

Impact of a Femalized Architecture, Engineering, and Construction Kinesthetic Learning Model on the AEC Career Knowledge, Self-efficacy, and Outcome Expectations of African American Middle School Girls

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Mercy Fash is a dedicated and accomplished PhD candidate in the Applied Science and Technology program at North Carolina Agricultural and Technical State University (NC A&T). Her research is primarily focused on increasing racial and gender diversity in STEM careers, addressing critical gaps and promoting inclusivity in these fields. Mercy's academic excellence and contributions to research have been recognized through several prestigious awards. In 2022, she was honored with both the CoST Graduate Rising Scholar Award and the NC A&T Graduate Rising Scholar Award. These accolades highlight her outstanding scholarly achievements and her commitment to advancing knowledge in her field. In 2024, Mercy's dedication to education and her exemplary performance as an instructor were acknowledged when she received the Senior Graduate Teaching Assistant Award. This award underscores her effectiveness as an educator and her ability to inspire and mentor students. In addition to her academic and teaching roles, Mercy has significantly contributed to the broader academic community as a reviewer for the American Society of Engineering Education. This role allows her to influence the quality and direction of engineering education research, ensuring that it remains rigorous and impactful. Mercy is also deeply committed to mentoring the next generation of scholars. She has served as a mentor to undergraduate and precollege students, guiding them through their academic and research journeys. Her mentees have presented their work at various prestigious conferences and symposia, including the NC A&T Undergraduate Research Symposia, Emerging Researchers Network Conferences, and American Society for Engineering Education (ASEE) Conferences. This mentoring work not only showcases Mercy's leadership and dedication to student development but also contributes to the broader goal of increasing diversity and representation in STEM fields. Mercy Fash's work and achievements exemplify her commitment to fostering diversity and excellence in STEM education and careers. Her contributions are paving the way for a more inclusive and equitable future in these critical fields.

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An Evaluation of the Impact of a Femalized Architecture, Engineering, and Construction Kinesthetic Learning Model on the AEC Career Knowledge, Self-efficacy, and Outcome Expectations of African American Middle School Girls

Abstract

Engaging African American middle school girls in out-of-school-time (OST) Architecture, Engineering, and Construction (AEC) programs can significantly boost their knowledge and awareness of these traditionally male-dominated fields. This study adopts Lent's Social Cognitive Career Theory (SCCT) and Bandura's self-efficacy theory to assess the impact of a femalized AEC kinesthetic learning model (fAEC-KLM) on the AEC career knowledge, self-efficacy, and outcome expectations (KSO) of African American middle school girls. Fourteen (14) African American middle school girls from Guilford County, NC, participated in pre- and post-intervention interviews, evaluating how the fAEC-KLM model influenced their AEC career knowledge, self-efficacy, and outcome expectations. Inductive thematic analysis of transcribed interviews using NVIVO qualitative software revealed key components of the fAEC-KLM that impacted KSO. Components such as lectures, peer interactions, and kinesthetic/experiential learning interacted with participants' learning experiences (prior OST educational programs, familial social support, deficient/adequate mathematical pedagogy, and pre-collegiate engineering education). These factors collectively enhanced participants' AEC career knowledge, bolstered their self-efficacy, and shaped their outcome expectations. The findings highlight the efficacy of targeted AEC activities within the fAEC-KLM in boosting career knowledge, self-efficacy, and outcome expectations, offering critical insights for developing OST programs that encourage African American middle school girls to pursue careers in AEC fields. These results emphasize the need for such initiatives to reduce the gender gap in STEM and AEC professions, contributing to broader efforts to diversify these vital sectors.

Keywords: AEC careers, middle school learning, African American representation

Introduction

The underrepresentation of women, particularly African American women, in Architecture, Engineering, and Construction (AEC) fields remains a global issue [1], [2]. Despite efforts to increase diversity in Science, Technology, Engineering, and Mathematics (STEM) fields, African American women continue to be significantly underrepresented in AEC professions [3], [4]. This disparity not only limits individual career opportunities but also deprives the industry of diverse perspectives and talents crucial for innovation and problem-solving in an increasingly complex world [1]. To address this challenge, targeted interventions that focus on early exposure and engagement are essential. The formative middle school years represent a critical period for shaping career interests and aspirations, particularly for young women [5], [6]. It is during this time that students begin to form more concrete ideas about their abilities and potential career paths, making it an ideal stage for interventions aimed at broadening their perspective on STEM careers, including those in AEC fields [7], [8].

Little empirical evidence exists to inform and support the design, development, and implementation of early and targeted interventions to increase AEC career knowledge, self-efficacy, and outcome expectations (KSO) in African American girls. However, considering that initial evidence from [1], [9] demonstrate that AEC-modified Out-of-school-time (OST) programs have been effective in increasing middle-school girls' AEC career KSO.

Purpose and Scope of Study

This study evaluates the impact of a novel OST intervention: Femalized AEC Kinesthetic Learning Model (fAEC-KLM). This study adopts Lent's Social Cognitive Career Theory (SCCT) [10], [11] and Bandura's self-efficacy theory [12], [13] in the development of the fAEC-KLM with the aim of increasing AEC-related KSO in African American middle school girls. This model is a five-day summer program specifically designed to engage African American middle school girls in AEC concepts through lectures, role models, and hands-on, experiential learning activities. The fAEC-KLM aims to address three critical factors that influence career choice and persistence in AEC fields:

1. *AEC Knowledge*: Many African American middle school girls have limited exposure to and understanding of AEC professions. The fAEC-KLM seeks to provide comprehensive, accessible information about AEC careers, their societal impact, and the diverse roles within these fields through verbal persuasion in the form of lectures, success stories female African American AEC professionals [12], [14].
2. *Self-Efficacy*: Drawing on [12] self-efficacy theory, the fAEC-KLM aims to boost participants' confidence in their ability to succeed in AEC-related tasks and careers. By providing mastery experiences through hands-on activities and exposure to successful role models, the fAEC-KLM seeks to enhance participants' belief in their capacity to pursue AEC professions.
3. *Outcome Expectations*: Based on the social cognitive career theory [15], the fAEC-KLM aims to positively influence participants' perceptions of the potential outcomes of pursuing AEC careers. This includes highlighting the personal, social, and economic benefits of these professions.

The fAEC-KLM incorporates several key components designed to address these factors:

- a) Lectures and presentations providing comprehensive information about AEC careers.
- b) Peer interactions to foster collaborative learning and support.
- c) Kinesthetic and experiential learning activities offering hands-on engagement with AEC projects (bridge building project).
- d) Exposure to successful African American women in AEC professions as role models.

Methods

This study employs qualitative methods to evaluate the impact of the fAEC-KLM on AEC knowledge, self-efficacy, and outcome expectations in fourteen (14) African American middle school girls from Guilford County, NC. Institutional Review Board (IRB) approval was obtained prior to data collection. One hour zoom interviews were conducted prior to and after fAEC-KLM intervention to evaluate consistency or changes in experiences and responses of participants on the impact of the model on their AEC-related KSO. During the interview, research participants (RPs) were asked thirteen (13) open-ended questions explaining their AEC-

KSO before and after fAEC-KLM intervention. By analyzing descriptive data from participant interviews, we aim to provide a comprehensive understanding of fAEC-KLM's effectiveness and the mechanisms through which it influences AEC-related KSO in African American middle school girls through inductive reasoning [16], [17].

Inductive thematic analysis [18], [19] was carried out on transcribed interviews utilizing NVIVO qualitative software in form of coding and constant comparative analysis were phrases, codes, rankings, and terms were captured to better understand the learning experiences of the participants and impacts on their KSO. The number of references (N) for each code generated in NVIVO was used to determine the frequency and commonality of experiences across all participants. Three levels of coding were carried out on each metric. The first level of coding involved identifying initial open codes that are directly related to each metric, capturing diverse participant experiences. The second level of coding involved grouping similar open codes into more concise focused codes to highlight patterns and recurring themes. The third level of coding involved the consolidation of focused codes into sub-themes, representing unifying characteristics and the underlying impact factors. The pre- and post-interview responses were analyzed through these subthemes to identify meaningful shifts, and the comparisons are outlined below.

Results and Discussion

The fourteen participants in this study comprise of 17% 6th graders, 58% 7th graders, and 25% 8th graders ranging from 10 to 13 years of age.

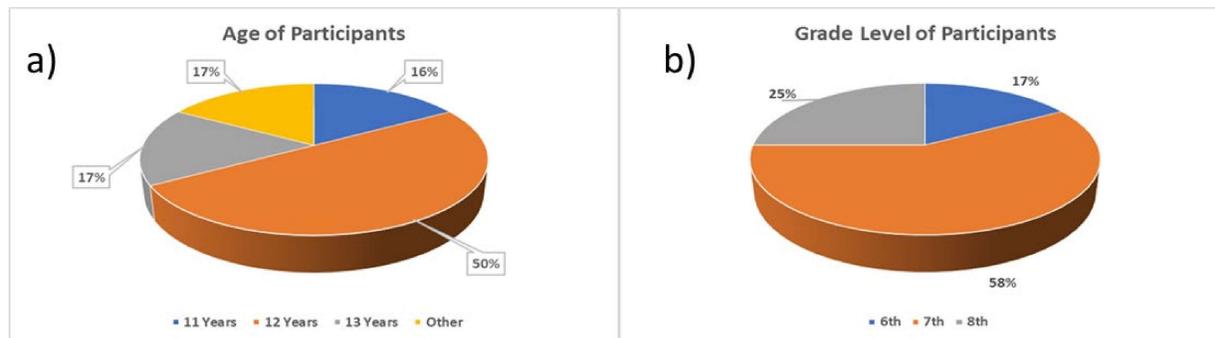


Figure 1: a) Age of Participants; b) Grade Level of Participants

Results from analysis revealed three emergent themes: *fAEC-KLM Impacts AEC Knowledge in African American Middle School Girls*; *fAEC-KLM Impacts AEC Self-efficacy in African American Middle School Girls*; *fAEC-KLM Impacts AEC Outcome Expectations in African American Middle School Girls*.

A. *fAEC-KLM Impacts AEC Knowledge in African American Middle School Girls*

The findings of this study have significant implications for educators, policymakers, and industry leaders seeking to increase diversity in AEC fields. By examining the effectiveness of a targeted, culturally relevant intervention, this research contributes to the broader discussion on strategies to engage underrepresented groups in STEM careers and provides insights into the design of effective outreach programs for young women of color.

To identify the impact the fAEC-KLM has on the AEC knowledge of RPs, responses from two interview questions provided insight.

1. *“Tell me what you know about female and African American participation in AEC careers?”*

RPs responses to these questions in the pre-interviews indicated their lack of preliminary or sufficient knowledge about AEC and the representation of females especially African American females in these careers. Before fAEC-KLM intervention, 93% (N=13) of RPs expressed their lack of knowledge of female and African American participation in AEC careers. Only one RP (AAMG11) expressed her knowledge on the underrepresentation of females and African American women in AEC by saying,

“Well, I don’t know much, but from like the stories we’ve heard and well, for instance like hidden figures and stuff. I just, I kind of realizing like these jobs, um African Americans, especially females, they’re kind of put to the back, and they’re not really like being shown or represented as much. But they most definitely like work as hard as the others and should be more represented.”

This RP’s responses suggest that her understanding of AEC careers was largely shaped by informal knowledge acquired through movies, highlighting the absence of formal education on the topic in her school’s curriculum. This underscores a broader issue—many schools do not incorporate lessons on the contributions of women and African Americans in specific STEM fields, including AEC, into their teaching.

However, post-interview responses revealed a significant shift, with all RPs demonstrating a 100% increase in knowledge about the participation of women and African Americans in AEC careers. They not only articulated their new understanding but also provided statistics to support their acquired knowledge. AAMG6 said:

“Well, I learnt that like, there’s a very small amount of women in construction, in architecture like very small. There’s like 23% of women in architecture in general like not even like African America-wise, in general. Whatever we share, African American women is like 9%, right? I was just very blown away by the fact that mainly in like the industry field, that they’re just mostly men. At the same time, I’m not very surprised, but I have a feeling that if women were to be interested in AEC, it would be to be the architect, like, you know, to be the one to draw the design and stuff. I don’t see much of women going into construction if they were to join but you know it’s just a personal opinion. I don’t know. Maybe just because of the way I think women are. They would prefer not to get their hands dirty a lot...”

This RP’s response demonstrates that while the AEC lectures enhanced her understanding of female and African American participation in AEC careers, there is still room for growth. She maintains the belief that some AEC careers are better suited for women than others.

The fAEC-KLM intervention had a significant impact on RPs’ knowledge, as evidenced by the contrast between their limited responses in the pre-interviews and the more comprehensive insights they shared in the post-interviews.

2. *“On a ranking scale of 1 (lowest) and 5 (highest), to what extent do you think you have the knowledge needed to make a decision about pursuing an Architecture, Engineering, and Construction (AEC) career? Explain how lived and learning experiences have contributed to your rank.”*

Responses to the second key question also provide insight into the impact of the fAEC-KLM on AEC knowledge. Pre-interview responses indicated that participants attributed their pre-intervention AEC knowledge to both formal and informal learning experiences. Informal learning experiences such as summer camps, personal skills, family members, and role models. Formal learning experiences such as regular school classes. However, RPs’ prior knowledge of AEC careers was limited and often based on misconceptions. Many participants conflated AEC, particularly engineering, with computer science, robotics, and coding due to previous experiences in STEM camps and school classes. Their attributed sources of AEC knowledge included summer camps, personal experiences, family members or role models, and school classes. Additionally, some participants associated their understanding of AEC with gendered peer interactions in school, particularly noting the underrepresentation of girls in engineering-related classes. These findings highlight a significant gap in accurate AEC knowledge among African American middle school girls prior to the fAEC-KLM intervention, underscoring the need for targeted educational programs that provide clear, accurate information about AEC careers and kinesthetic experiences in these careers.

Post fAEC-KLM intervention, all RPs showed more knowledge on AEC. They attributed the gain in knowledge on AEC to the effective interactions within the fAEC-KLM.

- a. *AEC Lectures (N=7)*: Well-structured lectures can be effective in transmitting complex information [20]. According to RPs, the AEC lectures had the most impact on their AEC knowledge within the fAEC-KLM. Not only did they appreciate the lectures, but they also emphasized on the impact of knowing about African American female AEC professionals. AAMG11 verifies that there was knowledge gain from AEC lectures on the underrepresentation of African American females in AEC:

“I would say the lecture on the AEC females or African American females gave us a bunch of like knowledge, background knowledge on AEC and what its about and also the important role models.”

The exposure to role models addresses the need for women of color in STEM to see themselves reflected in the field as discussed by [21]. The statements made by these RPs on the impact of the AEC lectures verify [20] that the content of a lecture or a topic being taught is important to stimulating career interest in STEM subjects. The effectiveness of lectures in the fAEC-KLM may have been enhanced by their integration with other active learning modalities such as note-taking and applying the knowledge gained.

- b. *Bridge Design and Construction (N=6)*: The kinesthetic bridge design and construction project was a significant contributor to knowledge gain, exemplifying the principles of experiential learning theory described in [22]. RPs described how the kinesthetic bridge design and construction project impacted their AEC knowledge. AAMG5 said:

“I feel like the bridge design and construction project was important, because it taught us how people in AEC like use their teamwork and what struggles they have to go through, and how much time and dedication they have to put into their

projects for it to work, and for their projects to be successful and help the society.”

This aligns with findings from [23], emphasizing the importance of kinesthetic learning in engaging underrepresented youth in STEM. Kinesthetic learning opportunities do not only develop technical skills but also problem-solving abilities and engineering mindsets. This can be seen in a statement made by AAMG12:

“Building the bridge kind of increased my knowledge because it was like cause and effect. So, like if something didn’t work, we had to either redo it or figure out a new solution to make it work and we never really gave up because we couldn’t give up. We just had to keep trying to fix the bridge.”

These statements made by RPs give deeper insights into the impact the bridge construction project in the fAEC-KLM had on their AEC knowledge.

- c. *Lecture on Bridge Design and Construction (N=6)*: The lectures on bridge design and construction also gave RPs insight and the relevant knowledge needed to build their preferred designs.

“I would say the lecture on the bridge construction and the different types of bridges gave us like a bunch of like knowledge and that helped us build the bridge.”

The effectiveness of lectures in the fAEC-KLM may have been enhanced by their integration with other active learning modalities such as note-taking and RPs mentioned throughout that taking notes during the lectures helped them retain the information better. [24] describes lectures as being particularly effective when they provide a framework for subsequent kinesthetic activities.

- d. *Peer Interactions (N=3)*: Many RPs highlighted the value of interacting with peers and discussing what they learned, reflecting the principles of social constructivism in education [25]. They appreciated that they could interact with their peers and develop a sense of belonging. AAMG20 said:

“Hanging out with other girls increased my knowledge by kind of being able to see the perspective of women that work in AEC careers, it kind of made me think about like... Hmm! I’m standing in a room, in like the room full of girls instead of a room full of men. So, it kind of made me see my perspective on things and stuff like that.”

Peer interactions are particularly beneficial for underrepresented groups in STEM. As noted in the study by [26], peer interactions and community building are crucial factors in the persistence of women of color in STEM fields.

To quantify increase in AEC knowledge, RPs were also required to self-rank their AEC knowledge in the pre- and post-interviews. Self-rankings were categorized into, increased AEC knowledge ranking, maintained AEC knowledge ranking, decreased AEC knowledge ranking.

- i) *Increased AEC knowledge ranking (N=8)*: Fifty-seven percent (57%) of RPs increased their self-rankings of AEC knowledge from mid (3) in the pre-interview to high (4 or 5) in the post-interview and seven percent (7%) increased from low (1 or 2) to mid (3). They justified their rankings by highlighting that they now believe that they know more about AEC as compared to before the fAEC-KLM intervention.

- ii) *Maintained AEC knowledge ranking (N=3)*: Twenty-one percent (21%) of RPs maintained the same interest rankings (high – high) in both pre- and post-interviews. Despite learning more about AEC during the fAEC-KLM intervention, these RPs had already ranked their knowledge high in the pre-interview due to misinterpreting the scope of engineering in AEC. With their new understanding, they felt there was no higher rank available.
- iii) *Decreased AEC knowledge ranking (N=2)*: Fourteen percent (14%) of RPs ranked their AEC knowledge high (5) in the pre-interview but ranked it mid (3) in the post-interview. This decrease in ranking was not due to reduced knowledge but rather a more realistic assessment of their knowledge. After participating in the summer camp, these RPs recognized that they still had much to learn and that the five-day camp could not cover all aspects of AEC.

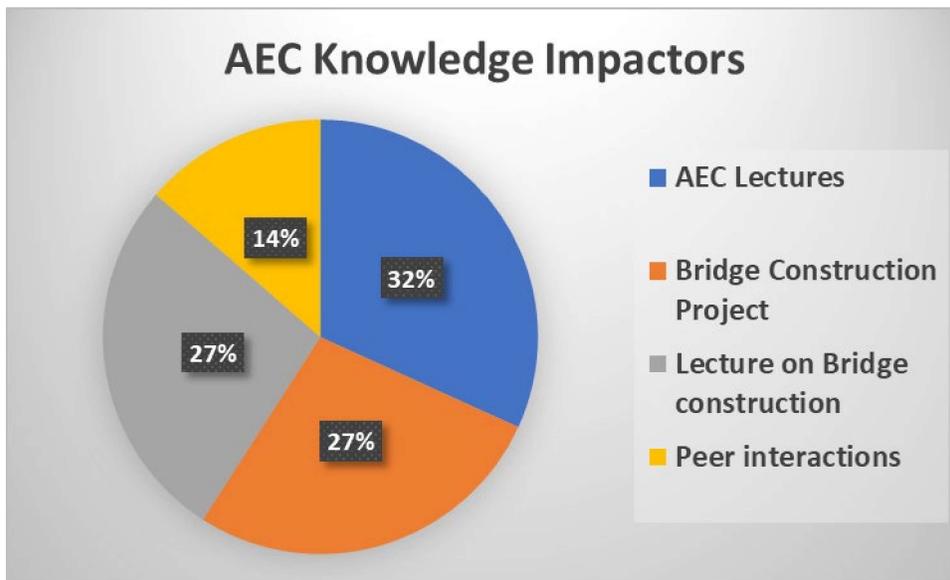


Figure 2: fAEC-KLM Components Impacting AEC Knowledge

The fAEC-KLM intervention proved effective in enhancing AEC knowledge among most RPs. A notable (64%) reported an increase in their self-perceived knowledge, while 21% maintained their already high rankings. Interestingly, the 14% of RPs who reported a decline in their rankings demonstrated a deeper, more nuanced understanding of the complexity of AEC careers, reflecting a shift toward more realistic expectations. These findings indicate that the intervention not only expanded RPs’ knowledge but also refined their perception of the scope and intricacy of AEC careers, especially by addressing the initial misconceptions about the role of engineering within AEC.

However, the study underscores the limitations of short-term interventions. Several RPs acknowledged that while the five-day summer camp was insightful, it could not comprehensively cover the entire AEC field. This awareness likely contributed to more modest self-rankings in the post-interviews, as participants developed a clearer sense of the field’s vastness.

B. fAEC-KLM Impacts AEC Self-efficacy in African American Middle School Girls

The responses for pre- and post-interview questions on AEC self-efficacy highlight the factors impacting the confidence RPs have in becoming AEC professionals. RPs highlighted prior AEC

self-efficacy impactors to include self-esteem/belief, and prior informal and formal STEM learning experiences. RPs also mentioned having deficiency mathematical pedagogies due to not having adequate math education during the COVID pandemic which reduced their prior AEC self-efficacy. However, post-interview responses on the impact of the fAEC-KLM on AEC self-efficacy revealed that RPs attributed their post-intervention AEC self-efficacy to experiences within the fAEC-KLM.

- a) **AEC Knowledge Gain (N=7):** RPs attributed their AEC self-efficacy to their increase in knowledge on AEC-related concepts and to them now having a better understanding of what AEC entails. This increased their confidence in becoming future AEC professionals. AAMG16 confirmed this by saying:

“The bridge design, like it helped me know that I can well, I can do whatever I set my mind to and the lectures helped me understand.”

The lectures also helped the RPs understand that their gender is not a liability rather it is important for them to know that they can do anything they set their minds to. AAMG16 said:

“...the lecture we had about being confident and saying I can do it, I think that it helped my confidence a little bit because if I thought like, usually, I don't like being the only girl doing something. So I think it increased my confidence a little bit by having a lecture about being able to do stuff and being confident and saying that, you're saying that you can do something.”

- b) **Self-belief (N=6):** For some RPs, the fAEC-KLM reaffirmed the belief they have in themselves to succeed. They attributed their post-intervention AEC self-efficacy to their determination and self-encouragement to succeed. A simple statement by AAMG10 explains this:

“I can actually do anything that I want to do.”

- c) **Successful female African American AEC professionals (N=4):** These RPs believe that since the few female African American AEC professionals they were taught about actually succeeded at things they set their minds to, then it means they can succeed at being AEC professionals. AAMG10 said:

“Because I would be another African American female in a career where it's not a lot, and I'll probably be pretty successful because a lot of the African American females that are in the careers are successful. So, if I would just take inspiration from them, I could be successful just like them.”

- d) **Kinesthetic Learning (N=4):** These RPs attributed their AEC self-efficacy to completing the kinesthetic activities within the fAEC-KLM. AAMG21 said:

“...after our bridge winning, that kind of boost my confidence a lot because it showed that some ideas that I could have could be like really successful like this actual point.”

AAMG21's team won the prize for best bridge at the summer camp and according to her, this boosts her AEC self-efficacy.

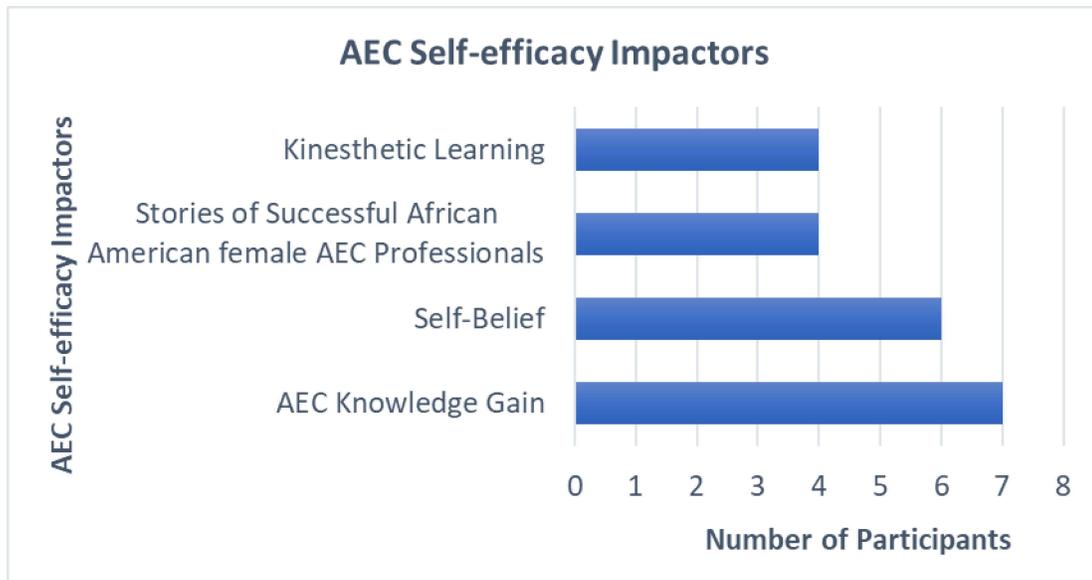


Figure 3: *fAEC-KLM Components Impacting AEC Self-efficacy*

The self-assessment of AEC self-efficacy completed by RPs shows that the *fAEC-KLM* intervention appears to have had a positive impact on the AEC self-efficacy of the majority of participants. 78% of participants either increased their self-efficacy or maintained a high level of self-efficacy post intervention. This suggests that the *fAEC-KLM* was effective in boosting confidence and interest in AEC among African American middle school girls.

C. fAEC-KLM Impacts AEC Outcome Expectations in African American Middle School Girls

Pre-intervention interview responses on AEC outcome expectations show that RPs had no knowledge of the benefits of AEC careers, which made it difficult for them to describe the benefits AEC careers can provide them. However, post-intervention interview responses revealed the vast awareness of AEC benefits the RPs have. The perceived benefits of pursuing AEC careers as expressed by RPs are detailed below.

- a) *Financial benefits (N=12)*: Majority of RPs appreciated the good salary benefits of AEC careers and highlighted it as one of the benefits they anticipate should they become AEC professionals. AAMG11 said:

“I’ve learned that it pays really well, and then, and that’s always a great benefit...”

RPs highlighted the good salary benefits as a reward for going through the necessary college years to be an AEC professional. AAMG12 said:

“It made me want to do it a little bit more... After you go through those years of college and you get straight into it, you could start working towards that high paid money.”

- b) *Knowledge and skill acquisition (N=5)*: RPs highlighted the consistent knowledge they will gain from being AEC professionals and how this knowledge can impact their communities. AAMG21 said:

“...seeing everything that you can accomplish, and how beneficial it can be. And it can be something as big as like a bigger project or something as developing a

certain type of sidewalk for everybody. Like you can benefit in lots of different ways.”

This shows that RPs were not allowing associating AEC benefits to their personal achievements but also to societal impacts.

Limitations of Study

1. **Small Sample Size:** the limited number of participants restricts the generalizability of the findings to other populations. Although the study provides valuable insights into the experiences of African American middle school girls, larger sample sizes would be necessary to strengthen the validity and applicability of the results across diverse contexts.
2. **Short Intervention Duration:** The five-day summer camp provided only a brief exposure to AEC careers, which may limit the depth and retention of knowledge acquired by participants. A longer intervention or follow-up sessions would allow for a more robust evaluation of sustained impact and career interest development.
3. **Persistent Stereotypes:** Despite gains in AEC knowledge, some participants continued to express stereotypical beliefs about the roles of women in AEC, such as assuming women are less inclined towards hands-on construction work. This indicates that short-term interventions alone may not fully dismantle deeply rooted cultural biases.
4. **Sample Representativeness:** The participants were drawn from a specific location and population of African American middle school girls. While this focus aligns with the study's goals, the findings may not reflect the experiences or challenges of other underrepresented groups in STEM, such as African American girls in other geographical locations, boys, or students from other racial or socioeconomic backgrounds.

Conclusion and Future Work

The fAEC-KLM intervention demonstrated significant potential in increasing AEC knowledge, self-efficacy, and outcome expectations among African American middle school girls. Key elements contributing to its success include hands-on learning experiences, exposure to successful role models, comprehensive knowledge gain about AEC professions, and positive peer interactions.

The findings suggest that early and sustained exposure to AEC fields through informal AEC learning experiences can significantly enhance knowledge, self-efficacy, and outcome expectations. For educators, practitioners, and policymakers, these insights provide valuable guidance for developing targeted interventions and policies to support diverse career pathways in AEC fields. Tailored interventions that incorporate hands-on learning, early exposure, and strong role models are effective in fostering KSO in AEC careers among African American middle school girls. Addressing misconceptions, supporting math proficiency, and providing diverse learning experiences can further enhance these efforts. These insights can inform the design of future STEM programs aimed at increasing diversity and inclusion in the AEC fields.

Future research could explore the long-term impact of such interventions and investigate ways to provide more comprehensive AEC education within time constraints. Additionally,

developing a more granular ranking system might help capture subtle changes in RPs' AEC knowledge, self-efficacy, and outcome expectations more accurately.

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