Learning Experiences and Self-efficacy of Minority Middle-School Girls during a "Bio-char Modified Cement Paste" Research Program at an HBCU

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In 2015, Dr. Ofori-Boadu established her STEAM ACTIVATED! program for middle-school girls. She also serves as the Executive Vice-President of Penuel Consult, Incorporated. She is married to Victor Ofori-Boadu and they are blessed with three wonderful children.

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ABSTRACT: Informal learning is effective in improving learning and self-efficacy through rich alternative learning environments. The underrepresentation of minority women in engineering and technology careers necessitates that historically black colleges and universities (HBCUs) engage minority middle-school girls in effective learning experiences to increase their self-efficacy and persistence. However, little is known about the learning experiences of minority middle-school girls during alternative learning programs at HBCUs. Following Bandura's self-efficacy theories and funded by the Engineering Information Foundation, a one-week science, technology, engineering, arts, and mathematics (STEAM) research experience program engaged minority middle-school girls in bio-char modified cement paste research experiences at an HBCU. Using a post-test and a self-reporting survey with open-ended questions, the purpose of this qualitative research was to gain insights into the learning experiences, self-efficacy, and persistence of the 22 girls engaged in this STEAM program. Basic thematic data analysis involved coding, categorization, comparative analysis, and descriptive statistics.

Results indicated that the girls increased in knowledge, self-efficacy, and persistence. The mean post-test score was 78%. The content of STEAM presentations demonstrated that the girls learned mostly from laboratory experiences and field trips. Self-efficacy improvements were attributed to mastery experiences and positive emotional states as the maximum percentage of girls who used words related to the four Bandura self-efficacy categories were: mastery experiences (86%); emotional states (62%); vicarious experiences (59%); and verbal persuasion (36%). The broader 18 emergent themes of girls' learning experiences included knowledge, doing, national priorities, fun, emotions, sustainability, civic responsibility, mentors, arts, soft skills, minority, and persistence. Most girls had positive learning experiences, with some transitioning from 'difficult' to 'easy' as they gained mastery experiences. A few girls expressed difficulty and discomfort with mathematics, measurements, equipment usage, and outdoor environments. The integration of arts improved learning, vicarious experiences, and emotional states. Pizza, donut, and similar decorated frisbees showed girls' close association with food preparation which is a typically female function in family settings. The girls used skits, sketches, and a rap song during STEAM presentations. Notably, young African Americans embrace rap songs, and the girls brilliantly integrated this culturally inspired art in their presentation. Eighty-six percent (86%) of the girls committed to 'Advance in STEAM' and 'Broaden Minority Participation' actions to strengthen their persistence. One girl noted that she wanted to make herself known so that people will know that she is both a minority and a woman, which makes her able to do anything that she puts her mind to. The girls emphasized their need for more STEAM programs, summer camps, mentors, engineering courses, internships, engineering games, hard work, and women engineer networks to strengthen their persistence. Due to personal reasons attributed to learning difficulties and other preferred career interests, 14% of the girls were hesitant about engineering and technology careers.

This research experience program improved the knowledge, self-efficacy and persistence of minority middle-school girls. It can be replicated successfully at other institutions, particularly at HBCUs. In the long term, effective research experiences in alternative learning environments can increase minority middle-school girls' self-efficacy, persistence and improve minority women representation in male-dominant engineering and technology careers.

INTRODUCTION

Women participation in STEM disciplines is still very low as women are not persisting in engineering and technology programs due to stereotype threats, weak professional identities, and poor sense of belonging [1]. While extreme gender gaps in STEM fields such as biology no longer exist, women are still underrepresented in engineering and technology fields as a result of biases and stereotypes associated with disciplinary differences [2][3]. Women make up only 9% of the construction workforce, with professional women being only 2.8% [4]. Minority women are severely underrepresented in engineering and technology fields, with only 1% earning bachelor degrees in engineering [1][5]. Considering that only 5% of the science and engineering workforce are blacks compared to 12% of U.S. workforce, women of color have even lower levels of representation [6]. White construction workers are 16.2 times more than African Americans [7]. Stereotypes, biases, chilly campus culture, classroom experiences, unsteady identities, and wavering sense of belonging are barriers to the successful degree completion and career entry of women [8]. Women underrepresentation in engineering and technology disciplines results from low levels of self-efficacy, which is further complicated by being a racial minority. The intersections among racial, ethnic, gender, religion, social, professional, and cultural identities impact the persistence of minority women into engineering and technology programs [1]. Women from minority racial and ethnic groups have limited access to STEM resources and experiences that could otherwise have enhanced persistence into male-dominated careers. STEM disciplines are stereotyped as male domains, with most of the society viewing males as better in STEM. Even, important gatekeepers such as teachers and parents stereotype STEM as male domains, with one study finding that on the average, fathers estimated their sons' mathematical IQ at 110 and their daughters' at 98 [9]. Although persistent, these stereotypes about female inferiority in STEM are inaccurate and not supported by current scientific data on actual female performance [10]. Unfortunately, cognitive social learning theories and related research show that although untrue, prevailing parent and teacher stereotypes about gender tend to influence the performance, personal decision-making, and self-efficacy of girls [10].

STEM self-efficacy in middle-school girls

Self-efficacy is having a 'can-do' attitude, and the cognition of possibility for solving a problem. It involves having the belief of ability, not the possession of actual ability [11]. It has an impact on an individual's selection of activities and environments [12]. Consequently, Bandura emphasized that it influenced a person's coping behavior, effort expended, and length of sustaining obstacles and averse experiences [13]. Persons with low self-efficacy harbor pessimistic thoughts about their development and accomplishments, and this affects their decision-making and impedes their motivation and academic achievement [13]. STEM inferiority has a negative impact on the self-efficacy, persistence, and progression of girls into STEM careers. Girls have reached parity with boys in STEM performance, and so, it is important that stereotypes about female inferiority held by teachers, parents, and girls themselves, are counteracted [10]. Research shows that middle school is a critical time in human development, and the STEM self-efficacy of girls begins to decline at this educational stage [14][15]. As such, middle school is a crucial intervention point to encourage girls to pursue STEM. Middle-school girls who have STEM interests should have access to learning opportunities to support persistence into STEM careers. Strategies to counteract women inferiority complexes in middle-

school girls are crucial to improve self-efficacy, since middle-school girls already have lower levels of self-efficacy [11]. Interventions that model Bandura's four sources of self-efficacy (mastery experiences, vicarious experience, verbal persuasion, and emotional states) are likely to improve self-efficacy [11][12][16]. Mastery experiences are associated with peoples' skills and effort and provides an internal feeling that successes can be repeated [12][16]. Vicarious experiences involve people observing and modeling others, relating their capabilities with others, and getting a sense that they can also be successful [12][16]. Verbal persuasion occurs when people receive encouraging words that assures them of success [12][16]. Emotional states involve physiological arousal and moods that influences performance and feelings of success [12][16]. Middle-school girls with high self-efficacy are more motivated to set higher goals, perform more challenging tasks, invest more effort, persist longer, recover more quickly from setbacks, and create new environments [13]. Considering the STEM persistence challenges associated with racial minority groups, well-designed and culturally friendly interventions and learning environments could increase the sense of belonging and self-efficacy of minority middle-school girls, and improve their persistence into engineering and technology careers.

Universities, particularly HBCUs, have the resources and culturally friendly environments to contribute to the nationwide effort to improve the persistence of minority middle-school girls into engineering and technology careers. Informal learning experiences and programs through HBCUs improved STEM interests, attitudes, identities, and self-efficacy of minority middle-school girls [16]. It is important that these programs continue to expand by drawing from evidence-based strategies that improve minority girls' self-efficacy, as self-efficacy correlates with persistence [17][18]. Improved girls' persistence is particularly critical for male dominated engineering and technology careers, and will provide solutions to the nationwide concerns about workforce shortages and lack of diversity in these careers. In the long term, this will contribute to more gender friendly 21st century engineering and technology innovations and developments [7]. However, research on the learning experiences and self-efficacy of minority middle-school girls during informal and alternative learning experiences at HBCUs is limited. Gender and engineering identity theorists emphasize that research that provides greater insights towards more gender equitable education for racial minorities will improve persistence [19][20][21].

Consequently, the purpose of this qualitative research was to gain insights into the learning experiences, self-efficacy, and persistence of the 22 minority middle-school girls who were engaged in a one-week 'bio-char modified cement pastes' research experience program at an HBCU. This program was part of a broader one-year science, technology, engineering, arts, and mathematics (STEAM) ACTIVATED! program funded through a 2018 Engineering Information Foundation (EiF) grant. The four research questions for this qualitative study are:

1. To what extent did research experiences contribute to the engineering and technology knowledge of minority middle school girls?
2. What were the salient learning experiences of minority middle-school girls?
3. How did the various research and learning activities impact the self-efficacy of minority middle-school girls?
4. Beyond this program, what actions will minority middle-school girls take to strengthen their own persistence into engineering and technology careers?

STEAM ACTIVATED! Research Program

In figure 1, the key STEAM ACTIVATED! activities implemented to improve the engineering and technology knowledge, self-efficacy, and persistence of minority middle-school girls are mapped to Bandura's four sources of self-efficacy [13][16]. The uniqueness of this program is its implementation at a highly ranked social mobility HBCU with an academic, social, and cultural climate that advances the social and economic mobility of college students. The instructors, coaches, tour guides, and engineering education seminar panelists were either female and/or from racial minority groups. This gave the girls the opportunity to interact with STEM professionals with similar minority characteristics. Also, the girls were allowed to integrate their preferred arts in their STEM projects and express their racial, cultural, arts, and STEAM identities through their STEAM presentations [16]. The key activities included:

Cement and Concrete Lecture: Using a Power Point presentation and class discussions, a lecture on cements, bio-char, cement pastes, concrete, sustainability, and the engineering design process provided the girls with the foundational knowledge needed to engage in this research experience. This two-hour session was very interactive as the girls asked important questions during the lecture. Lecture notes had been posted earlier in the HBCU's Blackboard Educational Suite.

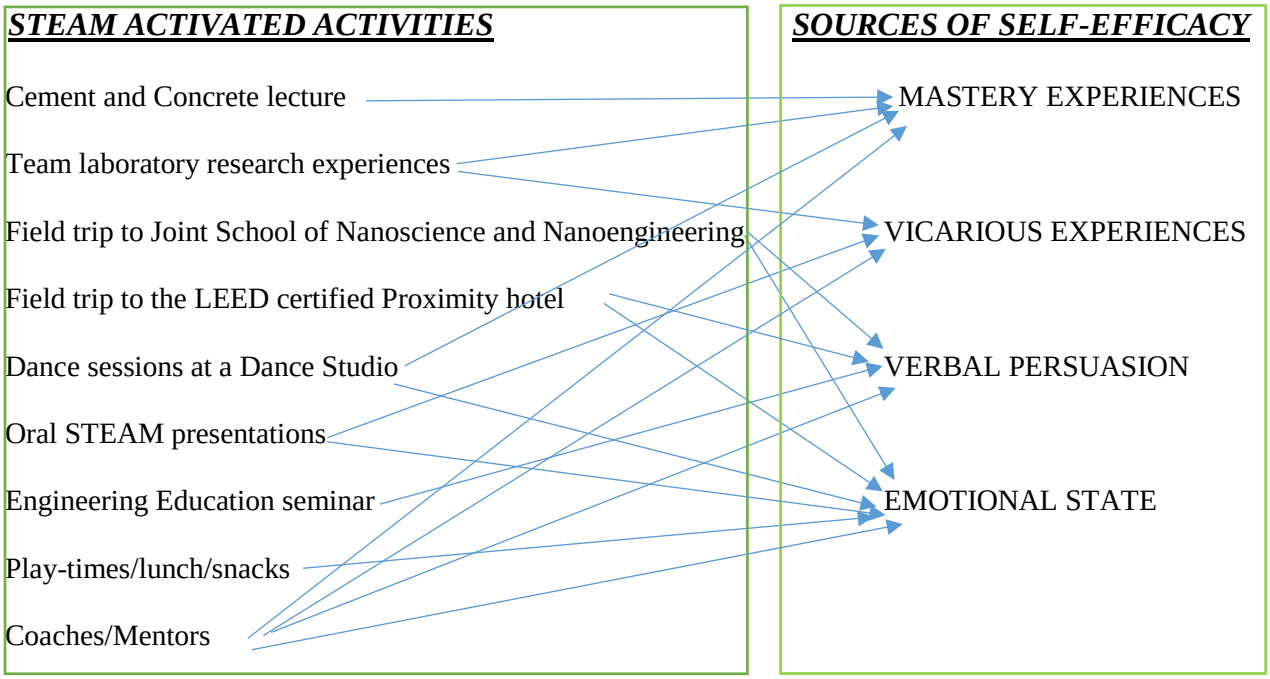

Figure 1. Mapping of STEAM ACTIVATED! activities to Bandura's sources of self-efficacy

Research Experiences in bio-char modified cement paste cubes: the girls were engaged in laboratory experiments requiring them to investigate the influence of bio-char on the strength and water absorption characteristics of cement paste (Figure 2). They were guided by three undergraduate student coaches/ mentors and one instructor, grouped into five teams, and provided detailed instructions for laboratory experiments. The girls learned how to document their research methods and findings. During the first three days, they calculated, measured, mixed, molded, cured, and monitored their samples. On the fourth and fifth days, they conducted the rebound

hammer and water absorption tests to determine the differences between their control and test samples. They also made and decorated control and test cement paste frisbees, which were weighed and thrown in a competition that occurred across an open outdoor space. Data collection and analysis involved throw distance measurement and a visual description of the state of the frisbee after it fell to the ground. Girls had to record and summarize the data in tables and charts for analysis and conclusions. Additional details on bio-char modified cement pastes are published in peer-reviewed journals [23-25].



Figure. 2a) Mixing cement pastes; 2b) cement paste in molds; 2c) decorated cement paste frisbee

Field Trip to Platinum certified Leadership in Energy and Environmental Design (LEED) Proximity Hotel: Girls were exposed to sustainable materials and technologies in this building.

Field Trip to Joint School of Nanoscience and Nanoengineering (JSNN): The girls were exposed to STEM research laboratories. They learned new terms. They also learned about the critical roles played by STEM researchers in developing novel innovations to solve nationwide problems.

Engineering Education Seminar: A panel of three engineering and technology women professionals and one undergraduate engineering student shared their personal and professional experiences to strengthen the self-efficacy and persistence of the girls.

METHOD

A self-reporting survey with 13 open-ended questions was administered to capture girls' salient learning experiences during the following activities: (1) Lecture; (2) Mixing of cement pastes; (3) Mixing cement pastes with bio-char; (4) Measuring cubes and frisbees; (5) Rebound hammer test; (6) Frisbee throwing tests; (7) Water absorption tests; (8) Proximity hotel field trip; (9) JSNN field trip; (10) Engineering Education seminar; and (11) Oral STEAM presentations. The last two questions required girls to describe actions that they would take to persist towards engineering and technology careers. Basic thematic analysis involved coding, categorization, comparative and statistical analysis. A post-test estimated girls' knowledge after this experience.

RESULTS AND DISCUSSIONS

All 22 girls were from racial and ethnical minority groups enrolled in neighboring middle-schools. Majority of them were 7th graders.

Research Question 1: To what extent did research experiences contribute to the engineering and technology knowledge of minority middle school girls?

The girls gained knowledge about cement and concrete materials as the mean post-test score was 78%. The first seven multiple-choice questions of the 10-item test were on the components of cement and concrete, as well as the cement hydration process. The average score for these seven questions was 81%, with girls excelling most at the questions closely related to the components of cement and concrete. These components were introduced during the lecture and reinforced during the hands on laboratory experiments. The last three questions were open-ended questions and required the girls to list 10 key steps in the water absorption test, the meaning of bio-modified cement, and the eight key steps in the engineering design process. The mean score for these items was 70%, with girls mostly able to answer the eighth and ninth questions, which were directly related to the laboratory experience. Many girls struggled with the last question on the typical engineering design process as they listed less than half of the steps. This was because they were absent or had not understood fully when the process was taught. Furthermore, this process was introduced during the lecture, but not actively reinforced during the laboratory experiments. Reinforcement of this process during the hands on laboratory experiences would have helped the girls retain their knowledge of the engineering design process.

Research Question 2: What are the salient learning experiences of minority middle-school girls?

Lecture: Three themes emerged from data analysis.

Knowledge Gained: Eighty-six percent (86%) of the girls indicated that they had gained new knowledge and understanding of cement and concrete production. They listed new vocabulary related to materials, chemical compounds and processes associated with cement hydration and concrete production. One girl noted differences between the composition of cement and concrete and stated that '…it was amazing. I learned the difference between cement and concrete…' Another girl focused on the negative environmental impact of cement production. She stated that '…making concrete (cement) uses a lot of energy and releases a lot of carbon dioxide...', while a third girl listed dicalcium silicates and tricalcium silicates as components of cement.
Emotions: Fifty-four percent (54.55%) of the girls made statements on the state of their emotions during the lecture. They used terms such as like, great, fun, amazing, bored, and interesting. Fifty percent (50%) of the girls noted positive emotional states, while 4.55% noted negative states. A girl stated that '…my experience was great and fun. I learned something I did not know about…' Notably, the negative 'bored' statement still involved an acknowledgement that new knowledge had been gained. The girl stated that '…it was an experience that I kind of felt bored out during it, but I learned from it.' Regardless of their emotions, the girls did learn from the lecture session.
Instructional Process: Eighteen percent (18%) of the girls made statements regarding the instructional process. One girl appreciated the neat and detailed power point lecture notes, while another girl wished that hand outs had been given out. This would have been beneficial as the girls could write notes for further reflection. It would have been a great addition to the lecture notes that the girls already had online access through the HBCU's Blackboard Education Suite.

Mixing of Cement Pastes: Four themes emerged from data analysis.

Doing: Sixty-two percent (62%) of the girls made 'doing' statements to include calculating, measuring, timing, mixing, and ramming. One girl noted that '…mixing and ramming the cement paste was really fun, and exciting but also pretty messy at the same time…'
Comprehending: Fifty-two percent (52%) of the girls made statements associated with learning and understanding from the hands on laboratory activities. One of the girls noted that '…I got to learn how to mix and make cement paste using my own measurements and percentages, which was really fun…' During experiments, the girls asked questions and demonstrated high levels of intellectual curiosity. Their questions were answered by the instructor, coaches, and peers.
Fun: Girls expressed fun, excitement and enjoyment during this activity, as reflected by positive statements from 48% of them. The hands on aspects of the laboratory experiments was fun because the girls handled samples during the learning process. Many girls had a sense of control over these experiments and loved taking the lead, making decisions, and working as teams towards success.
Sensing: Nineteen percent (19%) of the girls made statements related to two of their five senses, seeing and touching. This is because they saw and touched cement, bio-char, and water prior to and after mixing. A girl stated that '… we all had a close up chance to see how it reacts …' Furthermore, they had to scrape the pastes from the mixer and place them into the molds for curing. Considering that the girls worked in teams, they had to split up the various steps involved in the mixing process. Consequently, while the girls scraping cement paste into the molds touched and felt the pastes, the girls with the timers did not have the opportunity to touch the pastes.

Mixing Cement Pastes with Bio-char: The addition of bio-char to cement pastes generated some mixed reactions from the girls. Due to differences in the properties of cement and bio-char and the fact that the girls had first worked with control cement pastes, they were most concerned about the differences between the test and control pastes. Three themes emerged during analysis.

Observing Differences: Seventy-six percent (76%) of the girls used words such as color, texture, and flow to describe observed differences. This was an important learning experience as the objective of this activity was to assess the effect of bio-char on cement pastes. One girl noted that '…the first thing I noticed was the color change in the mix. It was darker and more like a cake crumbling…' Another girl noted that '…this was a nice experience because you got a new feel and got to contrast the two cement pastes…'
Emotions: Thirty-three percent (33%) of the girls expressed both positive and negative emotions towards bio-char. One girl stated that '…I did not like bio-char, because it did not come out like cement (control paste)...' It appeared they had a direct dislike for the material, because they believed that it had a negative impact on the control pastes. Another girl stated that she liked to work with bio-char modified cement pastes because it was not as watery as cement pastes. These girls expressed different perspectives and feelings over the same process.
Difficulty: Ten percent (10%) of the girls commented on the ease or difficulty of the mixing process. While one girl noted that it was easier to work with bio-char cement pastes because it was chunkier, another girl noted that it was a little harder but she liked the challenge. These mixed expressions were very subjective, and showed that the girls had contrasting feelings based on their personal perceptions and perhaps, processing differences.

Measuring cubes and frisbees (Calculation of volumes and surface areas): The girls expressed mixed feelings about the experiences associated with measuring the cubes and frisbees, as well as calculating surface areas and volumes. Three themes emerged during analysis.

Fun: Majority (52%) of the girls enjoyed measurements and calculations. After taking and recording their measurements, they utilized given formulas and calculators and then recorded their answers. One girl noted that '…fun, because I like doing this type of math …'
Difficult: Some girls expressed difficulty with measurements (33%) and math (29%). One girl noted that she loved math, but this math was hard. Since the girls were in teams with coaches, they had resources to fall on during times of difficulty. However, a few girls were sometimes shy and did not want to expose their difficulties. They felt even more reluctant to express their difficulty when the girls around them appeared to be having fun and excelling at their tasks.
Anxious: Thirty-four percent (34%) of the girls expressed various levels of anxiety regarding the outcome of their experiments. Some had concerns about how their teams would perform, particularly since there were some friendly competitions in progress. While competitions stirred up some girls to perform better, it caused stress in some other girls.

Rebound hammer test: Two themes emerged from data analysis.

Equipment Usage: Sixty-two (62%) of the girls stated that the equipment was easy to use. One of the girls stated that '…it was fun because I learned how to read the device. It was also fun because I liked using the hammer …' Nineteen percent (19%) of the girls faced some challenges with equipment usage and used words such as unfamiliar, new, difficult, and gets easier with practice. A girl stated that '…it was fun trying to use the hammer and not knowing how to use it at first, but then learning how to use it…' This statement demonstrated how girls transitioned from concerns with difficulty in using equipment to satisfaction with ease of using equipment.
Emotions: Nineteen percent (19%) of the girls were emotional about their own test results. They were unhappy that their cubes got damaged as it showed weaknesses in their cubes. A girl blamed herself stating '…it was fun, but it would have been better if I had not broken the cubes …'

Frisbee Throw Tests: Two themes emerged from data analysis.

Reporting results: In sharing their experiences, 48% of the girls focused on reporting the facts (What is this?), while another 48% focused on interpretations (What does this mean?). With reporting facts, one girl noted the differences in throw distance while another stated that her frisbee travelled 51'- 6". On the other hand, with the girls who focused on interpretation, one girl stated that '…the frisbee throwing test showed me that different throws, sizes, and ingredients affected how far the frisbee would go …' and another girl stated that '…my frisbee was broken up into so many pieces so it was a bad frisbee, I needed more water…'
Fun: Pizza, donut, and similar decorated frisbees showed girls' close association with food preparation which is a typically female function in family settings. Forty-eight (48%) of the girls had fun throwing frisbees outdoors and described their learning experience as fun, exciting, competitive, and hands on. They enjoyed the challenge of throwing their frisbees in an effort to have their frisbee go further than their competitors' frisbees. Some girls even expressed fun when their frisbees broke and were not so worried about it. Ten percent (10%) of the girls did not

appreciate the outdoor environment and expressed discomfort, tiredness, and a desire to go back indoors. One girl stated that it (frisbee throwing) was more tiring than fun.

Water absorption tests: Three themes emerged from data analysis.

Reporting results: Fifty percent (50%) of the girls made statements regarding their results and interpretation of results.
Emotions: Sixty-two percent (62%) expressed positive (43%) or negative (19%) feelings during data collection. This was because this test required the girls to take frequent measurements at specified time intervals. One girl noted that it was stressful because she had to get it right.
Doing: Thirty-two percent (32%) made statements regarding the actions taken during the test to include measuring and recording results.

Proximity hotel field trip: Two themes emerged from data analysis.

Sustainability knowledge: Seventy-three (73%) of the girls highlighted sustainability knowledge gained from the tour guide. They discussed sustainable materials such as fly ash and processes that improved energy efficiency. The LEED certification program was of interest to some girls.
Decoration: Forty percent (40%) of the girls commented on the hotel decoration using words like nice, liked, and cool to appreciate colors, textures, shapes, beauty, aesthetics, and luxury.

JSNN field trip: Four themes emerged from data analysis.

Knowledge: Majority (77%) of the girls focused on the knowledge gained from the JSNN field trip. Thirty-six percent (36%) stated that had learnt about the new term 'nano'. One girl noted she would like to take classes at JSNN in the future. The girls also learnt about how scientists and engineers use laboratories and equipment to research novel innovations to solve national issues. Specifically, the girls related to the tour guide's description of medical research related to cancer cures and improving brain functions with classical music.
Emotion: Thirty-two percent (32%) highlighted their emotional state during the trip, with some stating that the trip was fun and cool…while a few thought the field trip was boring.
Tour guide: Fourteen percent (14%) made comments about the tour guide, with many stating that he made the trip interesting.
Career directions: Nine percent (9%) of the girls made comments regarding the impact of this trip on their career directions. They expressed the desire to be engaged in similar research activities as future STEM professionals.

Engineering Education seminar: Four themes emerged from data analysis.

Panelists' experiences: Thirty-six percent (36%) of the girls learnt from the panelists' professional and personal experiences, particularly how they overcame challenges in male dominated careers.
Roles: Thirty-six (36%) of the girls made statements regarding learning about engineering roles.
Career directions: Twenty-three (23%) of the girls were inspired and seriously considered how the knowledge gained could be transitioned into their future careers.

Panelists' responses: Nine (9%) of the girls made comments regarding the excellent responses that they had received from the panelists when they asked pertinent questions.

Oral STEAM presentations: During the oral STEAM presentations, five teams of girls were encouraged to use their team-preferred arts to present knowledge gained during the program. They had the option to report on any learning activities that they preferred. A key assumption was that the girls would report on the activities that had the most positive influence on their knowledge, interest, self-efficacy, and persistence. Sixty percent (60%) of the teams focused on the laboratory experiments, with two groups providing step-to-step descriptions of the laboratory experiments through skits. Forty percent (40%) utilized skits and sketches to describe sustainable materials and practices learnt during the Proximity Hotel field trip. One group used a rap song to summarize key activities to include experiments and field trips. Rap songs, are typically associated with African American youth culture and the girls created a brilliant demonstration of how African American cultural arts can be integrated into STEM project presentations. Their use of art in explaining what they had learned allowed them to recollect the knowledge that they had gained during the program, agree on the teams' preferred arts, and present their knowledge gained using the preferred arts. Fifty-nine percent (59%) of the girls made statements about use or development of soft skills such as teamwork and creativity. During their presentation practice sessions, there was a lot of peer teaching and coaching. The teams were great at negotiating team options and agreeing on a team approach to this interesting and exciting arts-infused presentation. Notably, 46% of the girls indicated that they had fun working and presenting with their teammates.

Research Question 3. How did the various research and learning activities impact the self-efficacy of minority middle-school girls?

The research and learning activities in this STEAM ACTIVATED! program had an impact on the self-efficacy of the girls as demonstrated by the relationships existing between their self-reported learning experiences and the four Bandura sources of self-efficacy as described below:

Mastery experiences: Mastery experiences refer to task experiences that result in learning to perform a task effectively [26]. Successful results increase self-efficacy as girls gained confidence that they are able to complete a task successfully. Survey analysis showed that 100% of the STEAM ACTIVATED! activities contributed to mastery experiences and girls had gained knowledge, understanding, hard skills and soft skills. The top eight activities with over 50% of the girls using mastery experiences related terms to describe their learning experiences were: lecture (86%); JSNN field trip (77%); mixing cement pastes and bio-char (76%); Proximity Hotel field trip (73%); mixing cement pastes (62%); rebound hammer tests (62%); oral STEAM experiences (60%); and water absorption tests (50%). The successful outcomes from their research experiences boosted their self-efficacy as they were confident that they had developed specific knowledge and skills that would be successfully applied to their future engineering and technology careers. Notably, a few girls had challenges with mathematics, measurement, and equipment usage, and these mastery experiences challenges had negative impacts on their self-efficacy.

Vicarious experiences: These experiences primarily involve learning to perform tasks through the observation of others, and are influential in developing self-efficacy [26]. Survey analysis

showed the percentage of girls that utilized vicarious experiences related terms to describe their learning experiences in three activities were: Oral STEAM presentations (59%); Engineering Education Seminar (23%); and JSNN field trip (9%). Unlike mastery experiences, only the oral STEAM presentation activity had over 50% of the girls using vicarious experience related words that reflected peer teaching, mentoring, encouragement, task assignments, and soft skills. Some girls emerged as the leaders and role models in their teams. The oral STEAM presentations gave the girls the opportunity to work together in transforming the knowledge and understanding that they had gained into their teams' preferred arts presentations that were jointly delivered to the audience by all team members. The girls worked very hard together and were very mature in deciding which activities to include in their presentations and the best arts for their team presentation. Competition drove girls to work together to attain team goals in order to be competitive. Furthermore, teams learnt from other teams and shared ideas to make the learning process more effective. Vicarious experiences also occurred when the girls observed Engineering Education seminar panelists with minority backgrounds and successful careers. Notably, these girls were even motivated by the research achievements of JSNN researchers, even though, they never met them personally. Vicarious experiences were also observed during field trips when the girls mostly walked in pairs and discussed their experiences and knowledge gained during the field trip. Limited negative vicarious experiences were observed when a few girls were uncomfortable with the competitions and others were too embarrassed to share their task-related challenges because other girls were easily successful with the same tasks. These experiences negatively impacted the self-efficacy; and, it appears that the loss of task-related self-efficacy began to extend to the perception of a broader inability to be successful in engineering and technology careers. Early intervention on a one-on-one basis is needed to strengthen the persistence of girls with similar tendencies.

Verbal Persuasion: verbal persuasion involves feedback, judgment, and support received from influential others [26]. Survey analysis showed the percentage of girls that utilized verbal persuasion related terms to describe their learning experiences in two activities were: Engineering Education seminar (36%) and JSNN field trip (14%). Unlike mastery and vicarious experiences, no activities had over 50% of the girls using verbal persuasion related words. Positive feedback from the education seminar panelists and the field trip tour guides allowed girls to seriously consider the possibility of being successful in engineering and technology roles to contribute to novel innovations that solve national problems. Positive verbal persuasion was effective in improving girls' confidence, particularly considering their minority status in male-dominated engineering and technology careers.

Emotional states: Positive emotional feelings of being successful in a positive learning environment eliminates stress, fear, and anxiety; and therefore, increases self-efficacy [26]. Data analysis showed that 100% of the STEAM ACTIVATED! activities contributed to positive emotional experiences. However, the three activities that had over 50% of the girls using emotional state related terms to describe their learning experiences in their survey responses were: lecture (54%); measuring cubes and frisbees (52%); and water absorption tests (62%). Positive emotions during pizza, donut, and similar decorated frisbees showed girls' close association and comfort with food preparation, which is a typically female function in many family settings. Nevertheless, a few girls were uncomfortable with throwing frisbees in the outdoor environment, anxious about their research outcomes and competition, and had difficulty

in mathematics, measurement, and equipment usage. Their fears, anxiety, and concerns induced negative emotional states and reduced their interests and self-efficacy as it stirred up doubts about their own ability to excel in engineering and technology careers and environments.

Self-efficacy improvements were mostly attributed to mastery experiences and positive emotional states as the maximum percentage of girls who used words assigned to the four Bandura self-efficacy categories were: mastery experiences (86%); emotional states (62%); vicarious experiences (59%); and verbal persuasion (36%). Emerging themes from the most frequent words that the girls used to describe their own learning experiences are: (1) **Knowledge** – vocabulary, math, materials, chemical compounds, processes, sustainable materials, laboratory processes, nano; (2) **Understanding** – comprehending, effect, differences, applications; (3) **Doing** – Measuring, mixing, calculating, weighing, observing differences; (4) **Using equipment** – easy, difficult, transitioning from difficult to easy; (5) **National priorities** – medical, sustainability, STEM, environment, women underrepresentation in STEM; (6) **Sensing** – seeing, touching; (7) **Fun** – enjoyable, like, interesting, cool, fun; (8) **Emotions** – happy, pleased, feelings, stressed, bored, anxious, confused; (9) **Aesthetics** – nice, like, love, breathtaking, beauty, luxury; (10) **Sustainability** – LEED, energy efficiency, recycled materials; (11) **Level of difficulty** – easy, hard, difficult, challenging; (12) **Reporting** – reporting facts as is, attempting to interpret results; (13) **Civic responsibility** – help others, environment, solve problems; (14) **Mentors** – peer mentors, career mentors; (15) **Arts** – Skits, rap, dance, drawings: (16) **Soft skills** – teamwork, creativity, communication, intellectual curiosity, critical thinking, self-efficacy; (17 **Process** – instructional, touring, experimenting, presenting; (18) **Minority** – hard work, support, respect, recognition, mentors, outcomes, network; and (19) **Persistence** – Steam/engineering, minority, civic responsibility. In summary of her overall learning experience, one girl highlighted the following: (1) understanding the effect of bio-char content and frisbee size on throw distance; (2) having fun in crushing cement paste cubes; (3) having the desire to contribute to national issues; and; (4) letting people to know that as a minority and a woman – she can do anything!

Research Question 4. Beyond this program, what actions will minority middle-school girls take to strengthen their own persistence into engineering and technology careers?

While 86% of the girls expressed a desire to persist into engineering and technology careers, 14% were not as interested due to personal reasons such as weak math skills and other career interests. Two thematic action categories were used to summarize the actions that girls will take to strengthen their own persistence towards engineering and technology careers. Notably, these two themes highlighted ideas and actions that were inspired in the minority middle-school girls through their engagement STEAM ACTIVATED! activities:

Advance in STEAM actions: The girls committed to actions to increase their STEM knowledge in order to strengthen their engineering and technology persistence. Most of the ideas listed in figure 3 were generated from girls' experiences in STEAM ACTIVATED! lectures, research experiences, field trips, and oral presentations.

Broaden minority participation actions: The girls committed to actions to increase women and minority participation in engineering and technology disciplines. Most of the ideas listed in

figure 3 were inspired by the Engineering Education seminar panelists, instructors, and coaches/mentors.

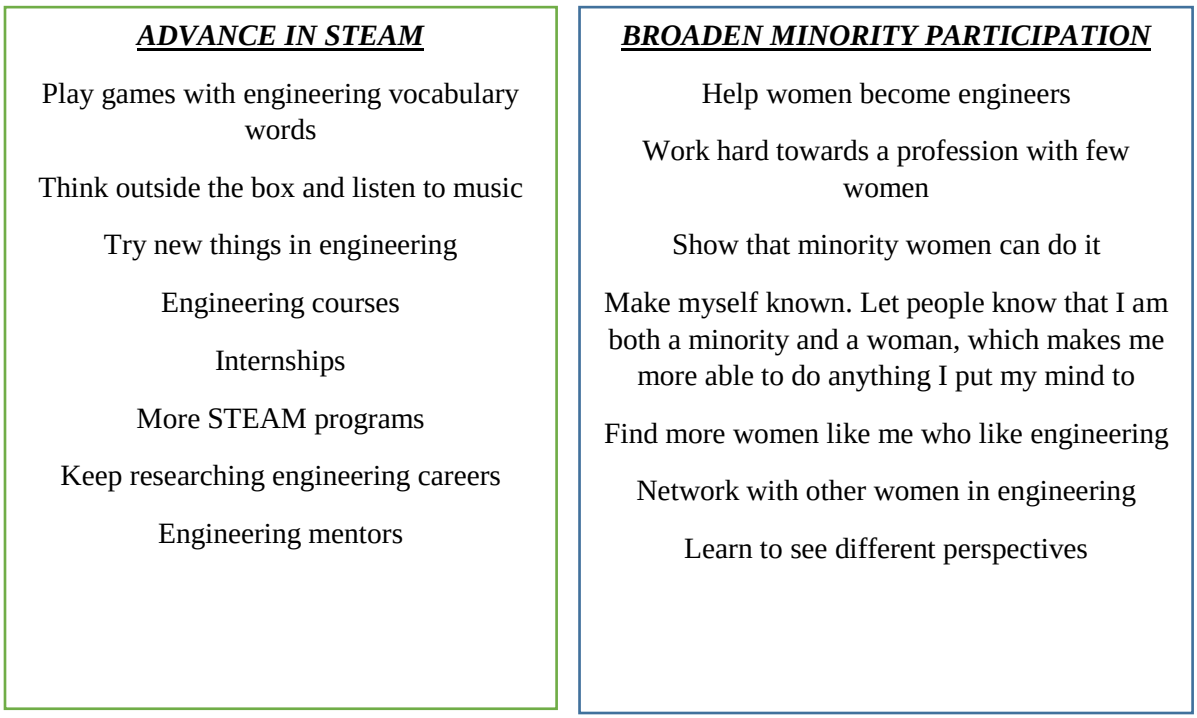

Figure 3. Actions to support engineering and technology persistence

Conclusion

Overall, this STEAM ACTIVATED! model was successful in increasing the engineering and technology knowledge, self-efficacy and persistence of minority middle-school girls, as the girls demonstrated that they had the capacity to learn and willingness to work hard to persist into engineering and technology careers and contribute to the solution of national issues. Overall, an analysis of the comments from the girls indicated that mastery experiences and positive emotional states were the most influential sources on girls' self-efficacy in this program. Early STEM education interventions that replicate this model at other universities, particularly HBCUs, could contribute to middle-school girls' self-efficacy and persistence into engineering and technology careers. In the long-term, this would improve women representation in the male-dominated engineering and technology careers.

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