Improving Middle-School Girls' Knowledge, Self-Efficacy, and Interests in 'Sustainable Construction Engineering' through a STEAM ACTIVATED! program

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Universities provide informal educational opportunities to cultivate girls' STEM interests and identities in an effort to increase female representation in STEM careers. Incorporating ARTs into STEM, the STE***A***M ACTIVATED! program was implemented to increase the 'Sustainable Construction Engineering' knowledge, interests, and self-efficacy of 31 middle-school girls. Self-efficacy is having a 'can-do' attitude that increases coping behavior, identity formation, and persistence. Following the Bandura model for improving self-efficacy, the 5-day program engaged girls in: (1) Mastery experiences through hands-on 'Construction Engineering' projects, dance, and field trip; (2) Vicarious experiences through teamwork, peer mentoring, competitions, and oral presentations; (3) Verbal persuasion through coaching, instruction, story-telling, and peer mentoring; and (4) Physiological states through reflections, I-CAN statements, power poses, and fine and performing art.

Data analysis of pre and post-tests, pre and post self-reporting 5-point Likert scale surveys, focus group sessions, and reflection sheets showed that this program had been effective. The 91% increase in Sustainable Construction Engineering knowledge, 7.41% increase in self-efficacy, and 7.35% increase in STEM attitudes were all statistically significant ($p<0.01$). The girls' strongest sources of self-efficacy were from observing peers (vicarious experiences), encouragement from parents (verbal persuasion), positive attitudes from fine and performing arts (physiological states), and continuous improvement and completion of projects (mastery experiences). While 16.13% of the girls provided no responses, most of the other girls demonstrated strong Arts identities with focus on: dance (32.26%), drawing (22.58%), singing (19.35%), music (6.45%), and baking (3.23%). The girls loved the opportunity to integrate their personal and group preferred arts into their STEM projects. At the end of the program, the girls were classified into four STEAM groups based on combinations of their STEM and Arts attitudes: 1) High STEM/High Arts attitude (83.87%); 2) High STEM/Low Arts (6.45%); 3) Low STEM/High Arts (6.45%); and Low STEM/Low Arts (3.23%). Overall, 90.32% of the girls expressed positive feelings towards the Arts-infused STEM projects; while 87% demonstrated some interest in dance-infused STEM learning. During their glue stick project oral presentation, one team developed a dance and used body movements to demonstrate tension, compression, shear, bending, and torsion. A strong overall mean rating ($\bar{x}$ = 4.20) was obtained for learning experiences at the Dance Studio as the girls strongly agreed that the dance movements increased their understanding of engineering concepts such as tension, bending, surface areas, center of gravity, three-dimension, and foundations.

The STEAM ACTIVATED! program increased the percentage of girls interested in engineering careers from 42% to 61.29%. Formation of engineering identities (EI) was estimated by combining girls' STEM attitude (SA) scores with engineering career interest (ECI) scores; and grouping girls into four EI groups. The following percent changes in the populations of the four EI groups before and after the program indicated positive program impacts on girls' EI: Group 1 – Strong SA and strong ECI (+19.35%); Group 2 – Strong SA and weak ECI (-9.68%); Group 3

– Weak SA and strong ECI (0%); Group 4 – Weak SA and Weak ECI (-9.68%). Forty-eight percent (48%) of these girls have already submitted applications for the follow up STEAM ACTIVATED! program funded through a recent Engineering Information Foundation grant. Best practices, lessons learned, and outcomes of this innovative and effective program for improving STEM self-efficacy, career interests, and engineering identities are discussed. Insights will be valuable to educators and researchers committed to increasing female representation in STEM careers.

Introduction

Science, Technology, Engineering, and Mathematics (STEM) disciplines are stereotyped as male domains, with most of the society viewing males as better in STEM, when compared to females. The society socializes male and female infants into masculine and feminine adults, and the roles that society ascribes to males are generally regarded as more desirable, effectual, and of a higher status [1]. 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 [2]. Although incredibly persistent, these stereotypes about female inferiority in STEM are inaccurate and not supported by current scientific data on actual female performance [3]. 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 children [3].

Literature Review

Self-efficacy may be described as having a 'can-do' or a 'dare-to-do' attitude. Self-efficacy is having the cognition of possibility for solving a problem; and involves having the belief of ability, not the possession of actual ability [4]. Self-efficacy has an impact on an individual's selection of activities and environments [5]. In fact, Bandura emphasized that self-efficacy influenced a person's coping behavior, effort expended, and the length of sustaining obstacles and averse experiences [6]. Consequently, persons with low self-efficacy harbor pessimistic thoughts about their personal development and accomplishments and this affects their decision-making and impedes their motivation and academic achievement [6]. Consequently, parent and teacher stereotypes of female inferiority in STEM disciplines has an extended negative impact on the choices, performance, and persistence of females in STEM. This should not be taken lightly as it has already significantly retarded female interest, engagement, and progress in STEM careers, as evidenced by large datasets on females in STEM.

Girls have reached parity with boys in mathematics performance, and as such, it is important that stereotypes about female inferiority held by teachers, parents, and the female students themselves are counteracted [3]. Particularly, strategies to counteract female inferiority complexes in middle-school girls are crucial and much needed to improve their self-efficacy. This is exceptionally critical, since females already have lower levels of self-efficacy, particularly in the middle-school years [5]. Middle-school girls with high self-efficacy will be more motivated to set higher goals, perform more challenging tasks, invest more effort, persist longer, recover more quickly from setbacks, maintain commitment to their goals, explore their environment and create new environments [6]. Educational policies and programs are needed to provide environments and resources that improve self-efficacy of middle-school girls. It is believed that improvements in girls' self-efficacy will increase their persistence into STEM disciplines in higher education, and eventually, into STEM careers.

It is in this context that the STEAM ACTIVATED! program was designed and implemented to improve the STEM knowledge, self-efficacy, attitudes, and interests of middle-school girls by broadening their participation in Sustainable Construction Engineering. The program drew foundational principles from socio-cognitive learning theories and was influenced by Bandura's self-efficacy model that focuses on the four sources of self-efficacy shown in figure 1: (1) Mastery experiences; (2) Vicarious experience; (3) Verbal persuasion; and (4) Physiological / Emotive State:

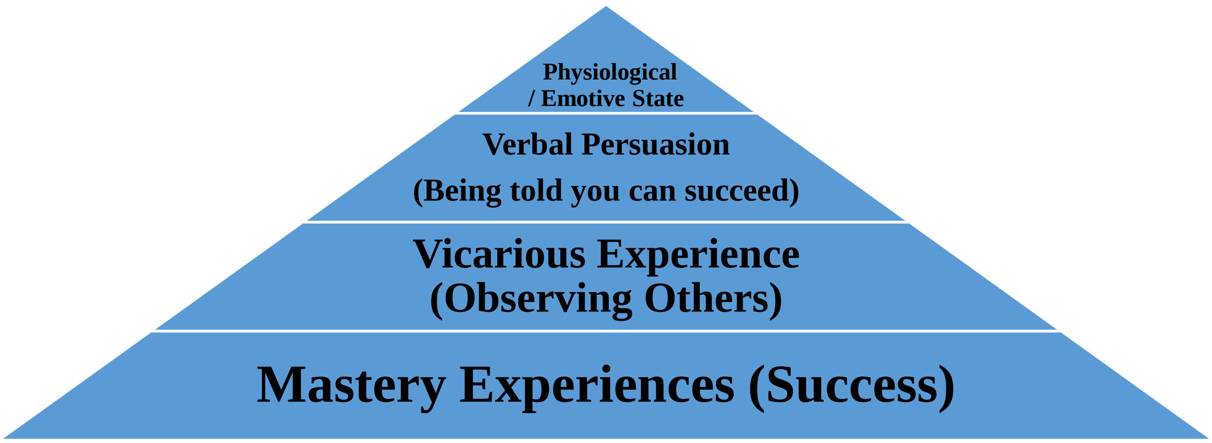

Figure 1. Four sources of Self-Efficacy

(1) Mastery experiences: Mastery experiences, also known as enactive mastery, enactive attainment, or performance attainment is the most effective source of self-efficacy [5][7]. This is because it is based on the direct and personal experience of people and is usually attributed to their own effort or skill [7]. It provides people with an internal feeling that their own personal success can be repeated; and, this improves their self-efficacy. Mastery experiences and personal accomplishments is enhanced when people actively learn by making things – especially things shared with others [8]. As such, proponents of social learning theories such as Seymour Papert emphasized that constructionism allows people to actively construct new knowledge from their experiences in the world, particularly when they are engaged in constructing personally-meaningful products [9]. The philosophy of constructionism draws its roots from constructivism theories developed by Jean Piaget and argues that people gain new knowledge and learn with particular effectiveness when they are engaged in making tangible objects in the real world [10]. Learning by doing is better than learning by being told and this approach is often applied to children's learning [8]. Strong mastery experiences correlated with self-efficacy [7]. In recent times, education researchers have also been exploring the concept of STEM + ARTs (STEAM) in teaching and learning. Numerous advocates encourage collaboration between STEM and ARTs in the form of STE***A***M (Science, Technology, Engineering, **Arts**, and Mathematics). Collaborations between Environmental Engineering and Art Education confirmed the potential for relevant connections between materials, design, society, and the natural environment [11]. On an increasing basis, STEM plus Arts (STEAM) is gaining significant interest as some K–8

schools have begun to place emphasis on Arts in their curriculums [12]. Future research to identify the diverse contributions and mutual benefits of STEAM collaborations is encouraged [11].

(2) Vicarious experience: Vicarious experiences, also known as modeling, is believed to be the second most effective source of self-efficacy; and it has an effect on self-efficacy through a social comparison where people relate their capabilities to others [5][7]. Others may include peers, parents, teachers, family members, and virtually anyone else [4]. Observing a similar individual successfully master a situation helps people learn, and makes them feel that they can also be successful. This improves self-efficacy. Social learning theories posit that people learn from one another through observation, imitation and modeling. In order for modeling to occur, the observer must first pay attention and observe the behavior to be modeled, remember the behavior that they have observed, be able to replicate the observed behavior, and be motivated enough to want to demonstrate the observed behavior and what they have learned [13]. Observational learning and vicarious experiences has positive effects on creativity, learning, and self-efficacy [14][15].

(3) Verbal persuasion: Verbal persuasion, also known as social persuasion, is believed to be the third most effective source of self-efficacy as people who receive realistic encouragement are likely to be to become more successful [5][7][16]. This is particularly effective, when verbal persuasion occurs after a performance achievement [16]. An author testified that her mother and teacher acted as her most powerful sources of verbal persuasion for self-efficacy in mathematics [4]. Empirical evidence confirmed that verbal persuasion improved self-efficacy beliefs in various domains including parenting and teaching [16-18].

(4) Physiological States: Physiological states, also known as affective arousal, is believed to have the least impact on self-efficacy. Positive emotions and being in a positive mood improves self-efficacy [4, 5] [7]. Emotions associated with stress, fear, discouragement, discomfort, depression and so on are associated with negative states and lower performance and self-efficacy. There is evidence to demonstrate that art-based interventions (music engagement, visual arts therapy, movement-based creative expression, and expressive writing) were successfully used to reduce adverse physiological outcomes [19]. Strong physiological arousal correlated with self-efficacy [7].

Various combinations of these four sources of self-efficacy have influenced self-efficacy in various domains [4, 5][7]. Self-efficacy, the belief in one's ability to successfully complete a task, has in turn, influenced decisions and affected choices. Self-efficacy is particularly important for students interested in difficult STEM subjects. This is because students with higher self-efficacy in their ability to understand and apply scientific concepts to real-world situations would be more likely to engage in STEM learning when compared to students with low-self efficacy who may tend to avoid efforts to learn STEM subjects [20]. Furthermore, as students realize their accomplishments, their own self-efficacy increases, and they are more willing to undertake more complex tasks and explore more complex ideas. Considering that self-efficacy might be important in influencing education and career decisions for men and women, it is critical that informal STEM programs designed to increase middle-school girls' STEM interests, incorporate these sources of self-efficacy [21-24]. Improved self-efficacy and engineering interests has been linked with improvements in career identity formation, which is how students see themselves as the type of people that can do engineering, as well as feel that engineering is for them [25]. Other factors contributing to STEM identity formation include role models, academic success, sense of institutional belonging, gender expectations, recognition, curricular relevance, and task oriented self-efficacy [26]. A critical examination of the impact of such educational strategies on self-efficacy and middle-school girls' attitudes to this educational strategies will be beneficial to future STEM program development.

Purpose of Study

To this end, the purpose of this research paper is to describe the STEAM educational strategies and lessons learned from a one-week non-residential summer camp designed to increase middle-school girls' STEM knowledge, self-efficacy, and interests. Furthermore, the effect of the STEAM education strategies on the STEM attitudes, knowledge, self-efficacy, interest, and engineering identities of middle-school girls are assessed. Considering the limited number of program participants and the fact that self-efficacy is domain specific, a limited case study research method will be adopted to provide insights into the extent to which educational strategies influenced the Sustainable Construction Engineering self-efficacy of minority middle-school girls. To this end, the research project will seek to answer the following questions:

a. Research Question 1. To what extent did the STEAM ACTIVATED! program influence STEM attitudes, interests, and engineering identities?
   Data source: Institutional Review Board (IRB) approved pre-survey and post-survey.
b. Research Question 2. To what extent did the STEAM ACTIVATED! program influence the Sustainable Construction Engineering knowledge of middle-school girls?
   Data source: IRB approved pre-test and post-test.
c. Research Question 3. To what extent did the STEAM ACTIVATED! program impact self-efficacy?
   Data source: IRB approved pre-survey and post-survey, reflection sheets, focus group discussions.
d. Research Question 4. To what extent does mastery experiences, vicarious experiences, verbal persuasion, and physiological/emotive states influence self-efficacy?
   Data source: IRB approved pre-survey and post-survey, reflection sheets, focus group discussions.
e. Research Question 5. What are the girls' attitudes to ARTs and dance?
   Data source: IRB approved pre-survey and post-survey, reflection sheets, focus group discussions.

Methodology

This research utilized a mixed method approach which involved the utilization of reflection sheets, surveys, tests, and focus group discussions to generate data for statistical analysis. The research documents were approved by the Institutional Review Board (IRB) and parents gave consent for research participation. The pre-survey/test instrument had four major sections: (1) Background information; (2) Attitudes to STEM; (3) Pre-test; and (4) Self-efficacy. These sections provided baseline data that was later compared with the post-survey/test. The post-survey/test had six sections: (1) Identifier information; (2) Attitude to STEM; (3) Post-test; (4)

Self-efficacy; (5) Sources of confidence; and (6) STEM and dancing. The survey sections utilized a 5-point Likert scale that allowed the girls to self-report and provide a rating on various statements listed in the survey. The test had multiple-choice questions, and the girls were required to circle the best responses to the test items. The girls provided short statement responses to open ended questions listed on the reflection sheets. These sheets allowed them to reflect and document their experiences in the program. During focus group sessions, the girls shared the opinions and experiences in response to open ended questions.

Description of STEAM ACTIVATED! program

The STEAM ACTIVATED! program was implemented at historically black university and funded by a local female-owned construction organization based in North Carolina. The president of the organization also serves as a leader in the local chapter of the National Association of Women in Construction (NAWIC). Middle-school girls (Rising 6^{th} to 8^{th} grade) were enrolled through flyers that were emailed to middle-school principals and families in the surrounding communities. Enrolment was based on a first-come first-serve basis. This one-week (8 hours/day) program was implemented in the summer semester and engaged 31 girls in a variety of fun and hands-on projects and a field trip. Team-based and hands-on projects were designed to increase middle school girls' knowledge, self-efficacy and interest in Sustainable Construction Engineering. Activities were designed to increase exposure to relevant vocabulary, concepts, practices, and careers associated with Sustainable Construction Engineering. Also, the development of soft skills such as critical thinking, communication, teamwork, leadership, and self-efficacy were emphasized. The uniqueness of this program was its incorporation of ART in STEM projects, and its implementation of socio-cognitive learning strategies based on Bandura's four sources of self-efficacy:

Mastery experiences

In order to develop mastery experiences in Sustainable Construction Engineering, fun and hands-on projects were adopted from the TeachEngineering curriculum. This curriculum was sponsored by the National Science Foundation (NSF) and meets the *Next Generation Science Standards (NGSS)* [27]. The projects included Glue Sticks Bend and Twist, Earthquake-proof buildings (toothpicks, straws, and marshmallows), and Balsa Towers with structural composite materials and sustainable materials. Drawing from discussions on structural design strategies that improve the strength and stability of buildings, the girls had to build models that could withstand various stresses, including lateral forces from earthquakes. Each team was provided with the same resources for their models. Teams took measurement and tested their models through various trials, recorded their data, and improved their models when necessary. Furthermore, the girls had to incorporate sustainable materials and their preferred form of ART, or design in their models. Figure 2 shows a Balsa model that girls built utilizing popsicle sticks (recycled wood) in its outdoor play area.

Figure 2. Balsa wood model

Due to time limits and lessons from a previous summer camps, the models were limited to two stories. This allowed the teams enough time to first come up with the architectural design, then the key components of their structure, and then build it. They had to regularly test their models to ensure that it was strong enough to withstand high loads, as this was one of the competition requirements. A key challenge to the girls was how to agree on the design, and then how to measure and cut the balsa wood to the correct dimension so that it fitted in perfectly in the model. Also, despite the instructions given on laboratory safety, a few girls could not resist eating the marshmallows to be used for their toothpick and marshmallow earthquake resistant models. Their ever sticky hands hindered their progress with their models.

During team competitions, the winning teams were rewarded for constructing models with the best building parameters to include height, footprint, structural load capacity, aesthetics, and ART demonstrations. The uniqueness of this program lay in the fact that all of the projects had to incorporate ART and sustainability themes. During the ART focused oral presentations, the girls utilized their unique ART preferences to present their STEM projects to their peers. Notably, some teams allowed each member to present their STEM knowledge gained using their individual preferred ART such as the violin performance, while for other teams, the team worked together on one form of ART and then presented their STEM knowledge gained. During their glue stick project oral presentations, one team of four girls developed a dance which utilized different body movements to demonstrate tension, compression, shear, bending, and torsion.

A STEM dance was created by a performing arts instructor to allow the girls learn and relate common engineering vocabulary and terms to dance movements with the human body. The girls were engaged in a 1 hour 15-minute dance session with movements that were tailored towards STEM topics such as center of gravity, surface areas, two and three dimensional forms, tension, balancing, foundations, and structures.

Also, a field trip to an existing Leadership in Energy and Environmental Design (LEED) platinum certified hotel with sustainability features exposed girls to sustainable materials, equipment, and construction methods.

Vicarious experiences

In order to engage the girls in vicarious experiences, all their hands-on projects involved team work, peer mentoring, competitions, and oral presentations. Each team comprised of three to four team members and a supervising coach. The girls had to assign individual tasks to members of the team. While some teams worked together continuously on their models, other teams assigned independent sections of their model to team members and then later combined their work to form a completed model. The girls were encouraged to observe and model peers within their team, and also observe progress made by girls in other teams. Also, the STEM ACTIVATED! coaches were required to physically demonstrate how to build small sections of their projects whenever the teams were struggling. Lastly, each team had to work together to develop an ART presentation and present it to their peers during oral presentations. This was a challenge as it took some time for the girls to agree on the form of ART to use, especially when they all preferred different forms of ART. Some teams eventually chose to present as individuals within the team, showing up their unique gifts and talents.

Verbal persuasion

The four STEM ACTIVATED! program coaches were construction undergraduate students who had been trained to instruct and guide the girls through their projects. Also, the coaches were required to actively use words to encourage and verbally persuade the girls to work progressively in order to complete their projects successfully. Coaches placed emphasis on creativity, critical thinking, listening, team effort, persistence, time management, problem solving and the development of other critical soft skills. Persuasive words that encouraged persistence were particularly critical for the teams when their projects failed to meet project requirements, and consequently, they needed to re-construct their projects. Story-telling that involved people, particularly women, who had been successful in STEM careers was used to encourage girls. The girls who emerged as leaders, particularly the older girls, were also encouraged to use positive words to encourage and peer-mentor their team members, and even, girls in other competing teams.

Physiological state

In order to maintain positive physiological states, the girls were engaged in confidence/power poses, reflection and I-Can statement sessions. During power pose sessions, girls practiced how to stand, sit, and present themselves in postures that enhanced and projected confidence [23]. Reflection sessions allowed girls to reflect on and write what they had learned from previous STEAM ACTIVATED! projects, while I-Can statement sessions allowed girls to share what they could now do as a result of the STEAM ACTIVATED! projects. Coaches and the instructors were personable and worked very hard to maintain a positive learning environment. Furthermore, the ART presentations and dance sessions were used to create positive environments and improve physiological states. The girls absolutely loved the ART presentations and enjoyed watching each other use their ART to express their STEM knowledge. Also, snacks and refreshments contributed to positive learning environments and as such, improved positive emotions.

Results and Discussion

Description of population

The 31 girls who participated in this program included 5th graders (12.9%), 6th graders (71%), 7th graders (10%), and 8th graders (6%). Eighty-one percent (81%) were African-American, and the non-African-American girls included White, Asian, and Hispanic. Twenty-seven percent (27%) of the participants had at least one person in their household working in the STEM field, while the 73% had no STEM household member. Regarding the highest educational degree holder in the household, 16% of the girls had at least one household member with a doctoral degree, 19% with a masters' degree, 3% with a bachelor's degree, 3% with an associate's degree, and 16% with a high school degree. Forty-three percent (43%) of the girls did not know.

Research Question 1. To what extent did the STEAM ACTIVATED! program influence STEM attitudes?

Results from the pre and post surveys were utilized to assess the effect of the program on STEM attitudes. On a 5-point Likert scale, the girls rated their level of agreement to statements that were associated with their current STEM attitudes. Example of statements included, 'I like science and mathematics', 'I like creating new things', and 'I will like to be an engineer.' A 7.35% increase in the overall mean STEM attitude score was obtained and this was statistically significant ($p<0.01$). The STEAM program increased the percentage of girls who expressed interests in engineering careers from 42% to 61.29%, as indicated in the pre and post surveys. A high gain ($\bar{x}$=19.29%) was obtained for the 'I will like to be an engineer' statement, and this is attributed to the special emphasis placed on encouraging middle-school girls to pursue engineering and technology disciplines. The extent to which improved STEM attitudes transitions into the long-term pursuit of engineering careers can only be determined with time. Follow up studies will be conducted to assess that at a later time. However, it must be noted that in a follow-up STEAM ACTIVATED! program scheduled to begin the following year, 48% of the girls from this current STEAM ACTIVATED! program have already submitted applications. This validates the fact that these returning participants and their families are interested in further exploring engineering and other STEM related careers. Other gains in STEM attitudes were associated with exploring things ($\bar{x}$=12%), improving the way things work ($\bar{x}$=11%), and building things ($\bar{x}$=11%). Engaging the girls in the development of models had given them the opportunity to actual build and improve models and this experience had improved their STEM attitudes. The girls had lots of fun completing their project and this had increased their desire to explore, build, and improve things. These attitudes are particularly valuable for engineering careers and will enhance professional success.

The impact of the program on the formation of engineering identities (EI) was estimated by combining girls' STEM attitude (SA) scores with engineering career interest (ECI) scores; and grouping girls into four EI groups. As shown in table 1, the following percent changes in the populations of the four EI groups before and after the program indicated positive program impacts on girls' EI: Group 1 – strong SA and strong ECI (+19.35%); Group 2 – strong SA and weak ECI (-9.68%); Group 3 – weak SA and strong ECI (0%); Group 4 – weak SA and weak ECI (-9.68%). The positive gains in Group 1 showed the much needed change in the STEM attitudes and engineering identities of some of the girls who were in Group 2 and Group 4 prior to participating in the STEAM ACTIVATED! program. This change can be attributed to the fact that the girls had been exposed to STEM activities that had improved their familiarity with engineering tasks, and had a positive impression on their own belief in their capacity to complete engineering related tasks such as building models. This had increased their confidence in their ability to perform engineering tasks, and consequently, increased their interest in pursuing engineering careers. In agreement with literature, Group 2 consisted of the girls who had the potential to excel in STEM because they demonstrated positive STEM attitudes, but were unwilling to seriously consider engineering as a future career. These girls demonstrated high STEM attitudes because they loved to build, create, explore, and solve problems; however, they were not interested in engineering careers. It must be noted though, that many of the girls in Group 2 were interested in other non-engineering, but science related careers in medicine, nursing, and teaching. The girls had developed stronger career identities in these non-engineering fields because they are frequently exposed to these professionals in their daily lives. Consequently, their low interest in engineering careers may be partly attributed to the lack of female engineering role models in their lives. However, their strong potential to be successful in engineering fields as demonstrated by their high STEM attitudes cannot be ignored. Consequently, the implementation of gender-equitable and well-designed interventions with effective female engineering role models could be used to overcome some of the serious barriers that hinder Group 2 girls' development of engineering interests and identity formation.

Table 1. Four Engineering Identity Groups

Engineering Identity (EI) Groups	Percentage of girls in EI groups prior to program participation	Percentage of girls in EI groups after program participation	Percent change
Group 1. Strong STEM attitude and strong engineering career interest	41.94%	61.29%	+19.35%
Group 2 – Strong STEM attitude and weak engineering career interest	48.39%	38.71	-9.68%
Group 3 – Weak STEM attitude and strong engineering career interest	0.00%	0.00%	0%
Group 4 – Weak STEM attitude and weak engineering career interest	9.68%	0.00%	9.68%

Notably, Group 3 had no girls before and after the program. This validated the fact that it is highly unlikely for a girl with weak STEM attitudes to desire a future career in engineering. Girls with weak STEM attitudes are most likely to pursue non-engineering careers and as such fall in Group 4. The STEM ACTIVATED! program was effective in improving the STEM attitudes and career interests of all of the girls who were in Group 4, prior to program participation. One hundred (100%) of the pre-program Group 4 girls moved to Groups 1 and 2 after program engagement. While Group 2 girls still do not prefer engineering careers, they at least have improved STEM attitudes, and with the right interventions, they could move to Group 1.

At the end of the program, the girls were classified into the following four STEAM groups based on combinations of their STEM and Arts attitude scores obtained from the post-surveys: 1) High STEM/High Arts; 2) High STEM/Low Arts; 3) Low STEM/High Arts; and 4) Low STEM/Low Arts (3.23%). Most of the girls (83.87%) had high STEM and Arts attitudes. A few girls preferred either STEM (6.45%) or Arts (6.45%), while 3.23% preferred neither STEM nor Arts. Considering that most extracurricular activities and social media engagements present girls with various Arts experiences, the girls loved their preferred Arts and easily connected and worked hard on their Arts-infused STEM projects.

Research Question 2. To what extent did the STEaM ACTIVATED! program influence the Sustainable Construction Engineering knowledge of middle-school girls?

Results from the pre-test and post-test were used to determine the extent to which the program influenced the girls' gain of Sustainable Construction Engineering knowledge. The test had 18 multiple-choice items which focused on structures, sustainability, and engineering careers. The low pre-test scores ($\bar{x}$=43.25%) gave a strong indication that the girls were not that knowledgeable about the sustainable construction engineering prior to participating in the program. The percentage of the girls with correct answers was high on test items related to STEM abbreviation (90%), foundation (71%), and columns (65%). This was attributed to the fact that these were common terms and the girls had been exposed to those words prior to participating in the STEAM ACTIVTED! program. On the other hand, the percentage of girls with correct answers was low on test items related to shear forces (9.7%), dead loads (9.7%), and earthquake design (12.9%). This was because these were more complex engineering terms which are not typically used in their everyday conversations. As expected, there was a 91.3% increase in their engineering knowledge, as determined from the higher mean post test score ($\bar{x}$=82.74%), and this was statistically significant ($p<0.01$). It demonstrated that the program had been effective in increasing girls' knowledge of Sustainable Construction Engineering. Feedback from the girls indicated that they had enjoyed and learnt particularly from the hands-on activities and the field trips. Several of the girls indicated in their reflection sheets and focus group discussions that the engineering models, art, dance sessions, peer teaching, and peer modeling had contributed to their understanding of sustainable construction engineering and their improved performance on the post-tests.

In both the pre-test and post-test, the girls were required to predict their test scores prior to the grading of their test. This was to assess the extent to which they were confident about their performance on the test. The mean predicted post-test score ($\bar{x}$=89.4%) was 21.07% higher than the mean predicted pre-test score ($\bar{x}$=68.33%)**,** and demonstrated that the girls had gained more confidence regarding their test performance. This was attributed to the knowledge that they had gained through the STEM ACTIVATED! program, which had led to an increase in their self-efficacy. Surprisingly, the mean predicted pre-test score ($\bar{x}$=68.33%) was 25.08% higher than the mean actual pre-test scores ($\bar{x}$=43.25%). The higher predicted pre-test scores suggested that the girls were over confident and believed that they would perform better on the test than they actually did. However, the predicted test scores were still low and suggested that the girls still felt that they were not know enough about the subject matter. On the other hand, the mean predicted post-test score ($\bar{x}$=89.4%) was only 6.66% higher than the mean actual post-test score ($\bar{x}$=82.74%). The smaller gap between predicted and actual post-test scores indicated that the girls were more realistic about their test performance after they had participated in the program. Their confidence was based on actual knowledge of the subject matter; and, the program had been effective increasing the engineering knowledge of middle-school girls.

Research Question 3. To what extent did the STEM ACTIVATED! program impact self-efficacy?

The mean post self-efficacy score ($\bar{x}$=4.35/5) obtained from the post-survey was higher than the mean pre self-efficacy score ($\bar{x}$=4.05/5) obtained from the pre-survey. This 7.41% increase in the overall self-efficacy of all the girls was statistically significant ($p<0.01$) and attributed primarily to the STEAM ACTIVATED! program. The low gains in self-efficacy can be attributed to the fact that while knowledge can be gained in short times of interaction, self-efficacy development requires longer periods of interaction, using well-established and well-defined strategies. In fact, in order to affect students' self-efficacy toward mathematics, the development of motivation should be consistent over a series of years, and not just in isolation [24]. Consequently, the low gains in self-efficacy improvements can be attributed to their prior high levels of self-efficacy and the short period of interaction with the girls. Continuity is so critical to self-efficacy and success, that students would make higher gains if they had a sequence of three teachers who had favorable attitudes towards mathematics [24].

As shown in figure 3, the largest gains in self-efficacy were associated with 'constructing a model' (20.64%), 'completing oral presentations' (19.83%), 'making an engineering judgment' (19.24%), and 'combining ART with STEM' (16.09%). These gains were mostly because prior to this program, many of the girls had not been exposed to constructing and judging models, nor had they completed oral presentations that required them to combine the favorite ART with their STEM knowledge. Consequently, they gave low ratings in the pre-survey. After their participation in this program, the girls had now gained personal hands-on experiences on how to construct models. Results from reflection sheets and focus group discussions revealed that the girls had learnt from the projects because they had had the opportunity to implement engineering principles and assess the impact of their design on the strength and stability of their models. Also, by measuring, testing and modifying their models, the girls had understood the model characteristics that could be modified in order to improve the performance of their models. During the testing of models, the girls observed how various model characteristics contributed to their strength and stability. For example, they learnt how the height and shape of buildings contributed to their ability to withstand earthquake forces. Such experiences contributed to their engineering judgment, and resulted in the higher ratings observed in the post-test results.

Focus group discussions also revealed that by persisting and successfully completing their building models and also observing other teams successfully complete theirs as well, the girls had gained higher levels of confidence in their abilities and skills for building models. Also, during the oral presentations, the girls had learned from other teams. Furthermore, the girls had enjoyed and learnt from oral presentations that allowed the use of ART in presenting engineering knowledge. The key favorite forms of fine and performing arts utilized by the girls during these presentations included songs, drawings, cartoons, poems, stories, dance, and musical instruments. Notably, during the oral presentation for the glue stick project, a team of four girls created a brilliant dance that utilized body movements to demonstrate tension, compression, shear, torsion, and bending in structures. Reflections sheets and focus group discussion revealed that the girls loved to listen to their peers share engineering knowledge while playing an instrument, reading a poem, telling a story, or singing a song. Beyond the peer teaching that occurred during these oral presentations, the use of ART contributed to maintaining positive environments. In summary, these mastery, vicarious, and physiological experiences had contributed to the increase in self-efficacy, and were in agreement with Albert Bandura's theories on self-efficacy.

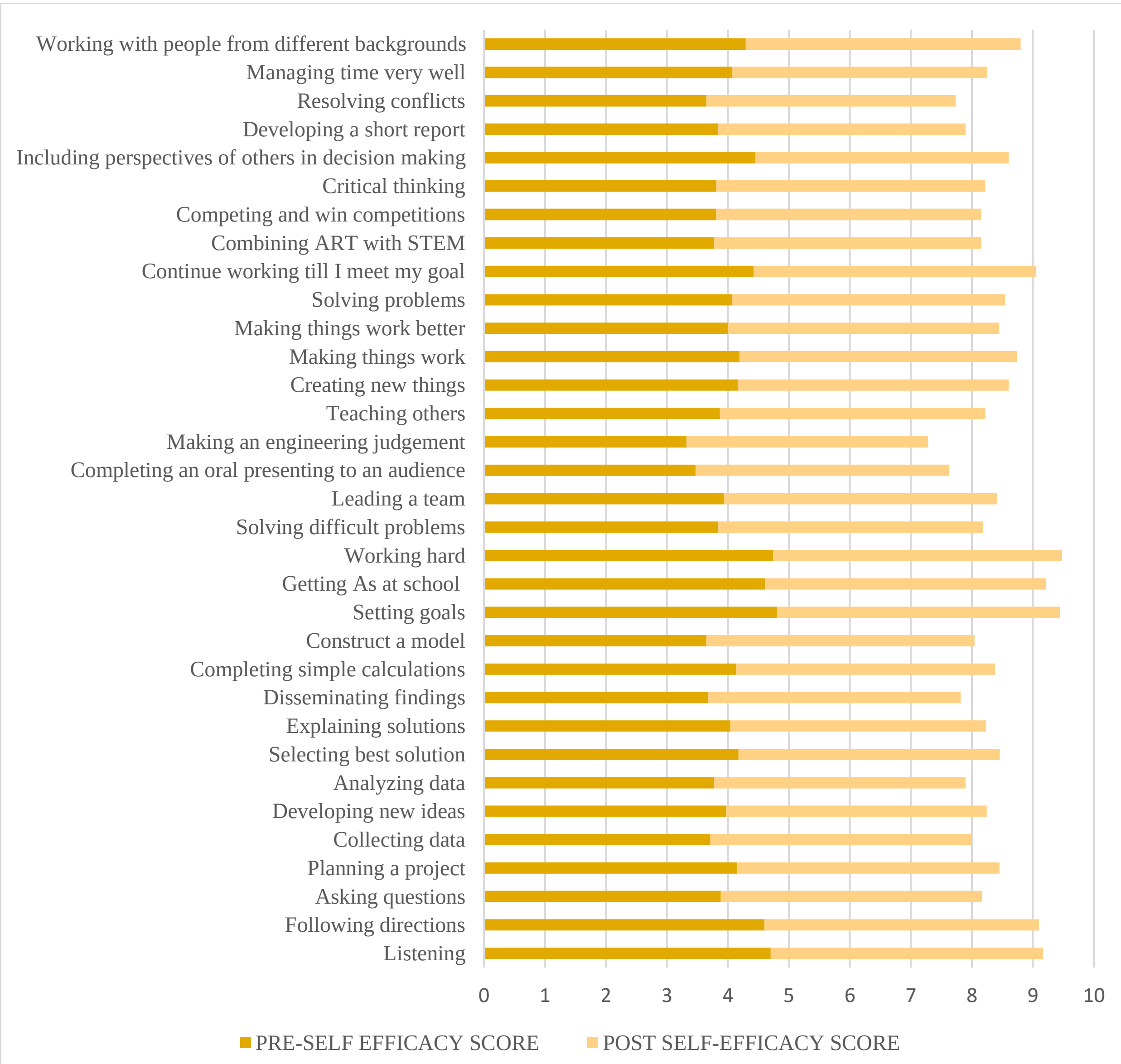

Figure 3. Impact of STEAM ACTIVATED! program on self-efficacy

The apparent losses in self-efficacy were associated with statements associated with 'including the perspectives of others in decision making' (-6.65%), 'listening' (-4.93%), and 'setting goals' (-3.48%). Prior to participating in the program, the girls had more favorable perceptions about their self-efficacy in relation to these activities and so gave high ratings to them during the pre-surveys. However, reflections sheets and focus groups discussions suggested that the lower ratings provided during the post-surveys were associated with the challenges that some faced while working with their team members. These girls were not very enthusiastic about listening to team members' opinions, setting goals together as a team, and including the perspective of team members in decision making. Within these teams, there had been disagreements and the team members had to work harder to come to a consensus about their project goals in order to make significant progress as a team. In the post-survey, one girl made a statement suggesting that she did not think that putting people in groups was a good idea. Nevertheless, all the girls finished their projects, and this indicated that they were able to work through their differences and eventually complete their building models. While difficult, it is not uncommon in to encounter challenges when working in engineering team settings, especially with team members from diverse backgrounds. These program allowed the girls to experience some of the challenges associated with engineering projects.

Research Question 4. To what extent did mastery experiences, vicarious experiences, verbal persuasion, and physiological/emotive states influence self-efficacy?

Data from the post-survey was used to assess the girls' perceptions on the extent to which various sources of self-efficacy, experiences and program strategies influenced self-efficacy (figure 4). Contrary to expectations, rather than to mastery experiences ($\bar{x}$=4.03/5), the girls gave the highest ratings to vicarious experiences ($\bar{x}$=4.19/5). While these results were not statistically significant, they suggested that vicarious experiences may have had the greatest influence on self-efficacy, although literature states that mastery experiences typically has the greatest impact on self-efficacy. Comments from reflection sheets and focus groups discussions suggested that self-efficacy and confidence in ability to be successful increased when the girls watched other girls in other teams work (vicarious experiences) and make progress with their models. These observations assured the girls that they also had the abilities and resources necessary to complete their models as well. As such the girls learnt from other teams through observation and modeling. One team in particular had to re-start their toothpick and marshmallow model three times; however, they never gave up. They learnt from other teams and continued to work on their model until it was strong and stable enough to participate in the competitions. Peer teaching was also observed as more knowledgeable girls taught and guided less knowledgeable girls.

Regarding the next most influential source of self-efficacy, mastery experiences, the girls agreed mostly with the statements that indicated that the continual improvement and completion of their models increased their willingness to keep trying to succeed. Drawing from constructionism theories developed by theorists such as Piaget and Papert, it can be concluded that active learning through observation, modeling, and hands-on projects continues to be a very effective strategy for teaching middle-school girls. Verbal persuasion had the same rating as mastery experiences, with girls agreeing that parents/guardians ($\bar{x}$=4.16/5) and coaches ($\bar{x}$=3.90/5) had increased their self-efficacy through their encouraging words. This concurs with literature that places emphasis on that the critical roles played by gate keepers such as parents. These gatekeepers have a lasting impact on the STEM career choices made by middle-school girls.

Figure 4. Sources of self-efficacy

In agreement with literature on self-efficacy theories, physiological states had the overall lowest influence on self-efficacy, as indicated by the lowest overall mean ($\bar{x}$=3.84/5) obtained from the post-survey results. In their post-surveys, many of the girls used terms such as 'fun', 'enjoy', 'love', 'cool', 'like', and 'come back again' to express the positive experiences that they had during their engagement in the STEAM ACTIVATED! program. However, these positive experiences had the least influence on their self-efficacy. While strategies such as power poses, I-CAN statements, and ART influenced the self-efficacy of the girls, their influence did not exceed the influence of vicarious experiences, mastery experiences, and verbal persuasion. It must be noted that a few of the girls were still shy and unwilling to participate in oral presentations, although they completed their projects. In fact in the post-survey, one girl stated that "I think my confidence has increased personally, not publicly yet ☺".

Research Question 5. What were the girls' attitudes to ART and dance?

The girls acknowledged that ART in STEM ACTIVATED activities had improved their positive attitude to STEM ($\bar{x}$=4.13/5) and made them feel connected to their STEM projects ($\bar{x}$=3.97/5). During the ART presentations to the audience, most of the girls were very excited and eager to use sounds, color, movements, words, and other forms of ARTs to demonstrate their knowledge of Sustainable Construction Engineering. Figure 5 showed that dance emerged as the most preferred form of ART with 32% of the girls selecting dance as their favorite art. Other preferred forms of ART listed by the girls in the post-survey included singing, drawing, dancing, music, baking, etc. These preferences were in agreement with the forms of ART that these girls chose to use during their presentations.

An good overall mean rate ($\bar{x}$ = 4.20/5) was obtained for learning experiences at the Dance Studio as the girls strongly agreed that the dance movements during the STEM dance session increased their understanding of engineering concepts such as tension, bending, surface areas, center of gravity, three-dimension, and foundations.

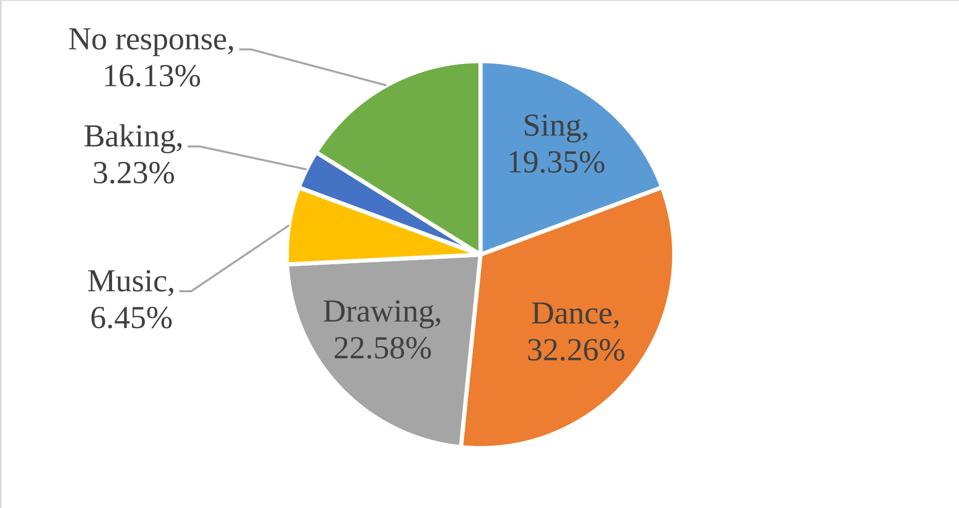

Figure 5. Preferred ART

As shown in table 2, the results from the dance section of the post survey confirmed that a minimum of 84% of the girls agreed with all of the positive statements associated with the dance and STEM. One hundred percent of the girls agreed with statements that indicated that they had felt tension in their bodies during the dance and experienced how surface contact areas affected the stability of their bodies. Ninety-four percent of the girls agreed with statements that related the stresses that they felt in their bodies to the stresses that existed in building structures. Also, 94% of the girls agreed with the statement that they understood how dance was related to STEM. This positive feedback was obtained because the dance instructor intentionally and consistently used vocabulary and dance movements that were related to forces and stability of buildings, and consequently, was very effective in using dance to teach the girls these concepts. However, it must be noted that only 84% of the girls agreed that they would want to visit the Dance Studio again. This was because a few of the girls were not so enthusiastic about the dance, as they preferred other art forms such as music, drawing and singing.

Lastly, 94% of the girls agreed with the statements that they understood how dancing helps develop connections with others. This was because most of the dances that were taught required the girls to have direct contact with each other. In one of the dances, the girls had to form structures with their bodies, with emphasis placed on the importance of foundations in the strength and stability of buildings. This team assignment required the teams to brainstorm on how they could connect their bodies to form building structures. All the teams were successful because as a community with the same goal, they devised strategies to connect their bodies in order to form a stable structure. Beyond the extremely enjoyable time that the girls had, the dance steps, movements and arrangements explored during the session allowed the girls to reflect on engineering principles that were being applied in their STEM projects.

Table 2. STEM and Dance

Statements	Strongly agree	Mostly agree	Agree	Mostly disagree	Strongly disagree
In general, I enjoy dancing	38.71%	35.48%	12.90%	3.23%	9.68%
I enjoyed the dance at the dance studio	51.61%	22.58%	12.90%	6.45%	6.45%
I felt tension in my body when I was dancing at the Dance Studio	48.39%	35.48%	16.13%	0.00%	0.00%
As a result of the dance, I understand how the tension in my body during the dancing is similar to the tension in a building structure	51.61%	25.81%	16.13%	3.23%	3.23%
By dancing with my heels raised, I felt how surface areas affect the stability of my body	58.06%	25.81%	16.13%	0.00%	0.00%
As a result of the dance, I better understand how the reduction in surface areas affects the stability of a building structure	48.39%	32.26%	12.90%	3.23%	3.23%
I understand how dancing with others helps develop our connections with others (community)	51.61%	32.26%	9.68%	3.23%	3.23%
I understand how dancing relates to STEM	48.39%	35.48%	9.68%	6.45%	0.00%
I would like to visit the Dance Studio again	38.71%	32.26%	12.90%	3.23%	12.90%

When exiting the Dance Studio, a conversation between one of the girls and the Lead Principal Investigator of this project is captured below:

Lead PI: Did you hear the dance instructor mention the word '**tension**' several times? (*Lead PI had been teaching girls about '<u>tension</u>' in structural members, and the girls had been applying that knowledge in their hands-on projects*)

Middle-school girl: I did not just hear her mention the word '**tension**', I actually felt '**tension**' several times in my body when we were exploring the different dance movements. I guess, that is how the different parts of buildings feel?

The girls actually experienced the tension associated with building in their bodies. They also experienced two-dimension and three-dimension forms in their bodies during the dance session, as they had to form two and three dimension forms with their bodies. This increased their understanding of the two and three dimension structures that they had to build as part of their actual STEM project. What an effective to engage them in a fun learning activity which helps them experience these engineering concepts in their own bodies? Yes, dance may be used to teach structures. The forces and connections between humans in a dance was similar to the structural connections between the various components of a building. Beyond STEM knowledge, dance and creative movements are known to improve also community, leadership, self-esteem, and life skills. Perhaps with some more extensive research, dance may be used to teach other engineering concepts.

Conclusion

Considering the negative effects of extensive biases and female inferiority stereotypes on female persistence into STEM careers, the engineering and technology community continues to seriously explore opportunities to engage girls of engineering promise in programs that will strengthen their persistence in engineering. These programs should have well-defined and gender equitable strategies in order to have any lasting effects on their STEM knowledge, attitudes, self-efficacy, career identity, and consequently, their persistence into STEM fields.

The STEM ACTIVATED! program was effective in engaging middle-school girls in activities and strategies that were based on socio-cognitive learning theories developed by renowned social learning theorists Piaget, Papert, and Bandura. The strategies implemented in this program resulted in statistically significant gains in middle-school girls' STEM attitudes, engineering career interests, and self-efficacy. While the gains in knowledge were relatively high, the gains in self-efficacy were not as high. This was attributed to the fact that while knowledge can be gained in a short period of time, longer periods of interaction are necessary to increase self-efficacy. Notably, all the four sources of self-efficacy (mastery experience, vicarious experiences, verbal persuasion, and physiological states) contributed to self-efficacy, with vicarious experiences appearing to have the greatest influence on self-efficacy. This was attributed to middle-school girls' willingness to observe, retain, and model the behavior of other girls who were being successful with their STEM models and projects. Mastery experiences allowed the girls to gain personal hands-on experiences that assured them that their successes could be repeated in the future. Verbal persuasion from gatekeepers, particularly parents and coaches, were also very critical in strengthening girls' self-efficacy. Furthermore, the girls enjoyed and learnt from the ART and dance sessions. They agreed that the ART and dance sessions had contributed to STEM knowledge gained, as well as positive environments, which in turn enhanced the self-efficacy of the girls. Considering that self-efficacy influences persistence into STEM disciplines, it was not surprising that the program had been effective in increasing the percentage of girls interested in pursuing engineering careers. The STEAM ACTIVATED! program also had positive impacts on the engineering identity formation of middle-school girls.

The wealth of STEM and ARTs resources available at universities uniquely positions them to contribute to enhancing the STEM attitudes, self-efficacy, and engineering identity formation of middle-school girls by engaging them in STEAM projects through out-of-school learning programs such as this STEAM ACTIVATED! program implemented at North Carolina Agricultural and Technical State University. In the long term, a consistent and concerted effort to enhance STEM education for middle-school girls through well-designed STEM out-of-school programs should increase female representation in STEM disciplines.

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