (100%)	61	100.0%

Question 4 (Table 5) asked the participants about their interest in taking more science classes in the future. We see that 66 – 75% of the GiSWA participants and 80 – 100% of the GiSLC participants indicated they are interested in future courses in science. A response rate of 13% - 33% indicated that their thoughts have not changed towards taking science classes in the future. Responses to this question however could be interpreted as students who were more inclined to already pursue STEM did not change their minds or some students may have been dissuaded in pursuing STEM due to the interventions.

Table 5. Girls' interest in science classes in the future

Q4. Has this program encouraged you to think about taking more science classes in the future	GiSWA 2013	GiSWA 2014	GiSLC 2104	GiSLC 2105	Totals Count and Percentage	
yes, I am thinking about taking more science classes in the future	7 (66.7%)	18 (75%)	11 (100%)	12 (80%)	48	78.7%
My thoughts about taking science classes in the future have not changed	4 (33.3%)	6 (25%)	-	2 (13.3%)	12	19.7%
No answer	-	-	-	1	1	1.6%
Total	11 (100%)	81.10%	11 (100%)	15 (100%)	61	100.0%

For question 5, 87% of the girls indicated they shared what they learned during the GiSLC and GiSWA with their family and friends. For question 6, the majority of the students 85% indicated they were more excited about science and 15% students were uncertain.

Table 6. Girls' interest in science classes in the future

Q5. I tell my family and friends about the things we do in this program.	GiSWA 2013	GiSWA 2014	GiSLC 2105	GiSLC 2105	Totals Count and Percentage	
Strongly agree	5 (45.5%_	15 (62.5%)	8 (72.7%)	12 (80.0%)	40	65.6%
Agree	6 (54.5%)	9 (37.5)	2 (18.2%)	3 (20.0%)	20	32.8%
Uncertain	-	-	1 (9.1%)	-	1	1.6%
Disagree	-	-	0	-	0	0.0%
Strongly Disagree	-	-	0	-	0	0.0%
Total	11 (100%)	24 (100.0%)	11 (100%)	15 (100.0%)	61	100.0%
Q6. Because of this program, I am more excited about science	**GiSWA 2013**	**GiSWA 2014**	**GiSLC 2105**	**GiSLC 2105**	**Totals Count and Percentage**	
Strongly agree	4 (35.4%)	11 (45.8%)	7 (63.6%)	9 (60.0%)	31	50.8%
Agree	4 (36.3%)	9 (37.5%)	3 (27.3%)	5 (33.3%)	21	34.4%
Uncertain	3 (27.3%)	4 (16.7%)	1 (9.1%)	1 (6.7%)	9	14.8%
No Response		-	0	-	0	0.0%
Total		100.00%	11 (100%)	100.00%	61	100.0%

Conclusion

The participants indicated that prior to the program, 25% were very interested, 38.1%, interested, 27.4%somewhat interested, 8.3% a little interested, 1.2% not interested at all. The GiSLC and GiSWA programs appear to have positively impacted the students. By the conclusion of the programs, between 70 – 96% of the girls either strongly agreed or agreed that the programs increased their understanding, self-efficacy, and interest in science. A total of 84% of the participants indicated they would like to participate in additional STEM activities like GiSLC and GiSWA in the future. The student responses show that 82% were interested in learning science courses and 73% indicated they were interested in taking more science courses in the future. We are currently in the last year of funding and completing the activities for the 2015 GiSWA program activities. Overall, we hoped the GiSLC and GiSWA would positively impact the female participants, reach girls who were interested in science from Title 1 schools, and increase their interest in pursuing STEM. The use of the cases, provided a real world lens for everyday STEM and how science impacts society. In total, these programs were designed to counteract some of the negative pressure that may sway girls and minorities from STEM during middle school and high school. By promoting confidence, increasing parent involvement, and inspiring interest in STEM through informal STEM experiences during the 7th and 8th grade we may impact the science and math courses that the students choose in high school and college, and ideally their career choice in the future.

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