It got me back to science and now I want to be a plant scientist: Arts-integrated science engagement for middle school girls

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Abstract

While middle school is a critical phase for science career development for all students (Maltese & Tai, 2009), this stage presents considerations for females in science, in particular. During middle school, the decline in science interest is greater for females than males and, for most students, the level of science interest developed during this middle school stage will persist throughout their lifetime, thereby influencing science career interests and attainment (Todd & Zvoch, 2017). This study aimed to stimulate and sustain middle school female students' interest in science study and careers by transforming opportunities for their participation in classroom science in ways that better appealed to and supported female science students. Research has shown that collaborative and active engagement with peers, hands-on and tangible modes of engagement, significant real-world connections, and choice have been effective in supporting middle school female students in science. Arts-integration has been explored as a cohesive framework that could potentially incorporate each of these characteristics into a science learning environment for five middle school female students. Pre- and post-interviews served as data to investigate the impact of a four-week arts-integrated science unit on the students' interests in science and science careers. The students explicitly discussed the positive effects of collaborative and active engagement with peers, hands-on and tangible modes of engagement, and significant real-world connections on their interest in science and science career planning. While they did not explicitly acknowledge choice, all of the girls indicated thorough enjoyment from learning and engaging in science in the ways presented in the study. All of the students advanced in their career planning as a result of experiences in the unit, either in terms of science careers or the arts. Findings are discussed in light of related research and future lines of inquiry.

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Introduction

Over the past 20 years, science and mathematics achievement on national assessments and attainment of post-secondary degrees for female students have increased (Gomoll, Hmelo-Silver, Šabanović, & Francisco, 2016). Small gaps in achievement still persist in favor of males towards later grades in middle and into high school grades, however (National Science Board, 2018a). Male graduates still pursue science-related careers more than females, and only modest gains have been made in increasing the representation of women in science and engineering careers (Gomoll et al., 2016). While 50% of the college-educated workforce was female in 2015, up from 43% in 1993, still only 28% of science and engineering professionals were female, up from 23% in 1993 (National Science Board, 2018b). Furthermore, female representation remained particularly low in the fields of physical science, engineering, and computer science, but, encouragingly, parity was nearly attained between women and men in life science careers (National Science Board, 2018b).

Interest in science is key to students' science career planning and attainment (Maltese & Harsh, 2015; Maltese & Tai, 2011; Tai, Liu, Maltese, & Fan, 2006). Cultivating and sustaining science interest among females has been challenging when they have encountered an inhospitable and/or masculine culture. Although often unintentionally, parents and educators have discouraged females from pursuing science studies (Ferreira, 2002). Parents have, furthermore, been found to more often purchase scientific toys for their boys than for their girls, and boys have had greater opportunities to play with manipulative and construction toys (Martincic & Bhatnagar, 2012). Teachers have also demonstrated gender biases against females, for instance, by praising male students more often, especially the more they participate in science class (Jones & Wheatley, 1990), as well as by lowering expectations for females and overlooking their strengths (Michell, Szorenyi, Falkner, & Szabo, 2017). Male students were also called on more often to answer questions in science class or allowed to call out or interrupt more than female students (Shakeshaft, 1995). Implicit biases in teaching and classroom environments persist, for instance, when females are underrepresented in classroom curriculum materials (Farland-Smith, 2015), or when cultural artifacts in classrooms predominantly reflect stereotypical male science interests (Michell et al., 2017). Early science experiences, especially for females, are important in cultivating interest in these fields and subsequent careers (Baker, 2013; Du & Wimmer, 2019; Gomoll et al., 2016). With early experiences lacking, females may encounter “experience gaps” relative to males, which can result in lower confidence levels and beliefs that they are behind their male peers (Friend, 2015).

Females of color and from low-income backgrounds face additional challenges in finding resources and supports in science, as they can encounter interpersonal and institutional constraints, such as historical, cultural, and socially legitimized norms, rules, and expectations, limiting understanding of who is/can be scientific and what is/can count as scientific practices and engagement (Calabrese Barton et al., 2013a; Calabrese Barton et al., 2013b; Farland-Smith, 2015). In response, females of color in science may transform and/or make invisible aspects of themselves to conform to more dominant masculine norms of their science learning/career environments, to gain positive recognition, and to establish themselves as part of the science community, including changes to their speech, dress, or mannerisms (Ong, 2005). When female science students and career professionals are the only, or one of few, females in their science learning/career environments, they can endure social isolation, exclusion, and lack of support or mentorship (Johnson, 2007; Malone & Barabino, 2009). Research on the underrepresentation of females in mathematics-intensive career fields suggests that, despite high levels of skills in mathematics, female students may be motivated toward other careers, due to even greater levels of interest and skill in these other fields, especially when these fields are more hospitable to females than mathematics (Breda & Napp, 2019). Science and mathematics as historically white male-dominated fields present many similar factors that can support or obstruct female students, especially in regard to presenting female students with inhospitable or unsupportive climates and that may be in conflict with their gender identities, e.g. (Brandt, 2008; Calabrese Barton et al., 2013b; Johnson, 2007; Kang et al., 2019; Ong, 2005). Therefore, a similar effect, as described by Breda and Napp (2019), may detract females from science to other more inclusive disciplines, such as literature, humanities, and the arts. In seeking to stimulate and sustain females' interest in science study and careers, those who work with female students in science, including researchers and practitioners, are encouraged to explore ways of transforming opportunities for participation in classroom science that better appeal to, and support ,female science students.

Middle school (approximately 11 to 14 years old) is a critical stage at which to focus as science career interests and expectations formed as early as middle school can be significantly influential on actual science career attainment (Maltese & Tai, 2011; Tai et al., 2006). While middle school is a critical phase for science career development for all students (Maltese & Tai, 2009), this stage presents considerations for females in science in particular. Research has found that, despite high academic performance, females’ interests and active participation in science during middle school decline (Hill, Corbett, & St Rose, 2010). Research has also shown that up until about ten or eleven years old, both boys and girls demonstrate evidence of comparable levels of science interest and confidence; but a gender gap appears at this stage, a disadvantage to girls, widening throughout high school (Ferreira, 2002; Todd & Zvoch, 2017). This gap persists into graduate school with females earning fewer science and engineering baccalaureate and doctoral degrees compared to males (Dubetz & Wilson, 2013). During middle school, the decline in science interest is greater for females than males, and, for most students, the level of science interest developed during this middle school stage will persist throughout their lifetimes, influencing science career interests and attainment (Todd & Zvoch, 2017).

The goal of the present study was to stimulate interest in science and science careers among female students in their middle school stage by transforming science learning opportunities in ways that would appeal to them, based on prior research findings. To this end, literature was reviewed and discussed (see the theoretical framework section later in this article) in order to identify and define major characteristics of science learning environments that have provided evidence of effectiveness for female students underrepresented in science. These characteristics were identified as: opportunities to learn in ways that allowed collaborative and active engagement with peers; hands-on and tangible modes of engagement; real-world connections; and choice.

Furthermore, an overarching pedagogical framework was sought out in order to cohesively integrate each of the aforementioned characteristics of science learning environments. Similarly, from reviewing literature and drawing upon knowledge of pedagogical frameworks, e.g. problem-based learning and culturally relevant pedagogy, arts-integration was selected and explored in this study for its effectiveness in supporting stimulating interests in science and science careers among middle school female students.

In the sections that follow, arts-integration as a pedagogical framework in the context of science education will be discussed, followed by a review of the literature used to define the targeted characteristics of science learning environments, i.e. collaborative and active engagement with peers, hands-on and tangible modes of engagement, real-world connections, and choice, with discussion of each of these in terms of arts-integration in science.

Arts-Integration in Science

Artists and art educators have recognized connections between the arts and science and argued that their integration would facilitate deeper learning and development among students, especially regarding critical thinking and problem-posing (McGarry, 2018). Merryl Goldberg (2017) argues that artists and subject area learners, as in science, must both work with conceptual ideas and knowledge bases, translating and applying these independently and proficiently. For such substantial learning to be facilitated, arts-integration should be systematically implemented.

Goldberg (2017) presents a methodology for such arts-integration where students learn *with* and *through* the arts, as well as *about* the arts. In learning *with* the arts, “Students learn *with* the aid of an art form,[such as a painting, poetry, music, play, or lyrics,] that informs the subject area” (Goldberg, 2017, p. 36). In learning *through* the arts, students create works of art themselves, such as writing and/or performing a play, choreographing a dance, composing music or poetry, or producing a watercolor painting or hand-drawn sketch. Goldberg (2017) continues that learning *through* the arts is particularly powerful as students are provided opportunities to grapple more deeply with ideas and knowledge and actively express their understanding. Further, learning *through* the arts also provides uniquely valuable outlets for expressing emotional reactions to what is being learned.

Learning *with* and *through* the arts also exposes students to works of art and artistic practices. This provides opportunities for teaching and learning *about* the arts, art history, and artists as well. Through arts-integrated subject learning, student interest in learning *about* the arts can, therefore, be promoted, as well.

Arts-integration into science is particularly appealing to stimulate science interest, as in classroom science, middle school females can encounter rigid cultural expectations about how they should engage or perform to be seen as academically proficient (Brickhouse, Lowery, & Schultz, 2000; Tan, Barton, Kang, & O'Neill, 2013). Thus, arts-integration can potentially provide such students opportunities in classroom science, beyond those traditionally expected or required, as means of engagement, exploration, expression, and learning, which may work to transform classroom science into a more welcoming space for them as females. For instance, an arts-integrated science opportunity to identify a research problem of interest may involve students engaging in focused reflection on the physical settings of their neighborhoods by creating drawings of these neighborhoods. Through careful and detailed drawing, students may be encouraged to focus on particular features that may be easily overlooked or dismissed. Elements of interest may become apparent and prompt students to begin to develop questions that can be refined into student-derived lines of inquiry for future research. This arts-integrated option is contrasted with an alternative, more traditional approach to deriving research topics where students may be asked by their teacher to identify and articulate a topic of interest. This latter instructional approach may involve a few minutes at the start of a lesson and quickly proceed to subsequent steps of the research process. The arts-integrated approach may offer a more structured and contemplative avenue for deriving scientific research questions for those students who may not be as responsive to a more short-term and fast-paced performance in the classroom. Diversifying classroom science behaviors and expectations through arts-integration in this way may show students that being scientific can include being artistic, and, more important, that there are diverse ways of being scientific. This is similar to Sochacka, Guyotte, and Walther (2016), who found that arts-integration in science can facilitate opportunities for students to engage with, or become exposed to, a more diverse range of scientific and artistic identities, either within themselves or among others.

Arts-integration further helps students become more active in shaping their learning and can support the establishment of more positive learning environments (Kosky & Curtis, 2008). Moyer and Miller (2017) described a school-community partnership with features of arts-integrated science that reflected such active decision-making and positivity among students. In learning about watersheds, the students in the study decided to address areas of unused lawn on the school grounds to promote better rainwater infiltration by installing a garden. The food produced from the garden was also supplied to the school cafeteria. The students also planted native flora for pollinators. To hide a propane tank in order to beautify and improve the aesthetics of the school property, they created a mural of a watershed. Finally, “. . . [E]ach student placed a hand-painted rock in the landscape design in a symbolic gesture showing that [they] are all responsible for the health of the watershed” (Moyer & Miller, 2017, p. 18). Learning science in this way had:

> . . . given students complete ownership and responsibility for their own learning. They see the “big picture” application of their knowledge, which not only reinforces why careful scientific practices are important, but the significance of their everyday actions as citizens (Moyer & Miller, 2017, p. 19).

Students are more motivated and benefit from interdisciplinary approaches in problem-solving with arts-integration in science (Payton, White, & Mullins, 2017; Sochacka et al., 2016). With inquiry at the core of both disciplines, arts-integration in science can enhance students’ opportunities in learning to question, ponder, reflect, critique, and dialogue in seeking answers to problems through investigations and devising innovative solutions (McGarry, 2018). The arts offer science students the ability to work through problems using materials in grounded, tangible ways that facilitate authentic and experiential learning experiences (Guyotte, Sochacka, Costantino, Walther, & Kellam, 2014). Further, when these arts-integrated experiential experiences are connected to ill-structured, complex problems involving multiple stakeholders in society, they can encourage civic engagement among students (Guyotte et al., 2014).

Theoretical Framework

Designing an Arts-integrated Science Learning Environment for Middle School Females

While arts-integration has been shown to be effective in increasing science interest, engagement, and motivation among diverse groups of students, this study is particularly interested in exploring ways to enhance interest in science and science careers among middle school females. To that end, literature was reviewed in order to identify and define major characteristics of science learning environments that have provided evidence of effectiveness for female students underrepresented in science. Specifically, these factors provided opportunities to learn in ways that allowed collaborative and active engagement with peers, hands-on and tangible modes of engagement, real-world connections, and choice.

It is encouraging that arts-integration is also well-aligned with these characteristics of learning environments. Therefore, in addition to Goldberg (2017), these characteristics have been used to inform the design of an arts-integrated science project implemented with a group of sixth grade female students (11 – 12 years old). The ways in which the aforementioned characteristics of learning environments have been reported in research to support middle school females in science and are aligned with arts-integrated learning environments are discussed next, followed by a description of the arts-integrated science unit investigated in the present study.

***Collaborative and active engagement with peers*.** Learning environments that allow opportunities for positive social interaction and collaboration among middle school females have had a positive impact on their science engagement and success. In an after-school robotics club, Gomoll et al. (2016) found that working with and receiving feedback from their peers were significant in stimulating interest for a group of middle school girls, for instance, by incorporating that feedback into their ongoing problem-solving and robotics design. Some girls even worked to solicit further feedback and willingly provided feedback to their peers, as well. The after-school program of focus in Ferreira's (2002) study was structured in ways to provide such positive interactions during learning opportunities. With all participants working together for eight months, the findings demonstrated consistent gains in female students' attitudes toward science, math, and engineering, as measured by a Likert-style survey. The students' mathematics teacher confirmed these attitudinal changes and also identified their increased participation, their openness in discussing problems in mathematics, and their decreased classroom disruptions. Based on research that indicates females participate more actively in female-only environments (Sax, 2006), informal and formal science programs have been designed with female-only context, and positive outcomes of female attitude toward science and higher engagement with science have been observed (Moore, 2003; Koenig & Hanson, 2008; Dubetz & Wilson, 2013). For young females of color, the opportunity to interact with other females of their racial background was also significant in maintaining active engagement in science. As an example, in Angela Calabrese Barton et al.'s (2013b) study, one young African American girl was initially highly interested, self-confident, and engaged in science as a process of "figuring things out using her brain" (p. 51). She participated in science in different contexts, including the science classroom and a lunch time science club. Over time, however, the demographics of the club shifted, such that the number of White girls increased over time as White female members invited more of their White friends to join. As a result, African American girls left the club, and, eventually, the young African American girl left as well, choosing to spend time with her African American friends over continuing her efforts in science in the context of the club.

Arts-integrated learning environments also support active, collaborative engagement with peers. Karahan, BİLİCİ, and Ünal (2015) investigated the impact of science, technology, engineering, and mathematics (STEM)-integrated media design processes on eighth grade students' attitudes toward science and technology classes and their views about these design processes in after-school activities. Student engagement in media design processes served as opportunities to learn *through* the arts. Karahan et al. (2015) found similarities between engineering and media design processes in terms of problem solving through teamwork and collaboration. The students were asked to create public service announcements, which relied on collaborative learning and skill development. Wynn and Harris (2012) also argued that arts-integration in STEM learning environments encourages collaborative group work that helps prepare students for future professional working environments.

***Hands-on, tangible modes of engagement*.** Learning through hands-on, tangible activities has been positively received by middle school females, but more so than just being “fun,” according to Buck and Ehlers (2002). Rather, these researchers reported that the middle school females with whom they worked emphasized that teaching through hands-on experiences supported them in learning the material more deeply. Elaborating more, they voiced that a teacher merely asking them to do a hands-on activity without explaining the lesson to be learned was ineffective for their deeper learning. Inquiry learning in science through “hands-on, minds-on” activities have been shown to increase problem-solving skills and self-confidence, improving student learning in science, mathematics, and writing (Sutman, Bruce, May, McConaghy, & Nolt, 1997). In Ferriera’s (2002) report on the positive impact of hands-on activities in an after-school program for female science students, one of the participants stated that she had “liked when [they] made things, because it just goes to show girls can do the same as boys” (p. 46). Todd and Zvoch (2017) reported on a summer science intervention program for female students who would be starting middle school later that year in the fall. The program offered the participants hands-on, student-centered activities, as well as relatable near-peer mentors and positive reinforcement. The intervention program supported the participants' development of science affinities, which are undergirded by science interests, self-efficacy, attitudes, and identity.

Motivated by their prior experience as female scientists, Dubetz and Wilson (2013) developed, "Girls in Engineering, Mathematics, and Science" (GEMS), a series of science and math workshops with a wide range of hands-on activities designed for middle school females. GEMS aimed to increase female students' interest in science and math and potentially encourage more female students to enter STEM careers. After attending a GEMS event, the participants' interest in science and math, on average, increased by 35%. The participants' confidence and problem-solving also improved. Observations during one of the engineering exercises (heart valve design) indicated that the participants were initially hesitant to start the design process and wanted to be told what to do to avoid failure. This behavior correlates with findings from Dweck's (2007) research in which female students tend to lose confidence and adapt less easily than boys when given confusing tasks. However, when the GEMS female participants realized that they could determine the point of failure in their valve design and then try something different, they no longer feared failure and were able to complete the task. They saw that scientists and technologists do not usually succeed on the first try, and the stigma of failure was alleviated. The development of a self-confident attitude that encourages female students to risk failure is crucial to success in science and mathematics (Dean & Fleckenstein, 2007).

Females tend to lag behind males in early technology experiences, resulting in lower confidence levels and beliefs that they are behind (Friend, 2015). Hands-on activities may aid in narrowing or overcoming that gap as with Moore's (2003) hands-on program that focused on outdoor science activities for beginning middle school female students, which resulted in significantly more positive attitudes in terms of confidence and anxiety levels toward doing science. Additionally, Koenig & Hanson (2008) saw positive impact from a hands-on after-school science program in terms of the female participants' interest in science, science classes, and science careers, as well as fewer inhibitions about asking questions. In King and Pringle's (2019) *I AM STEM* out-of-school program, Black middle school females benefited from the opportunity to engage in significantly more frequent and high quality hands-on science learning experiences, compared to their regular school-based science learning opportunities. As a result, the girls newly enjoyed doing and learning science and became agentic in pursuing ongoing science-related experiences throughout the school year. Therefore, for female students who lag behind their peers in science, hands-on learning may support them by boosting interest and sustaining engagement.

Arts-integration expands opportunities for students to participate in learning through active movement or hands-on manipulation beyond traditional written forms (Philpot, 2013; Pruitt, Ingram, & Weiss, 2014).

Sheffield, Koul, Blackley, and Maynard (2017) reported on young female students engaged in “making” as a hands-on, engaging, project-based way to apply their scientific subject knowledge. “Making” integrates the arts as creativity, design, and engineering are at its foundation. As a result of these hands-on “making” experiences, the students enjoyed creating scientific artifacts and learning science. The female students were sustainably engaged, struggled and persisted through both frustration and joy in accomplishing the making. “Tinkering is a branch of making that emphasizes creative, improvisational problem solving. It centers on the open-ended design and construction of objects or installations, generally using both high- and low-tech tools (e.g., Arduino microprocessors with pipe cleaners, hot glue guns, and feathers)” (Bevan et al., 2015, p. 99). “Tinkering” integrates hands-on artistic and engineering design and scientific thinking as well. Hands-on “tinkering” opportunities for young females in after-school STEM programs supported their active engagement in science, which was characterized by investments in time, thought, and emotion, and facilitated collaborative peer experiences where friends aided each other in constructing their devices (Bevan, Gutwill, Petrich, & Wilkinson, 2015). The middle school female participants in Gomoll et al.’s (2016) after-school robotics club were also motivated to engage and persist by opportunities to “tinker” with tools and materials in personalizing their robots.

Hardiman, Rinne, and Yarmolinskaya (2014) state that arts-integration enhances students’ engagement with conceptual ideas by allowing them to “rehearse content” (p. 144) through various artistic practices, e.g. oral production or physical creations/installations. For the students in Gurnon, Voss-Andreae, and Stanley’s (2013) study, learning *through* hands-on artistic experiences, which involved designing and fabricating sculptures representing mature proteins, allowed experiences analogous to “rehearsing content.” The students accomplished deeper understandings of conceptual ideas beyond their previous intellectual engagement. As an indication of their deeper learning, as the students participated in a public art display as a culminating learning experience, they posed deeply thoughtful questions about the topic, including some current questions hotly debated in the scientific research community.

***Real-world connections*.** Opportunities to learn about science as it relates to the real world has been positively impactful on middle school females’ engagement and success in science. In their research, Buck and Ehlers (2002) engaged 58 middle school females across six different states in focus group discussions about their feelings and experiences in science education. They found that the participants saw their individual fit in science and explored science extensively by asking many questions; however, they rarely had the opportunity to explore that fit, nor found answers to their questions within their middle school science classes. Therefore, the participants tended to experience a disconnect between science class and the real world, thus limiting their development in science. Moore (2003) researched the impact of an intervention that was more authentically situated in the real world in which sixth grade female students learned to investigate woodlands specimens, safety and tracking in the woods, and the impact of human-caused pollution on ecosystems. They ended the days composing poetry about their experiences. Data were collected from all participants via surveys of the girls' confidence and anxiety levels related to doing science. Analysis of the survey data revealed significant growth in the girls' confidence in doing science, as well as reduction in anxiety.

Similarly, Koenig and Hanson (2008) focused on educating middle school females about science and math in everyday applications with an emphasis on STEM careers and found that 90% of the participants experienced positive changes in attitudes and interest in science, science classes, and science careers. Farland-Smith (2009) integrated real-world connections into the design of her intervention for middle school females by providing learning opportunities that exposed the participants to adult professional scientists in laboratory and field settings. From qualitative data, the intervention resulted in a "keen appreciation of the sciences" and "both a heightened and broadened awareness of science as a human endeavor" (Farland-Smith, 2009, p. 415), improving upon the participants' already positive perceptions of science and scientists. In a girls-only after-school conversation club, young female students learned to construct digital scientific stories using media design technologies. The instructors started with engaging in dialogue with the girls in order to identify everyday real-world experiences that were important to them. Next, the instructors identified connections between these real-world experiences and science. This pedagogical strategy was a more meaningful introduction to science for the female participants and helped them successfully position themselves as “insiders” to the culture of science, including feeling skilled and recognized in that scientific space (Gonsalves, Rahm, & Carvalho, 2013).

Incorporating real-world connections was found to support positive student learning outcomes in arts-integrated learning environments, as well. The students in Clark and Button’s (2011) study engaged in an arts-integrated learning environment that was focused on the real-world challenge of sustainability. Students had to present solutions to problems posed around the three pillars of sustainability – environmental, economic, and social – and, as a result, expanded their understanding of science through sustainability, increased their imaginative conscience, and engaged in community action. The young women in Moore’s (2003) program, above, who engaged in science learning *through* poetry were immersed in the real-world setting of nature while learning about ecosystems, safety, and other topics. Others have advocated for grounding art and science education in real-world contexts, arguing that art and science can “meld fluidly together” (Bequette & Bequette, 2012, p. 40) as design work in both disciplines has aesthetic and functional implications in real life. While the outcomes of design processes are different for artists and scientists, Bequette and Bequette (2012) claim that negating aesthetics shortchanges students and compromises arguments advocating the interdisciplinary nature of science learning. They go on to argue that real-world authenticity of art projects, where the art is the end-product, and not just a means to an end, helps in the retention of young people in science, due in part to the sustained cross-disciplinary learning.

***Student Choice*.** Effective pedagogy for adolescent learners confirms higher levels of success when student choice is integrated into learning (Holland, 2000; Muir, 2001). Science learning environments that provided middle school females choice in how they participated in the practices of classroom science enabled them to negotiate satisfying science identities that met the requirements for participating in classroom science and also integrated past experiences, interests, and preferences (Calabrese Barton, Tan, & Rivet, 2008). The female students had choice, for instance, in creating and using a song as a learning tool, in performing the task of the recorder/note-taker and observer during small-group work rather than every group member being forced to manipulate live specimens, and in being able to physically move around the classroom and interact with classmates. The middle school female participants with whom Buck and Ehlers (2002) worked also reported higher engagement in the science lessons when afforded the opportunity to choose what was studied. Brickhouse et al. (2000) described how young females of color variably engaged in and constructed identities in science. The young females responded differently to opportunities for hands-on laboratory work, classroom discussion, and leadership. These different classroom settings and performance opportunities revealed the young females’ capabilities and interests in science; however, their formal classroom curriculum and instructional practices were insufficiently flexible to allow the females choices for how they could engage in science or demonstrate their capabilities. As a result, some science-interested and skilled young females were positioned as disengaged or under-performing.

Arts-integration into science can support student choice as the arts include a broad and highly varied set of practices, and the arts can be subjective and open-ended (Goldberg, 2017). When integrated into classroom learning, these characteristics of the arts provide students flexible options in participating to learn and demonstrate proficiency, thus appealing to diverse student interests and being inclusive of students’ various needs and preferences (Goldberg, 2017), analogous to differentiated instruction in which students find ways to understand concepts through multiple points of access (Tomlinson et al., 2003). For instance, the arts expand modes and means of expression, beyond traditional text-based activities, for students who primarily speak languages other than English and provide varied means of assessment, particularly performance-based assessments that allow the display of a wider repertoire of skills and understanding among students.

Kosky and Curtis (2008) provided their students expansive choice in their learning through arts-integration and found that this choice was the most significant factor to positively influence student motivation and participation. Both educators and artists acknowledge the ways in which the arts support differentiated access to learning for diverse students and how the arts meet diverse students' needs and preferences (Mason, Steedly, & Thormann, 2008). The arts require innovation and technical skill, which is accomplished through creative problem-solving (Wynn & Harris, 2012), and, at the same time, present students with choice in their decision-making. Mason et al. (2008) found that providing options in how students can engage and problem-solve through art has been successful for students with disabilities nationwide.

Research Focus and Question

The goal of this study was to explore the ways in which arts-integration into science may work to enhance sixth grade (11 – 12 year old) female students' interests in science and science careers. To this end, a methodology for arts-integration (Goldberg, 2017) has been defined, and research describing the effects of arts-integration on student science interest has been discussed. Narrowing the focus to middle school females in science, specific characteristics of science learning environments that have enhanced interest in science have been identified, and the alignment between these characteristics and arts-integrated learning environments examined. These characteristics, specifically collaboration and active peer engagement, hands-on and tangible modes of engagement, real-world connections, and choice, have informed a framework for designing an arts-integrated science unit for implementation with a group of middle school females. The educational context within which these students were situated and the arts-integrated science unit are detailed next. The research question that has guided the investigation into the effectiveness of the unit with the students was: *In what ways did an arts-integrated science unit enhance interest in science and science careers among a group of culturally diverse middle school female students?*

Research Context

The study focused on five sixth grade female students in an English Language Arts (ELA) classroom of 20 students (10 girls, 10 boys) in a recent spring semester. At the time of the collaboration, there was no longer a science class being offered for these students as a result of the teacher having left the position abruptly the previous fall. The absence of science education for the students in this class was problematic from a social justice perspective. Student data presented later will illustrate the students’ own awareness of their disadvantaged position, due to the lack of science education at their school. The opportunity to implement an innovative science education intervention would benefit this group of students, despite a dedicated science classroom and science teacher being the expected ideal situation. Furthermore, the ELA teacher, Ms. Connie, was previously enrolled in a doctoral level science education course taught by the researcher. Ms. Connie challenged the traditional division between science and the arts, including writing and literature, and expressed interest in interdisciplinary teaching involving arts-integration into science. As an innovative classroom teacher, Ms. Connie welcomed the opportunity to design new instructional resources and a learning environment that integrated the arts and science while continuing to make progress with her curricular obligations in ELA. Thus, Ms. Connie did not feel inhibited by arts-integration, along with science-integration, into her ELA classroom, and the project proceeded as an arts-integrated science and ELA unit. The arts-integration methodology (Goldberg, 2017) presented earlier guides the integration of the arts into all subject areas, and, thus, is well-suited to ELA, along with science. Ms. Connie's confidence and optimism in the exploratory opportunity at hand was further reinforced by the researcher, with expertise in science education, serving as a co-designer and co-teacher during the unit.

At the time of the study, the school was designated by the state-wide assessment system as "needs improvement" but "progressing" academically. Most students were designated within the same assessment system as "novice" in reading (55.1%), writing (39.8%), and language mechanics (69.9%), and apprentice in mathematics (43.2%). The racial and ethnic composition of the student body in 2015-16 included: 45.2% White (not Hispanic), 46.9% African American/Black, 4.5% Hispanic/Latino, 1.1% Native Hawaiian/other Pacific Islander, and 2.3% two/more racial/ethnic identities. There were 50.8% females and 49.2% males in sixth grade. Eighty-seven percent of the students enrolled in the school received free lunch, an indicator of low socioeconomic status.

Participants and Data Collection

This qualitative study focused on five female participants in the sixth grade class of 20 (10 girls, 10 boys total). Pseudonyms and select background information are summarized in Table 1. The participants were interviewed prior to, and immediately following, the four-week unit. Interviews focused on students' cultural backgrounds, families, and interests (subject, career, out-of-school and extra-curriculars); experiences at school; connections between home and school; career exploration and planning; and reflections on their experiences in the arts-integrated science unit. The first author was also present in the classroom throughout the entire unit as a participant observer and co-teacher. This provided access to participant observation data and field notes as well.

Table 1

Participants

Pseudonym	Race/Ethnicity	Languages Spoken
Melissa	Black	English & African dialect
Nancy	White	English
Anya	Black	English
Ianna	White	English
Alisa	Latina	Spanish & English

Arts-integration in Science and ELA to Explore Climate Change

Academic Goals

The unit developed spanned four weeks and focused on the topic of climate change. The academic goals for science were aligned with the Next Generation Science Standards (NGSS Lead States, 2013) and centered on students asking questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century. To achieve this goal, the students engaged in science and engineering practices. These included asking questions and defining problems where students considered new information on climate change and formulated questions of interest to pursue. Additionally, students sourced and analyzed multimedia-based data on climate change to develop evidence-based claims about climate change. Finally, they obtained, evaluated, and communicated scientific information by summarizing insights they had gained from sourced multimedia scientific information, as well as communicated messages they wished to share about climate change to an audience of their peers.

Core scientific ideas of focus in the unit included global climate change, specifically that through multiple data sources, scientists have determined that the average global temperature has increased by about 1°F since the late 1800s. Furthermore, although this increase seems small, the effects on life all over the globe due to climate change have been significant, for instance, in terms of the increased intensity of weather events, e.g. hurricanes, and economic costs from damage of such weather events, loss of habitat and biodiversity, and rising ocean levels. Human activities, such as farming and fossil fuel consumption in driving and everyday home-based activities, have been identified as some of the largest, most significant contributions to climate change beyond natural fluctuations in global temperatures (NGSS Lead States, 2013). Additionally, in regard to science, students learned by thinking through a crosscutting conceptual lens that considered stability and change, as well as cause and effect, to understand that the greenhouse effect has been destabilized due to industrialization and human activities that have caused changes in Earth’s climate system. Finally, students considered the influence of science, engineering and technology on society and the natural world as industrialization has supported innovations in society that has improved the quality of life, but also has had an impact on the natural world, as well as on humans.

While students worked to advance their understanding of conceptual ideas in science, skills in science and engineering practices, and utilization of metacognitive lenses to think scientifically, the learning activities (detailed next) supported their development in ELA as well. The academic goals for ELA, guided by Common Core State Standards (National Governors Association Center for Best Practices and Council of Chief State School Officers, 2010), centered on students writing arguments to support claims with clear reasons and relevant evidence; writing informative/explanatory texts to examine a topic and convey ideas, concepts, and information through the selection, organization, and analysis of relevant content; and writing narratives to develop real or imagined experiences or events using effective technique, relevant descriptive details, and well-structured event sequences. Arts-integration into science and ELA served to support National Core Art Standards (2014), specifically in the field of creating art – conceiving and developing new artistic ideas and work.

Arts-integrated Science and ELA Learning Activities

The sequence of learning activities is summarized in Table 2. Activities that did not involve arts-integration, but preceded or followed arts-integrated activities have been included in the table and unit description below in order to fully detail the context of the students' experiences.

Table 2

Summary of Arts-integrated Science-ELA Climate Change Unit

• Students shared prior knowledge and perspectives about climate change in open-ended discussion. • Students read and discussed sustainability-related **poetry**. • Students learned ***about*** cinquain and haiku poetry. • Students wrote and/or **sketched** in response to sustainability-related **poetry** discussion.	• Learning *with* poetry • Learning *about* poetry • Learning *through* sketching
• Students created original **poetry** and **sketches** about evidence-based climate change claims.	• Learning *through* poetry and sketching
• Students developed initial climate change questions to research. • Students explored core content and finalized climate change questions by participating in multimedia-based activities. • Throughout the unit, students routinely engaged in **sketching** and informal writing to debrief learning experiences and document core content from the multimedia-based experiences. • Through routine **sketching**, students also	• Learning *through* sketching

iteratively drafted plans for research and culminating art creation.	
• Students organized and analyzed teacher-provided and/or additional multimedia source information to communicate answers to research questions in a written essay. • Students learned ***about*** activist art. • Students designed and produced **works of visual art** to further communicate their climate change research findings, their interests, and their progress to an audience of their peers.	• Learning *about* activist art • Learning *through* visual art

For the arts-integrated science-ELA climate change unit, students first thought scientifically and critically about climate change in whole class, open-ended discussion about:

(1) What is climate change?

(2) What do you know about climate change?

(3) Is climate change happening?

(4) Why do you (not) believe that climate change is happening?

This solicited students' prior knowledge and prompted their reflection on everyday experiences and observations as initial data to construct explanations. Students shared at length, and all ideas were included. This share-out served to stimulate student-generated topics/questions for upcoming research. Students submitted their draft questions, providing an opportunity for teacher feedback/guidance. Students' initial questions were organized based on commonalities. The goal at this point was not to revise the questions into testable questions nor to direct students to specific science ideas just yet, but to encourage student-driven interests to unfold. This was important in supporting underrepresented students' interests, choice, and expression in science.

Next, students learned about sustainability *with* poetry by reading and discussing sustainability-related haikus and cinquains. Haikus and cinquains are poems that are formatted based on syllabic/rhythmic and content rules. An unformatted haiku poem was presented: "Forty years from now Children will live in a world Shaped by our choices." Students read, thought silently, then communicated their ideas and questions in oral, written, and artistic forms. They shared as a class and wrote and sketched their thoughts in reaction to the poem in their "artistic scientific notebook" (a large sketchpad). Students, therefore, also learned *through* sketching. Next, the formatted haiku was presented, named as a haiku, and the rules reviewed, thus providing an opportunity for students to learn *about* poetry. Building from these experiences and guided by ELA and science academic learning goals, students were assessed *through* poetry and drawing. Specifically, students were asked to write a ten-line poem that clearly stated a claim, supported by evidence, about climate change. The poem had to include a simile or a metaphor and supported by a hand-drawn picture.

The goal was to support students in engaging in authentic scientific practices, but in developmentally-appropriate and culturally-responsive ways. To do so, students explored the science ideas by engaging in multimedia activities. These included using Google Chromebooks to journey through a virtual global expedition to sites affected by climate change, such as the Swiss Alps, the Arctic, and sub-Saharan Africa (Environmental Protection Agency, 2017), providing students access to digital game-based simulations and vivid, visually-appealing videos; collaborative close-reading and group discussions of online media-based scientific reports; watching the documentary, Frozen Planet (BBC Earth); and reading and responding to strong statements regarding climate change. These activities advanced ELA standards and science and engineering practices as students finalized research questions, learned core content from analyzing source data, and obtained scientific information.

These multimedia activities and experiences were developmentally-appropriate and culturally-responsive, as they provided options in learning modalities, included diverse cultural perspectives, integrated technology, supported peer interaction, and appealed to young students' interests, e.g. the aforementioned digital game-based simulations and vivid, visually-appealing videos of the Environmental Protection Agency's virtual global expeditions. Reading accessibility was considered in selecting materials. Trustworthy scientific (e.g. NASA) and children's science (e.g. National Geographic Kids) articles were chosen. This would assure that the writing styles and reading levels would be straightforward and accessible to the general public and middle school students with little need for extensive scientific background, and further supplemented by graphics. Articles helped students define climate change, use the model of a greenhouse to understand Earth's system of temperature regulation, understand the time scale of climate change over the last century, and list several factors influencing climate, as well as explain how the factors identified work to influence climate change. Student exploration of these multimedia sources was supported by learning *through* sketching and further supported differentiated student engagement. They sketched ideas, explanations, and arguments they were formulating and also sketched to visually summarize or supplement summaries of scientific information they explored.

Students selected multimedia sources (at least three) relevant to their questions and extracted evidence to construct explanations. Using *Google Classroom* as a shared digital resource, students were able to see their classmates' questions. To support students, all questions were organized into a table and cross-walked with relevant multimedia sources that they explored in earlier days of the unit. This table was provided in hard copy to each student as a resource as they worked. Further, the classroom teacher and research continuously prompted students to source climate change evidence from these multimedia sources made available to them when they initially completed the various multimedia, developmentally appropriate and culturally responsive activities. Using various sources of evidence modeled authentic scientific practice by not relying on only one source of evidence.

Various sources also supported student choice as students chose among teacher-provided materials and their own from Internet research. Students would summarize their learning experiences and research findings in a written essay.

Students then organized their research findings and communicated their understanding *through* art by creating original visual renderings using their choice of materials. To support student creativity, choice, and differentiated instruction, a diverse set of art materials and tools were provided, including materials for pencil/color pencil sketching, watercolor, acrylic, oil, and fabric painting; clay sculpting; fabric painting; and graffiti. Beyond simply reporting their findings, in order to report on work done by scientists and others, students learned *about* activist art, i.e. art as a medium to communicate one's message for change. To this end, one guest instructor, a visual and performing artist and educator, Ms. Wellzy, taught the students that through scientific understanding and effective communication, they have the power to "change the narrative" and to tell stories they wished to tell. In this unit, these stories needed only to be related to climate change. This, again, emphasized student voice and served to communicate to these students that, through scientific understanding and skill, they could influence social change, e.g. sustainable living. Throughout the unit, students were provided brief opportunities, often as exit activities, to reflect on ongoing learning and to translate the ideas they had at that point into plans for their final artwork. In the last week, students had extended time to create their designs. Students were not restricted to earlier plans and were free to develop newly designed work.

The arts-integrated unit above included opportunities for the students to learn *with*, *through*, and *about* art. Learning *about* art included opportunities to learn the artistic rules of haiku and cinquain poetry and the tradition of activist art. Students were also given a choice of what kind of final art creation they would use to express their understanding and perspectives. In doing so, they also learned *about* various art forms, including the tools and materials used in those art traditions. Most students chose to use modeling clay to create sculptures. Students also created watercolor paintings and colored pencil sketches.

Creating a Supportive Arts-integrated Science Learning Environment for Middle School Females

In seeking to enhance interest in science and science careers among middle school female students, particularly effective characteristics of science learning environments were identified. These, furthermore, align with arts-integration. These characteristics include collaborative and active engagement with peers, hands-on and tangible modes of engagement, real-world connections, and student choice. The middle school female participants regularly participated collaboratively and actively with their peers as they worked in groups to analyze data, plan and create artwork, and explain concepts to each other. The creation of art, as a culminating project, provided a primary hands-on activity to center learning about climate change, but the participants also sketched, used laptop computers, examined plants, manipulated 3-D graphical displays of data, and more, in hands-on, tangible learning activities. The unit was centered on the important and timely real-world problem of climate change, which aimed to provide social relevance to the participants. Finally, the participants had many opportunities for choice in the project, including the aspects of climate change on which they focused, the research questions they developed, the learning activities they completed, the data sources they analyzed, and, importantly, the entire artistic process resulting in the production of their visual arts rendering, including the artistic materials and tools they used.

Data Analysis

The pre- and post-interviews were all transcribed verbatim and read several times for familiarity. Each interview was then coded using an *a priori* lens for active and collaborative engagement with peers, hands-on and tangible modes of engagement, important real-world connections, and choice and the findings considered in terms of directly impacting each participant’s interest in science and science careers. Two team members coded the data (first and fourth author) and had discussions to arrive at consensus.

Findings

A motivation for conducting the arts-integrated science intervention in an ELA classroom was due, in part, to the social justice issue whereby the female students no longer had equitable access to science class. Some of the female students indicated recognition of their disadvantaged position as a result of no longer having a science class; they stated that they would have to work hard to make up for the loss of science instruction altogether:

> I'll probably have to take science in the future because we haven't really learned science at all this year for a couple of months now. So I'm thinking probably my grades next year probably be something like a C or B because I don’t know all the stuff from this year. So, it would be a lot harder. (Nancy, pre-interview).

Prior to the study, past science education experiences for these students were characterized as lacking important real-world connections and as teaching misaligned with the ways in which they preferred to learn, particularly as they desired to learn through hands-on activities and experiments. Although some of the students had science career plans, none of them were excited about science class. Rather, they struggled with science, saying that it was “confusing” (Ianna, pre-interview), and that they were afraid that they would “mess up” (Nancy, pre-interview).

Critiquing the lack of important real-world connections in her prior science learning experiences, Ianna indicated her preference for the arts-integrated science unit on climate change, stating: “. . . because [the unit] tells me more and I can learn more about the world, but in [my old science class], I only learned about heavy and stuff [as content area topics]” (post-interview). In regard to hands-on and tangible modes of learning, Melissa stated that these experiences were limited in her previous science class due to the teacher's instructional style and lack of supplies. Similarly, Alisa and Ianna discussed the lack of hands-on activities: "[With] our old science teacher, we never use to learn like that. . . . We never did experiments and projects. We just learned about the [content] (Alisa, post-interview); "We didn't really do any experiments, he just made us write down things on the board" (Ianna, post-interview). Meanwhile, the girls indicated a preference to learn in active, tangible ways: "I like seeing how things work in different ways" (Ianna, pre-interview).

At the beginning of the study, two of the five students, Ianna and Nancy, had science career plans, and both aspired to be veterinarians. Nancy was also considering being a teacher, but did not identify a content area. A third student, Anya, planned to be an artist, as well as a chef and a professional athlete. The other two students also identified non-scientific career interests. One of them, Melissa, was interested in pursuing the performing arts or business studies, while the second, Alisa, was interested in pre-K teaching.

Following their experiences with the arts-integrated science unit on climate change, four of the five students identified science career plans. Two of these four students initially planned to be veterinarians. Ianna maintained her initial veterinarian interest, while Nancy changed her plans to pursue being a scientist or a math teacher (formerly a teacher with no content area identified). The other two of the four students were initially interested in non-scientific careers. Melissa switched plans to plant biologist (formerly business and performing arts), and Alisa switched plans to middle or high school science teacher (formerly a pre-K teacher). Alisa was also considering being an ELA teacher, and, given the students' positive interactions with their ELA teacher in this setting, consideration should be given to Ms. Connie serving as a positive career role model. Anya did not plan for a science career, however, she narrowed her array of career plans to be an artist, chef, or professional athlete to becoming an artist. She enjoyed the arts experiences in the unit, stating "I like drawing pictures . . . and painting art is like my favorite thing. . . . I do like doing art and stuff and making sculptures now" (Anya, post-interview). These career interests are summarized in Table 3. Career interests that align with the focus of the unit are indicated in bold and italics.

Table 3

Pre-/Post-Career Interests

Pseudonym	Pre-Career Interest	Post-Career Interest
Melissa	Performing Arts and Business Studies	Plant **Biologist**
Nancy	Teacher or **Veterinarian**	**Scientist** or Math Teacher
Anya	Artist, Chef, or Professional Athlete	*Artist*
Ianna	**Veterinarian**	**Veterinarian**
Alisa	Pre-K Teacher	**Science** or English Language Arts Teacher

Each of the four characteristics of arts-integrated science learning environments investigated in this study was considered in terms of how they supported the middle school female participants’ interests in science and/or science careers. First, regarding active and collaborative engagement with peers, the girls worked in groups, which they often formed themselves, to complete multimedia learning activities, analyze media data, plan and create artwork, and explain concepts to each other. Both Melissa and Ianna reflected positively on their classroom experiences with arts-integrated science and discussed how they had increased positive interactions with their peers as they worked on their projects. Melissa stated that:

> [The arts-integrated science unit] made me feel like I can make new friends by doing class work and not other stuff. . . . I can talk on task. . . . One of the people in my group had clay and they did . . . a [yellow] sun . . . . but it was kind of green. And I told them that you should paint over it. . . . more than one layer (post-interview).

Similarly, Ianna discussed how she developed a new friendship within the transformed classroom setting of the arts-integrated science unit:

> While [Alisa and I] were working on our clay [sculptures], we were talking to each other, getting to know more about each other. . . . Alisa, Amanda (a pseudonym), and Anya. That was the team I was working with (post-interview).

Similarly, Anya stated that “. . . [the unit] helped change some things because I used to be shy and not know anyone in my class. And then once I saw the artwork and stuff, I talked to them and then we became friends" (post-interview). Alisa stated that: "[In the unit, we get to communicate with each other [and] help each other . . . . If we don't know just ask each other and they'll come and help . . . ." (post-interview). As females in science may be limited by socially isolating experiences in science classrooms, it was encouraging to learn that the arts-integrated unit supported welcoming environments that facilitated new friendships, positive peer interaction, and collaboration.

Hands-on and tangible modes of engagement were also supported in the arts-integrated science unit. The culminating creation of a visual arts rendering to represent their research-informed activist message about climate change provided a primary hands-on activity to center the participants' science learning experiences, but the participants also sketched, used laptop computers, examined plants, and manipulated 3-D graphical displays of data as hands-on, tangible learning activities. Learning *through* sketching, in particular, was consistently used for students to reflect on and debrief activities of the day, to organize notes on new content learned or data analyzed, and to iteratively design their upcoming works of visual art.

All of the female participants expressed high levels of enjoyment from engaging in these hands-on and tangible activities in order to learn science, as indicated by some earlier quotes. For some, these hands-on activities had the impact of influencing decision-making toward science-related careers and feelings of being skilled in science. This impact was particularly dramatic for Melissa, who discussed a new interest in scientific experimentation, particularly with plants and flowers, and explained that her career plans had changed from business and performing arts to the scientific field of botany. Melissa was particularly influenced by the small group hands-on activity in which students examined and identified the parts of a plant brought in by a biologist as a guest teacher, as well as analyzed data relating temperature patterns, pollen levels, and rates of asthma. Through her culminating artwork, Melissa illustrated her new-found interest, along with her fond memory of working with the plant biologist and flowers, via a watercolor painting depicting flowers and the greenhouse effect. In her post-interview, Melissa said:

> [I'd like] to be a person who explores flowers. . . . and plants. . . . Experimenting with how they change [over] time. . . . [I have changed career plans from performing arts and business studies] because now that we're doing stuff like that [in the arts-science unit,] I wanted to experience for myself how science really actually works, by actually experiencing and touching and stuff . . . . Now I want to be a plant scientist . . . . (post-interview).

Melissa reflected on how science engagement in the unit differed from the past, how she enjoyed engaging in science as structured in the arts-integrated science experience with her ELA teacher, and how the project made up for their loss of science class by saying:

> [I liked] . . . painting and I learned more stuff that I should know. . . . Doing our research and [the plant biologist] had brought a plant that made me learn more about climate change because in my earlier years we didn't talk about that kind of stuff. . . . We also did experiments with the paint. [Miss Connie] showed us how to mix . . . and make lighter colors. It's fun. . . . We didn't have the [science] teacher . . . [but] now I feel like we still do science no matter who the teacher is." (post-interview)

In the unit, Melissa had authentic opportunities to perform actively as a scientist and as an artist in working directly with plant specimens and art materials. Like her peers, Melissa indicated the significant loss of science class for her and stated that the arts-integrated science unit, even when implemented in an ELA class, furthered her development in science. Melissa stated that the unit "got [her] back to science" and stimulated a new career interest as a "plant scientist" (post-interview). So moved by this new engagement in science, Melissa further discussed her desire to serve as a science career role model and to bring science to students who similarly lacked equitable access:

> I will work with kids, teach them how I'm going to college and going to become a scientist, plant person . . . . I will make a program for kids who don't have science stuff at their schools and sometimes I'll just do it for anybody and I go to their school and teach them. . . . do

> experiments . . . . To make them think about what they want to be when they grow up. Maybe I can inspire them (post-interview).

In her pre-interview, Nancy stated that she was afraid that she would “mess up” in science and that math was too difficult, although she worked hard at it. Following the arts-integrated science unit, Nancy discussed how it helped her to learn new things, including words that she did not know prior, and to feel more skilled, saying: “[I] did [feel more skilled] because I was actually learning something that had to do with science. . . . We were doing something like a science project, but it was also a language arts project because you're reading and learning. And then, on the other hand, you are learning about changes on the Earth” (post-interview).

Anya expressed feelings of satisfaction in being able to create artwork through the hands-on activities of the unit, as well. She was very interested in art, stating: “I like drawing pictures and painting. Art is like my favorite thing. . . . I would be happy [if other teachers integrated creative arts in their teaching] because I do like doing art and making sculptures now.” (post-interview). Beyond sheer enjoyment in creating art, Anya stated that the hands-on activities supported scientific understanding and motivated her to learn more about climate change:

> I didn’t know nothing about this stuff and then I learned a lot about global warming and climate change and carbon dioxide. . . . I do want to learn more about global warming and stuff about climate change

> and carbon dioxide. I think it was fun. . . . I want to do it again because it was fun thinking about this stuff and I didn't know that stuff so I want to learn more. And every day I go home and I tell my mom what I learned at school about science . . . . (Anya, post-interview)

Anya became actively engaged in science and indicated that she now included her mother in that active engagement. Ianna and Alisa also indicated that they enjoyed the hands-on activities and research. Alisa expressed a new interest in becoming a middle or high school science teacher — she previously wanted to be a pre-K teacher — in order to continue the kinds of hands-on activities that she experienced. She stated: ". . . in science, you do experiments and projects with kids every day" (post-interview).

The girls were previously critical of the lack of important real-world connections in their past science experiences. Ongoing opportunities to learn *through* sketching to debrief learning experiences, document core content learned, and plan the upcoming visual art renderings of the unit served to continually ground their engagement in artistic processes in the important real-world scientific challenge of understanding and addressing climate change. This served to make the process of engaging with and creating art compelling and more than busy work. As Ianna earlier stated, the arts-integrated science unit was productive for her in being focused on a real-world, socially relevant issue: ". . . [the unit] tells me more and I can learn more about the world . . . " (post-interview).

Additionally, the arts-integrated science unit was motivating and impactful to some of the girls in aligning with, or furthering, their career interests. For instance, learning about the threat of polar bear extinction was motivating for Ianna, as this topic connected directly with her interest in animals and desire to be a vet. Ianna stated that: “[As a vet,] I want to help dolphins and seals and polar bears. . . . Polar bears can become extinct. . . . Polar bears don’t need to die and become extinct and this is all caused by climate change and it needs to stop” (Ianna, post-interview). Ianna’s passionate message following arts-integrated science learning experiences is contrasted with her recalling what she learned from her traditional science class:

> We didn’t really do any experiments . . . . We only did one experiment and it was about – I can’t remember. But he had a cup and another cup. One was filled with water and one wasn’t. And he put a ball in one and –. It was about heaviness (pre-interview).

In this case, Ianna could not recall what she had learned, but rather struggled to identify the purpose of the science experiment that the teacher had conducted, in contrast to the students themselves participating in a hands-on learning opportunity. Similar to Ianna, Anya connected with the activities in the unit that had relevance to her real-world interests that existed outside of school, and, as a result, narrowed her array of career choices: “When I grow up, I think I want to be an artist because we did [the unit and] it made me learn a lot about art. So, I think I want to be an artist" (post-interview). Anya had earlier career interests in being an artist, along with other careers; but the opportunity to learn more about a topic in which she had an authentic interest served to reinforce and further that career interest.

Finally, the girls had many opportunities for choice in the project, including the aspects of climate change on which they focused, the research questions they developed, the learning activities they completed, the data sources they analyzed, and, importantly, the entire artistic process, including the artistic materials and tools they used, through which they created a representation of their knowledge. Despite this, none of the girls explicitly discussed having choice in the unit as the reason for their enjoyment; however, as indicated above, they all expressed high levels of satisfaction with the opportunity to learn and engage in science in arts-integrated ways as supported by the unit.

Discussion

Active and collaborative peer engagement was an important factor in this study contributing to increasing the five girls' interest in science and science careers, as well as their enjoyment in the unit. In other studies, the positive impact of female-only environments have been identified (Dubetz & Wilson, 2013; Koenig & Hanson, 2008; Moore, 2003; Sax, 2017); however, female-only groups were not intentionally organized in this study. Despite this, interviews and participant observation reveal that some of the girls did work in female-only small groups. As the class was comprised of 50% each of male and female students, females were not overrepresented. Evidence of choosing to work in female-only groups encourages further exploration of the impact of intentional female-only contexts to enhance the effects of arts-integrated middle school science learning environments.

Hands-on, tangible modes of learning was also an important factor contributing to increasing the girls' interest in science and science careers. Prior to their engagement in the unit, the participants in the present study critiqued the lack of hands-on learning in former science. They did not merely want "fun" activities and explained why they preferred hands-on methods. For instance, Ianna stated that she ". . . like[d] seeing how things work in different ways . . . ." (pre-interview). Similarly, Melissa explained that she ". . . wanted to experience for [her]self how science really actually works, by actually experiencing and touching and stuff . . . ." (post-interview). Their comments align with the middle school female participants in Buck and Ehlers' (2002) study who expressed that a teacher merely asking them to do a hands-on activity without explaining the lesson to be learned was ineffective for their deeper learning.

Additionally, hands-on experiences have been shown to boost middle school females' confidence in science (Dubetz & Wilson, 2013; Moore, 2003; Sutman et al., 1997). In the present study, these students also discussed feelings of greater skill as a result of the arts-integrated science unit. This enhanced confidence in science abilities is even more important, especially in light of earlier discussions where students described their previous science experiences as confusing and difficult. Further, as they expressed awareness of their disadvantaged position from having lost access to a science class, boosting their feelings of science confidence may aid them when they return to a regular science class schedule. Overcoming perceptions of science as difficult and of falling behind peers would be critical for the middle school female students, given the gender gaps that arise and widen during this stage (Ferreira, 2002; Todd & Zvoch, 2017).

These students also critiqued their former science class experiences for their lack of real-world connection in favor of an emphasis on decontextualized content. Students who are not motivated by science as presented traditionally in school may struggle in classroom science, despite being actively engaged and developing in out-of-school settings where science is more authentically grounded in the real world (Calabrese Barton et al., 2013b; Calabrese Barton et al., 2008; Calabrese Barton & Yang, 2000). Real-world connections were established by centering the unit on the authentic real-world challenge of climate change. Further, students' work as artists was framed as activists and communicating powerfully and persuasively the implications of what they had learned about climate change through the arts.

Learning about climate change from the perspective of an activist artist supported more meaningful science development for Ianna than her previous traditional science classroom experiences, revealed in her passionate message about the threat of polar bear extinction and other harm to animals. At the same time, she struggled to recall the purpose of a science demonstration in an earlier class with her former science teacher. She did not recount this prior science experience with interest or excitement and dispassionately critiqued the emphasis on decontextualized content topics. This was very reflective of Calabrese Barton et al.’s (2013a; 2013b) study, whereby a young female student, Diane, vividly and excitedly recalled past science learning experiences that were grounded in meaningful, real-world contexts. Similar to the female participants in Buck and Ehlers’ (2002) study, Ianna had a long-established science career interest in becoming a veterinarian, which had preceded her experience with the unit and, therefore, did not struggle with identifying as a future scientist. However, the girls in both contexts expressed a lack of interest in traditional classroom science, but a desire for science presented to be connected to the real world. One must be wary about the disconnect between traditional classroom science and out-of-school science experiences, especially if the excitement and interest that female students, like Ianna, express are connected to science in real-world context, but not to classroom science. This may have implications of eroding their already established science career interests.

Real-world connections supported Anya’s engagement in the unit, despite not stimulating science career interests. She was interested in being an artist, as well as possibly a chef and/or professional athlete. The opportunity to create art was a positive experience for her that connected with her prior out-of-school interests. By the end of the unit, she narrowed her career exploration to planning for a career as an artist. While the project set out to encourage female middle school students' science career interests, one important goal of educators is to support students in identifying and attaining careers that best fit their interests and would allow them to be self-determined and satisfied in life (Blustein, 2006). Thus, while Anya became more interested in the arts than in science, it is encouraging to learn that her experiences in the arts-integrated science unit supported her positive career development.

The arts and sciences share a common challenge of equitable engagement, as both fields have been perceived by many as elusive domains exclusive to few individuals with particular or exceptional knowledge and skills (Calabrese Barton & Yang, 2000; Markowitz, 1994). Working to expand accessibility to these fields may benefit from situating arts-integrated science in real-world contexts, particularly in topics or domains with which students are familiar or interested. Familiarity and interest are often associated with prior knowledge and skills (Bandura, 1997). Therefore, arts and science integrated into such unified topics or domains may build upon students' prior knowledge and skills. In so doing, students may recognize that similar bases of knowledge and skill span both the arts and science. Furthermore, if students perceive themselves as skilled or capable of growth in either science or art, they may also recognize their ability to develop knowledge and skill in the other discipline as well.

Much of the girls' explicit reflections focused on the impact of the arts-integrated science unit in terms of supporting active and collaborative peer engagement, hands-on and tangible modes of learning, and real-world connections. While choice was not explicitly discussed by the girls, research has shown the significance of choice (Brickhouse et al., 2000; Calabrese Barton et al., 2008; Tan et al., 2013). There was evidence that student choice was important to some of the female participants in this study, although discussed in a non-academic area of school. Melissa, for instance, explained that one major dissatisfaction she experienced at school was having to wear a uniform as she was unable to showcase her individuality and culture: "If we were out of uniform . . . . [The uniform] makes us all the same but when I'm out of uniform, like I get to show what we get from Africa . . . . Like me, jewelry that I get from there . . . ." (Melissa, pre-interview).

Melissa sought autonomy in choosing how she dressed for school each day. While choice may have supported the overall appeal of the unit for the girls, this was not explicitly stated. Future research would seek to explore the effect of choice in arts-integrated science settings among middle school females.

Conclusion

This project aimed to transform science engagement opportunities for a group of culturally diverse middle school females, who, at the time of the study, experienced an inequitable lack of access to high quality science education. Arts-integration is a valuable approach to re-conceptualizing and transforming formal science learning environments, namely the science classroom, to be responsive to the needs of underrepresented and underserved students in science, including females, low-income students, and students of color. This study has provided practical guidelines and examples for translating arts-integration in the core content area of science into action, especially emphasizing factors identified as best practices for supporting middle school females in science, namely active and collaborative peer engagement, hands-on and tangible modes of engagement, real-world connections, and student choice. Findings from the empirical examination of the unit have explicated the ways in which the arts-integrated science unit has enhanced the female participants' interest in science and science careers.

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