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Early Exposure/Long-Term Gains: Encouraging Underrepresented Middle School Students to Pursue STEM Careers

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Introduction

Improving STEM education has long been one of the top priorities of past and current United States Presidents. The Office of Science and Technology and the American Institute of Research (AIR) both support efforts designed to enhance and increase awareness and interest in STEM careers (American Institutes for Research, 2018). Despite their efforts, the United States continues to under-produce qualified STEM talent to satisfy future employment demands. According to the National Math and Science Initiative, 60 percent of new jobs will require skills possessed by only 20 percent of the current workforce. The United States is expected to be short by as many as 3.5 million STEM workers by 2025 (National Math and Science Initiative, 2022). These statistics are in blatant contrast to those in other countries. For example, according to the United Nations Educational, Scientific and Cultural Organization (UNESCO, 2020), "students in Oman and Tunisia were most likely to graduate in a STEM field, with between 43% to 46% of students receiving a degree in an engineering, scientific, technical or mathematical field". Further, according to the National Science Foundation and National Science Board, India and China currently lead the world in awarding Science and Engineering degrees. Next is the United States, followed by Brazil, Mexico, the United Kingdom, Japan, Turkey, Germany, South Korea, and France (National Science Foundation/National Science Board, 2022).

Statistics for the underproduction of workers in the STEM field are even more alarming in the African American community. The United States Census Bureau indicates that African Americans represent 12.4 percent of the U.S. population (Nicholas, et.al., 2021). However, only 37% of African Americans, 18-to-24 years of age, are enrolled in college (The Condition of Education, 2020). What is even more alarming is that only 45.9% of African American students

complete their degrees within six years (United Negro College Fund, 2018). Finally, according to the Pew Research Center Report, African American students earned only 7 percent of STEM bachelor's degrees (PEW, 2021). This is below their share of all bachelor's degrees (10%) or their share of the adult population (12%). African American adults are also underrepresented among those earning advanced degrees in STEM. These rates are extremely low compared to other races and ethnicities.

Literature Review

In recent decades, research examining the correlation between students' interest in STEM and the pursuit of STEM careers has increased. One reason students do not pursue STEM careers is the lack of exposure to career possibilities at an early age (Christensen & Knezek, 2017). The early exposure of middle school students to STEM is critical for their effective transitioning to high school and ultimately for post-secondary endeavors. This early exposure is instrumental in building a foundation for the ever-changing skills needed for the workforce and boosting student achievement and test scores (STEM Education Works, 2021). Although early exposure is critical to all middle school students, it is even more critical for those from underrepresented minority communities. According to a Pew Research Center, Blacks and Hispanic adults are less likely to earn a degree in a STEM field and they tend to make up a lower percentage of STEM graduates relative to their share of the adult population (Kennedy, et.al., 2021). According to March for Science (2017), students from underrepresented minority communities leave the STEM field due to a weak foundation in the areas of math and science during their primary years, cultural barriers in the college atmosphere, and a lack of diverse pathways into STEM careers.

To address the problem of lack of early exposure to STEM, informal education

programs have played a critical role in providing students with early STEM learning experiences. According to Cheryan, Ziegler, Montoya, & Jiang (2017), "a critical benefit of informal STEM experiences is the potential for supporting positive attitudes and interests about STEM and combating negative stereotypes, which may be particularly important for fostering inclusivity and diversifying representation in STEM fields." A student's positive attitude towards STEM can contribute to their long-term STEM interests and success. Demir, Onal, Onal (2021) further state that working with the middle school age group is particularly important since middle school represents the first years when career awareness begins to form. Sidharth Oberoi, the President & Chief Academic Officer of Zaniac, further states, "One of the most important factors that limit the United States' ability to stay ahead of the STEM curve is the lack of introduction to these educational areas at an early age" (Oberoi, 2016). Exploratory and peer-reviewed research written by Xie, Fang, and Shauman (2015), linked the ever-increasing importance of STEM education, particularly for traditionally disadvantaged groups, to the U.S.'s enduring economic expansion and well-being. One of the key drivers to sparking inspiration concerning STEM among elementary and middle school age students is the awakening of curiosity through innovative programming. This early exposure to an informal STEM experience should lead to more STEM ready for high school and college students who may ultimately pursue more STEM related careers.

Valverde and Davidow (2022) report that there is a scarce amount of data that highlights the powerful impact of early exposure to STEM education and how it can also result in a heightened interest in STEM-related careers. A powerful tool to provide vital access to this early

exposure to STEM education is through community and institution-based STEM programs. Many communities and institution-based STEM programs have focused on offering programs at the early childhood or elementary levels. For example, an effective STEM program, which is under the umbrella of the National Inventors Hall of Fame (North Canton, Ohio) is called Club Invention, Inc. It is open to students in grades first through sixth to allow for powerful, hands-on engaging afterschool STEM related experiences, such as the *E.Z. Science* program where students conduct experiments and test results (National Inventors Hall of Fame, 2022). Another program is the *Boulder Builders* program where students can act as engineers and architects by building and testing various structures for stability and longevity. They also have the option of creating viable habitats for people and animals (National Inventors Hall of Fame, 2022). The programs are very successful in rendering effective engagement and heightened awareness in STEM education among students through interwoven components of creativity, collaboration, technology, and engineering concepts. However, at such a young age, it is difficult to determine if these programs have truly stimulated an interest in STEM subjects and careers.

Studies have also focused on students interested in the types of curriculums or models. For example, concerning the K-12 curriculum, researchers identified beneficial programs that incorporate engineering concepts with robotics activities. The results fostered positive correlations that were linked to gaining STEM experiences and bolstering communication skills, analysis, teamwork, critical thinking, and analytical development (Kimmel et al., 2014;). A study by Moreno (2016) also investigated the effectiveness of an engineering integrated STEM curriculum design for use in an after-school environment. This study particularly examined the “Think Like an Astronaut lesson” and found that the lessons were appropriate for 5th graders in an after-school environment, and may potentially help

increase students' STEM-related content knowledge and skills. Although various types of research have been completed on early exposure to STEM during early childhood, there has been limited research that has focused on underrepresented minorities and the stimulation of their interest in STEM subjects and careers at the middle school level. Due to the lack of research on the impact of STEM education on middle school students, Tennessee State University (TSU) has focused its program on STEM education with the middle school student population in the underserved community of Nashville, Tennessee.

Purpose of the Study

The purpose of this quantitative survey research study was to examine underrepresented minority middle school students' attitudes toward STEM and their expressed interest in STEM post-secondary subjects and careers after participation in the MUREP project. It is hypothesized that exposure to the various strategies of the MUREP project will produce interest in STEM subjects and careers. This study was guided by the following research questions:

- RQ 1: What were underrepresented minority middle school students' attitudes towards STEM subjects (Sciences, Technology & Engineering, and Mathematics) after participation in the MUREP program?
- RQ 2: Over a three-year period, how did the MUREP program influence underrepresented minority middle school students' attitudes toward STEM subjects (Sciences, Technology & Engineering, and Mathematics)?
- RQ 3: What were underrepresented minority middle school students who expressed interest in STEM post-secondary subjects and careers after participation in the MUREP program?

- RQ 4: What differences exist between underrepresented minority male and female middle school students' attitudes towards STEM subjects (Sciences, Technology & Engineering, and Mathematics)?

For research questions one and three, descriptive analysis was used to generate percentages and frequencies, and to summarize data. For research questions two and four, inferential statistics were used to analyze data to address the associated hypotheses.

The MUREP Project

Tennessee Minority University Research Education and Project (MUREP) Aerospace Academy is a NASA supported project housed at TSU, a Historically Black College and University (HBCU). The mission of the project is "to increase the pool of historically underrepresented, underserved, and differently abled students who will be prepared to enter and complete postsecondary studies in science, technology, engineering, and mathematics, thus creating a diverse and globally competitive workforce". The goals of the project are to (1) inspire underserved and underrepresented minority students to express interest in STEM post-secondary degrees and careers; (2) intellectually engage underserved and underrepresented minority students in firsthand learning experiences involving emerging technologies and high-tech applications; and (3) educate students by utilizing rigorous STEM curricula designed and implemented by effective evidence-based strategies employed by NASA and leading STEM professionals.

Curriculum

The TSU MUREP program curriculum was designed to reflect an integrative approach to teaching and learning. The curriculum design was based upon curriculum content obtained from

Aerospace Dimensions Modules produced by Civil Air Patrol and aligned with NASA's mission directorates of Aeronautics Research. Students selected opportunities of interest from three modules: Module 1: *Up, Up, and Away: Flight, Airplanes and Airports*, Module 2: *Atmosphere and the Rockets That Break It*, and Module 3: *Beam Me Up Scotty! Space and Spacecraft.*

Students engaged in firsthand, materials-rich, and problem based opportunities that involve scientific or engineering investigations. They connected first-hand experiences to STEM career opportunities. They also explored exciting and innovative STEM subjects through the thematic lens of their favorite superheroes from this year's hottest blockbuster movies, such as Transformers, Black Panther, and the Avengers. Students explored career opportunities aligned with the previously mentioned modules. Finally, students experienced emerging technologies that were aligned with module lessons from the Aeronautical Education Laboratory (AEL), such as the planetarium, 3-D printers, virtual reality, drones, Little Bits Premium Space Kits, EV# Legos, Lego Mindstorms, VEX robotics, wind tunnel, flight simulator, interactive software, Osmo Coding, Oculus Glasses, and DNA kits.

Project Design

Students of the MUREP project were engaged in a year-round innovative program design. The project offered STEM enrichment sessions through a combination of in-school, out-of-school, and community outreach models. The in-school sessions were accomplished through monthly STEM days during school hours for middle school students. The out-of-school sessions and community outreach occurred during the evenings, weekends, and summer.

Research Design

This study used a quantitative survey research design. According to Creswell and Guetterman (2019), "survey research designs are a set of research procedures in which investigators administer a survey to a sample or to the entire population of people to describe the attitudes, opinions, behaviors, or characteristics of the population." For this study, this approach was used to survey African American middle school students' attitudes and interests in STEM subjects and careers after participation in the MUREP project. For research questions one and three, descriptive analysis was used to generate percentages and frequencies, and to summarize data. For research questions two and four, inferential statistics were used to analyze data to address the associated hypotheses. Specifically, t-tests and or ANOVA were the statistical test selected to be appropriate for assessing whether there were statistically significant differences. This study addressed the following two hypotheses which are aligned to research questions two and four:

1. There is no statistically significant difference over a three-year period in underrepresented minority middle school students' attitudes toward STEM subjects (Sciences, Technology & Engineering, and Mathematics).
2. There is no statistically significant difference between underrepresented minority male and female middle school students' attitudes in STEM post-secondary subjects and careers after participation in the MUREP program at a local HBCU.

Instrumentation

The project administered the *Middle and High School (6^{th}-12th) survey* which contains four scales. The surveys consist of questions that ask the students about their confidence and attitudes toward math, science, engineering, and technology. Additionally, items on the survey ask students about their attitudes toward 12 different STEM career areas, their performance

expectations for themselves in the next year, whether they have plans to attend post-secondary school, and whether or not they know adults who work in STEM fields. The survey employs a Likert scale response format. Students were asked to rate their agreement on a five-point response scale ranging from "strongly disagree" to "strongly agree" for each given statement. The survey was validated utilizing the Lawshe Method. The construct's reliability levels were measured using Cronbach's Alpha. The constructs for math (.90), science (.89), and engineering and technology were .90 (*Friday Institute for Educational Innovation (2012).*

Participants

There were 418 students assessed from 2019-2022, 212 males and 206 were females, (see table 1 below). There were 250 students in 2019, 44 in 2020, 28 in 2021, and 96 students in 2022, (see table 2 below). The variability in students' participation during the 2019-2022 years was due to COVID 19. Surveys were administered via email instead of face-to-face. There were one hundred and seventy-one (171) 6th graders, one hundred and thirty-eight (138) 7th graders, and one hundred and nine (109) 8th graders. Most (345, 82.5%) of the students were African American, followed by 20 (4.8%) Caucasian, and 32 (7.7%) students who described themselves as other (see table 3 below).

Table 1: *Student Gender by Year of Study Cross Tabulation*

		Student's Current Grade Level			
		6th Grade	*7th Grade*	*8th Grade*	*Total*
Student Gender	*Male*	85	74	53	212
	Female	86	64	56	206
		171	138	109	418

Table 2: *Student Gender by Year of Study Cross Tabulation*

Gender By Year of Study						
		2019	2020	2021	2022	***Total***
Student Gender	*Male*	121	26	14	51	212
	Female	129	18	14	45	206
Total		250	44	28	96	418

Table 3: *Student Gender by Race*

Students' Gender by Race								
		Caucasian	African American	American Indian or Alaska Native	Asian	Hispanic or Latino	Other	*Total*
Student Gender	*Male*	11	169	5	7	4	16	212
	Female	9	176	3	1	1	16	206
		20	345	8	8	5	32	418

Results and Discussion

Research Question (RQ1): What were underrepresented minority middle school participants' attitudes towards STEM subjects (Science, Technology, Engineering, and Mathematics) after participation in the MUREP program?

Over the duration of the project, 56.7% (237) of the underrepresented minority middle school participants expressed a positive attitude towards mathematics, 61% (255) of the participants expressed a positive attitude towards the science subjects, and 56.46% (236) showed a positive attitude towards the engineering and technology subjects. Collectively, there was an overall average of 58.05% (243) of the underrepresented minority middle school participants who expressed positive attitudes towards STEM subjects of mathematics, sciences, and engineering & technology, after participation in the MUREP program.

Research Question (RQ2): Over a three-year period, how did the MUREP program influence underrepresented minority middle school participants' attitudes toward STEM subjects (Science, Technology, Engineering, and Mathematics)?

For the subjects of mathematics and sciences, there were no statistically significant differences in the students' attitudes from year to year. The *p-value* for the ANOVA test results for mathematics from year-to-year (2019-2022) returned an insignificant *p-value* of .230, ($F(3,414) = 1.44$, $p = .230$). It should be noted that the students' overall attitudes towards mathematics were consistently positive and remained statistically at the same level from year to year during the entire project, hence the non-significant result.

The *p-value* for the ANOVA test results for science from year-to-year (2019-2022) returned an insignificant *p-value* of .273, ($F(3,414) = 1.30$, $p = .273$). Consequently, it was concluded that there were no statistically significant differences in the underrepresented minority middle school participants' attitudes toward the STEM subject of science from year to year (2019-2022). The students' overall attitudes towards science were consistently positive and remained statistically at the same level from year to year during the entire project, hence the non-significant result.

For the STEM subjects of engineering and technology, there were statistically significant differences in the students' attitudes from year to year. The *p-value* for the ANOVA test results for engineering and technology from (2019-2022) returned a significant *p-value* of .025, ($F(3,414) = 3.142$, $p = .025$). There was a significant difference in the following pairs of years, 2019 – 2021 (*p-value* .004), 2020 – 2021 (*p-value* .004), and 2021-2022, (*p-value* .010).

Research Question (RQ3): What were underrepresented minority middle school participants' expressed interest in STEM post-secondary subjects and careers after participation in the MUREP program?

Over the duration of the project, 50.48% (211) of the underrepresented minority middle school participants expressed interest in mathematics post-secondary careers, 54.07% (226) expressed interest in the sciences post-secondary careers, and 59.33% (248) expressed interest in the engineering and technology post-secondary careers. Collectively, there was an overall average of 54.63% (228) of the underrepresented minority middle school participants who expressed interest in STEM post-secondary subjects and careers (Mathematics, Sciences, Engineering & Technology), after participation in the MUREP program.

Research Question (RQ4): What differences exist between underrepresented minority male and female middle school participants' expressed interest in STEM post-secondary subjects and careers in Mathematics, Sciences Technology & Engineering after participation in the MUREP program?

When assessing the gender differences based on expressed interest in STEM post-secondary subjects and careers in Mathematics, Science, Mathematics and Engineering & Technology after participation in the MUREP program as stated in RQ4, it was noted that males and females were statistically very similar in their expressed interest in the STEM subject areas of Mathematics ($t(416) = 1.73$, $p = .084$) and the Sciences ($t(416) = 0.098$, $p = .922$) along with careers related to both. Hence, the null hypothesis related to math and science STEM subjects failed to be rejected. On the other hand, when it came to Engineering & Technology, the male (212) students were assessed to have a statistically significantly higher expressed interest in

engineering and technology and related careers, (t (405) =3.036, p=.003) compared to the female (206) students and consequently hypothesis science and technology was rejected.

Conclusions

In conclusion, over 50% of the participants consistently expressed a positive attitude towards STEM subjects after participation in the MUREP program. Also, the students' overall attitudes towards science were consistently positive and remained at the same level from year to year during the entire project. Further, it was shown that over 50% expressed interest in STEM post-secondary subjects and careers after participation in the MUREP program. Finally, it was noted that males and females expressed similar interest in the STEM subject areas of Mathematics and the Sciences along with careers related to both.

Our results have shown that gender equality in the STEM subjects and career interest are possible even at the middle school level/age. Additionally, our study indicates that engaging students as early as middle school age can create future interest in STEM subjects and career potential in secondary and post-secondary education. These results concur with those of current literature and national efforts on the importance of early STEM exposure in the stimulation of interest in STEM degrees and ultimately an interest in post-secondary career endeavors.

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