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Using Hands-on Experiences Including Various Forms of ARTS to Increase Ninth-Grade Female Students' Interest in STEM

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Abstract

Aim: The research aims to increase interest and a greater awareness of STEM fields among female minority students by providing hands-on STEM-infused workshops incorporating the arts as a central theme.
Methodology: The research methodology involved conducting workshops for thirty-seven female students, primarily from low socioeconomic backgrounds, who attended fifteen-hour-long STEM-infused hands-on workshops presented by university professors in the College of Education and the College of Arts and Sciences.
Findings: The study's results revealed that the 15-week STEM workshops positively impacted the female students' attitudes toward STEM. In addition, the post-survey results showed a significant increase in their interest in Science, Technology, Engineering, and Mathematics. The data from the results is a promising finding, as it indicates that targeted interventions can effectively increase STEM interest among young female students from underrepresented backgrounds.
Implications/Novel Contribution: The implications of this research are significant as it addresses the underrepresentation of female minority students in STEM. In addition, the project enabled students to participate in STEM education inclusively and innovatively. Our aspiration is that through this initiative, students will be able to contribute to promoting diversity and inclusivity within the STEM fields. In addition, the results of this research may provide insights into practical strategies for increasing diversity and inclusivity in STEM fields.

Keywords: High school STEM education, Female students, Integrating the arts, STEM interest, and awareness.

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INTRODUCTION

Job and career opportunities in STEM experienced tremendous growth each year. Because of this, industry professionals, politicians, and educators strongly encourage and support students matriculating into degree programs in the STEM field. While the growth in the number of graduates needed to fill the increasing number of opportunities is promising, there are still limited female and minority students in the STEM fields (National Science and Technology Council, 2018). The lack of female and minority students in the STEM fields may be due to a need for more interest in STEM exposure early on. Disenfranchised students need the opportunities afforded to students in more affluent areas of a school district, city, or state (Anderhag et al., 2016). Research shows a lack of minority female students going into the STEM fields. It is partly due to the need for more exposure and awareness of the various options available in the STEM fields. The researchers measured STEM knowledge and understanding amongst ninth-grade minority female students at the beginning and end of the research study.

The growth of job and career opportunities in STEM fields has been significant and is projected to bolster even more demand for STEM professions through 2029 (Fry & Funk, 2021). However, research shows that a small percentage of women and minorities are in these fields. Therefore, STEM interest begins early, highlighting the need to expose students to STEM-related workshops at a young age. This research study aims to expose ninth-grade female students from all racial and ethnic backgrounds to STEM through hands-on workshops. The study also incorporates the arts into the curriculum, as research showed that the infusion of the arts could help scaffold the teaching of science concepts. The research location is a public charter school that receives funding from the state, and the participating students were chosen based on their academic performance.

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Research has shown that middle and high school students in the United States are underperforming in STEM subjects. According to the U.S. Department of Education (2015), only one-third of 8th-grade students perform satisfactorily in science and math. Once students reach their senior year of high school, only 22% are proficient. Not only are they underperforming in science and math, but a limited number of students enrolled in engineering-related courses (National Science Board, 2016). Further, approximately half of STEM students change their college majors if they do not drop out altogether.

Regarding gender, males are more likely to enroll in STEM courses in college and graduate with STEM degrees (Burgess, Hauberg, Rangvid, & Sievertsen, 2022). Women who attain college degrees in STEM are less likely to enter careers in engineering, computer science, and the physical sciences (Fry & Funk, 2021). Most women with STEM degrees typically work in health-related careers. Only 15% of the nation's engineers and architects workforce are women (Fry & Funk, 2021). Hispanics and Blacks are the most underrepresented in the STEM fields. Hispanics comprise 8% of STEM workers in the U.S., while 9% of Blacks work in STEM careers (Fry & Funk, 2021).

The researchers and workshop presenters are faculty members at a private university in Florida. The study aimed to include 9th-grade female students from all racial and ethnic backgrounds and expose them to hands-on workshops related to STEM. Further, it is the view of the researchers involved in this study that this population of underserved, minority students would benefit from the infusion of the arts in the project. According to Brouillette (2019), "Now there is growing recognition that, in STEAM projects, the arts not only play their traditional content area role but also scaffold the teaching of science concepts that students could not otherwise envision" (p. 58). One challenge educators face when introducing new and often unfamiliar STEM concepts is building a personal connection that will have meaning. Through creative, arts-based approaches, this challenge is more likely to impact the imagination and interest of the student. This effort to connect is carefully crafted by the educator, with an emphasis placed on STEM disciplines. The arts are a paved learning pathway that allows students to invent, problem-solve, create, and make what they are learning tangible. The research location is a public charter school that receives funding from the state. The principal and his leadership team provided the physical space and staffing necessary to support the STEAM workshops. In addition, STEAM professionals recruited from Nova Southeastern University (NSU) delivered art-focused presentations at the weekly meetings.

The ninth-grade female students from SLAM Palm Beach High School participated in this research study provided by faculty members from NSU. The parents of the students granted permission to allow their children to participate since they are not adults. The students were chosen based on their academic performance. One group of 25 female students was from the school's advanced science class (biology), with the remaining 12 students participating on a volunteer basis. The biology class had a Florida-certified teacher and two aides.

METHOD AND MATERIALS

All participants in the study were ninth-grade female students from the school's advanced science class and those who volunteered to participate. The school helped identify all 37 students who participated in the research study. Participants had the right to refrain from participating in the study at any time. If students decided not to participate, they still received the regular science program at the school. There was no guarantee or promise that participants would receive any benefit from participating. However, a possible benefit of participating in the research study was to increase their science knowledge and awareness of the STEM (STEAM) field. In addition, the researchers expected that the information gained from the survey would benefit others in similar settings.

Before the start of the project, participants took a pre-survey using the S-Stem questionnaire to assess their perceptions and knowledge of STEM classes and careers. The students then participated in weekly STEM workshops with a pre-planned STEM curriculum created by the presenters and researchers. After 15 workshop sessions, the researchers compared the pre- and post-survey data on the S-Stem questionnaire.

Nova Southeastern University professors worked collaboratively to develop the creative, arts-based science-focused curriculum. We enriched each science-based instruction with an innovative platform. Professors shared their professional histories with students to establish a connection. Sharing information about how each professor became a scientist and educator helped forge a necessary relationship with the students. Building a trusting relationship with students was an additional focus for the educational team.

The study aimed to benefit the participants by improving their perceptions of the STEM fields and their science knowledge. The lead researcher stored the participant information on a university computer and ensured that all information about the research participants was handled confidentially, within the limits of the law. The researchers will use the data for granting agencies and publications to share knowledge with other researchers and educators.

The lack of knowledge and skills to continue in STEM education is a significant issue, particularly among K-12 minority students and predominantly females within the United States. To meet the need for STEM professionals, educational leaders in the United States emphasize bolstering the nation's STEM workforce (Fry & Funk, 2021; Kharabi Masouleh, 2020). This research study aimed to increase interest and participation in STEM fields among female students from all backgrounds by exposing young students to STEM and incorporating the arts into the curriculum.

Many K-12 students, predominantly minority female students in the United States, lack the knowledge and skills to continue their STEM education and ultimately enter the workforce. There is an estimated 13% growth rate of STEM careers between 2017 and 2027, compared to 9% in other career fields (Education Commission of the States, 2020). To address the demand for STEM experts, education authorities in the United States strongly assert that "strengthening the nation's Science, Technology, Engineering, and Math (STEM) workforce is crucial for maintaining a competitive advantage in a rapidly evolving global job market" (National Education Association, 2016).

In their earliest years, children are natural scientists and engineers. By the time these same students reach the middle grades, approximately 50% have lost interest in focusing on higher education or a career in one of the STEM disciplines (Murphy, 2011). Some researchers believe that students are interested in STEM disciplines, while others feel a strong interest never develops (McCreedy & Dierking, 2013; Mazhar, Jam, & Anwar, 2012). Whatever the reason, the STEM pipeline is diminishing when students reach middle school and continue into college. According to Anderhag et al. (2016), the demographics most affected are low SES students from racial and ethnic minority groups and females (Figure 1).

Example 1	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
	o	o	o	o	o

Figure 1. Perceived Reasons for Gender and Ethnic Under Representation in STEM

Equal gender representation is one of the most significant concerns for educators. Studies have shown that, while gender disparity is lessening, more can be done to recruit females into STEM-related courses and careers (Hawkins, 2015). Efforts to rectify this problem have shown that exposure to informal STEM experiences in the early years can lead to positive results in learning and participating in STEM disciplines (Langdon, McKittrick, Beede, Khan, & Doms, 2011). This research project involved developing and delivering weekly STEAM hands-on workshops to high-school females and evaluating their effect on STEM interest, awareness, and knowledge. One of the overarching research questions that guided the researchers' work was, "Will student participation in STEAM workshops increase high school females' STEM interest and awareness?"

In the most recent census, West Palm Beach, Florida, had approximately 110,000 residents, with a racial breakdown of 37% non-Hispanic white, 34% African American, and 25% Hispanic, earning a median income of roughly $54,000 (United States Census Bureau, 2019). The School District of Palm Beach County (SDPBC) consists of 160 K – 12 schools enrolling approximately 170,000 students annually. The district offers over 300 Choice programs that allow students to focus on various personal interests (e.g., the International Baccalaureate program, programs dedicated to music and the fine arts, information technology, and foreign languages). In addition, three schools host Choice STEM programs at the high school level (Palm Beach County Schools, 2020).

The study occurred in a West Palm Beach, Florida, urban school district. SLAM Palm Beach High School is a Title 1 school serving predominantly Hispanic students with approximately 200 students enrolled. In the most recent school year, the population was 70% Hispanic, 14% Black, 12% non-Hispanic white, and 4% represented other racial and ethnic groups. The population is 44% female and 56% male, and 88% of students are eligible for free or reduced lunch. The school has 10 Choice Programs, and no Choice STEM programs (Palm Beach County

Schools, 2020).

Based on the Central Limit Theorem (CLT), the sample size of 37 is sufficient for statistical significance. Therefore, the researchers used the Central Limit Theorem to guide the study. Using the CLT, the sampling distribution will always work if the sample size is large enough, in this case, 37 students.

Before the workshops began, the students were given a pre-survey on Science, Technology, Engineering, and Mathematics in October 2022 (Figure 2).

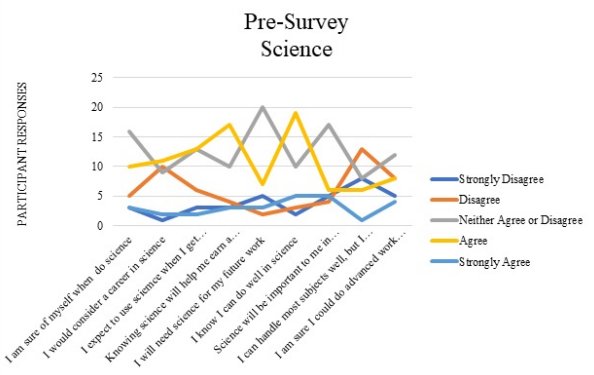

Figure 2. Sample Pre-Survey Results (Science)

This study aimed to introduce various science-related topics to young, primarily Hispanic female students in a Title I high school. Faculty presenters from the College of Education and the College of Arts and Sciences at Nova Southeastern University organized weekly STEM workshops.

Specific steps included:

1. The principal and his leadership team identified a purposive sample of 37 9th-grade female students meeting the required demographic characteristics to participate in the study.

2. The students completed the S-STEM after the introductory meeting and a post-survey at the end of 15 STEAM workshops.

The research team coordinated 15 weekly STEAM lessons with the ninth-grade female students. The activities described below focused on all aspects of STEM integrating the arts. This research aimed to develop and deliver a STEAM-focused weekly program at the high school. Administrators at the school provided teachers, staff, and the physical space necessary to support the program. In addition, STEM professionals from the researchers' private university delivered focused presentations at the weekly meetings, including engineering, anatomy, elementary physics, food science, botany, 2-D painting/drawing, sound, engineering, Tai Chi, and physiology.

Engineering

1. As an initial project, we introduced students to the science of engineering and aerodynamics. Learning about how the Earth and the weather can interact with artificial objects such as airplanes, kites, and weather balloons helped establish a curiosity. Further, artists/engineers, such as Theo Jansen, were highlighted to introduce the natural connection between creativity, the arts, and science. Next, we placed students into teams, and they had to create a unique paper airplane. Then, considering what they learned about aerodynamics through the lesson, students developed airplanes that they tested and flew as a contest to determine which planes would fly longer, higher, faster, and so forth. Following the lesson, students reflected on why they experienced the results with each unique plane.

2. Tia Chi and Engineering: The students learned angular momentum conservation or rotational inertia through various demonstrations facilitated by the university physics professor. During this experience, he told the students that Tai Chi movements were all circles, twists, or rotational. Then he introduced some research results about Tai Chi exercises at Harvard Medical School. Students then participated in a Tia Chi exercise with the professor.

Chemistry Activities

1. The Chemistry of cooking: The professor baked three batches of cookies before the lesson. Each was identical, aside from one chemical compound. Batch one contained baking soda, batch two contained baking powder, and the final batch omitted the white sugar for brown sugar. The students tested each batch, then wrote about the experience from a scientific perspective. Many students shared that they had not considered the connection between science and cooking. Learning about the chemical composition of food was a profound discovery for the students.

2. Food coloring: Students investigated the properties of dyes and pigments by experimenting with food coloring and observing how they mix and interact. They also learned about the chemical properties of different colors and how they relate to the absorption and reflection of light.

3. Nail coloring: Students learned about the chemistry of nail polish by investigating the chemical composition of different types of nail polish and how they dry and adhere to the nail. They also explored the chemical properties of nail polish removers and their effects on the nail.

4. Star Chemistry: Students explored "Life - but not as we know it." We asked the students, 'Is there life out in space?' This question has fascinated people for centuries. Astro-chemists and astronomers are working on it, investigating many molecules in space.

Physics Activities

1. Tai-Chi: Students learned about the principles of physics by practicing Tai-Chi, which involves movements based on the principles of balance, momentum, and energy transfer. They also learned about the physics of sound waves and vibrations by exploring the use of music in Tai Chi.

2. Weights: Students investigated physics principles by experimenting with weights and measuring the effects of gravity, mass, and friction. They learned about the principles of buoyancy and displacement by experimenting with different types of objects in the water.

Mathematics Activities

1. Cooking: Students used cooking to practice math skills such as measuring ingredients, converting units of measurement, and calculating cooking times and temperatures.

2. Weights: Students used weights to practice math skills such as measuring and converting units of mass, calculating forces and velocities, and graphing data.

Biology Activities

1. Botany: We introduced the study of botany to the students through the "eyes" of various botanists and artists. We introduced students to botany and its many career paths. The presenter provided different fresh flowers and plants for students to hold and study. Focusing on the reproductive aspects of the flowers was one way for students to understand the "beauty" of science and its connection to their lives. The presenter used a slides series highlighting works by Georgia O'Keeffe and others. Sharing the beauty of nature through landscape and still life helped pave the way for students to connect to this project. Students followed up the initial lesson by creating a painting of the flowers and plants they received as a part of the lesson.

2. Cooking: Students explored the biology of food by investigating the sources and functions of different nutrients, such as vitamins, minerals, and carbohydrates. They also learned about the effects of cooking on the nutritional content of food.

3. Nail coloring: Students engaged in this activity in which they determined whether nail polish was hydrophobic or hydrophilic. They did a "Liquid Kaleidoscope" activity which involved adding drops of nail polish to the water and using a toothpick to swirl the colors to make a design. They could then dip their fingers to put the arrangement on their fingernails. There was a lot of trial and error to get it right, but they had enough time to do all their fingernails. One student even asked to do one of the presenter's nails, which came out nice.

4. Music and Medicine: The topic was "The Scientific Method: Investigating the Connection Between Music and Medicine." The goal was for them to learn about the scientific method by developing their hypothesis to test an aspect of music that may affect their resting heart rate. Students questioned whether listening to their

favorite song would change their resting heart rate and tried different music genres like rock, funk, hip hop, and bachata. They designed and conducted their experiments, collected data, and analyzed their results.

RESULTS AND DISCUSSION

The Student Attitudes Toward STEM Survey (S-STEM) measures students' interest and awareness of STEM content and careers (Friday Institute for Educational Innovation, 2012) and has shown acceptable levels of reliability and construct validity (Faber et al., 2013). The S-STEM consists of four sections to measure one's perception within the STEM domain (i.e., science, technology, engineering, and math). For this study, the researchers used a modified version of the science section consisting of nine statements with answers ranging from "Strongly Disagree" to "Strongly Agree." The responses represent a numeric value ranging from 1 to 5; the researchers obtained an overall average of the student's input.

Correlation Analysis

Data gathered from the 9th-grade female students leads us to assume their abilities and feelings toward math, science, engineering, and technology remain the same. A correlational analysis was used to interpret the data. Correlation analysis measures the strength of the relationship between variables. A high correlation indicates a strong relationship between the variables. Four areas of STEM were categorized into three groups: math, science, engineering, and technology. Results from the study were used to determine if there was any connection between students' understanding of science and their attitudes about the various science fields throughout the project. For instance, does a student who responds positively to "I like math" also react positively to "I am good at math?"

We used several methods in correlational analysis. The most popular is the Pearson and Spearman correlation. It identifies a degree of association between variables. However, the Spearman correlation is a non-parametric test suitable for data. The Spearman correlation contains two questions about ability and feelings for this analysis. The questions will also be from the same subject. Finally, the comparison is the same, meaning they must be either positive or negative.

The researchers compared two statements from each subject to determine the correlation between students' attitudes and abilities. For mathematics, "I like math" (M1) and "I can get good grades in math" (M8) are analyzed. The science questions included are "I am sure of myself when I do science" (S1) and "I would consider a career in science" (S2). Lastly, the questions considered for engineering and technology were, "I like to imagine creating new products" (ET1) and "I am good at building and fixing things" (ET3).

We used several aspects of the resulting analysis to help determine the strength of the association between variables. A correlation coefficient lies between -1 and +1. A positive correlation coefficient indicates a positive relationship, while a negative correlation coefficient signifies a negative relationship. A value of 0 allows the researchers to know that no connection exists. The significance value is another important attribute, enabling one to understand statistically significant results.

Identifying correlations between variables is crucial for many research problems. For example, assessing this data for correlation allows us to know if a positive relationship exists between the sample students' feelings toward a particular subject and their ability. The results lead us to assume that one with positive feelings toward a subject will likely perform well in that area, and students with negative feelings toward a subject presumably do not perform well.

CONCLUSION

The study's results revealed that the 15-week STEM workshops positively impacted the female students' attitudes toward STEM. In addition, the post-survey results showed a significant increase in their interest in Science, Technology, Engineering, and Mathematics. The data from the results is a promising finding, as it indicates that targeted interventions can effectively increase STEM interest among young female students from underrepresented backgrounds.

The study also highlights some limitations that should help guide future research. First, the study was in a single Title I high school, which limits the generalizability of the results to other settings. Further research should be conducted in other schools to determine whether other researchers can replicate the study and have similar outcomes. Secondly, the study only measured changes in attitudes and interests toward STEM and did not assess the

impact of the workshops on academic performance or career aspirations. Future studies should consider including these measures to provide a more comprehensive evaluation of the intervention's effectiveness.

Another limitation of the study is that the researchers could not collect data from students involved in the project management classes, which limits the ability to compare the effectiveness of different teaching approaches. Future research should consider using a randomized control trial design to evaluate the impact of various STEM interventions on student outcomes.

In conclusion, the study provides promising evidence that targeted STEM interventions can increase interest and engagement among female students from underrepresented backgrounds. However, further research is needed to determine the impact of such interventions on academic performance and career aspirations and evaluate the effectiveness of different teaching approaches. The study will help to inform the development of effective interventions that can support the inclusion of underrepresented groups in STEM fields.

Most researchers will agree that a study's validity lies in identifying an appropriate research problem, developing a robust methodology, strictly adhering to the methods during implementation, properly analyzing the data, and accurately interpreting the results. Studies cannot be invalidated; instead, researchers must recognize threats to the validity of the results and try to control them in the best manner possible. In this case, a sound study was designed and implemented. However, given the ongoing issues in online classrooms and their effect on students, teachers, and administrators, we must continue the research in this area.

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