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Exploring Impacts of a STEM Day Camp on Adolescent Desire to Pursue STEM in College

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ABSTRACT: Out-of-classroom activities can help cultivate interest and literacy in Science, Technology, Engineering and Mathematics (STEM) subjects. To determine how a week-long out-of-classroom experience might impact STEM interest in adolescents, a free summer camp was offered to students entering grades 6-8. During this time, students participated in coding courses, microbiology lessons, and earth science sessions. This study uses statistical regression methods on pre- and post-camp surveys to gauge relationships between parental support, socioeconomic factors, and student desire to major in STEM disciplines in the future. Our results indicate that respondents who felt more encouraged at home showed improvement in opinion regarding their desire to major in STEM disciplines after the intervention. Families that encouraged STEM literacy also tended to belong to well-represented ethnic groups in STEM, suggesting, among other things, the intergenerational pattern in STEM matriculation and the challenge that this poses to increasing enrollment of underrepresented groups in related disciplines.

INTRODUCTION

The necessity to encourage American youths to participate in fields of Science, Technology, Engineering and Mathematics (STEM) has long been noted as important to the long-term overall success of the United States (National Science and Technology Council, 2018). Understanding how to navigate through a world in which technology and the sciences are becoming increasingly integrated with our everyday lives has become a necessary skill; this will likely remain the case for the next generation of Americans. STEM literacy has become a "prerequisite for full participation in modern society," as a STEM literate public is more equipped to adapt to technological changes, handle complex problems, and make better informed personal choices ranging from health to cybersecurity to finances (National Science and Technology Council, 2018). STEM literacy starts with the school system, but this competence can be difficult to achieve. In 2019, the National Assessment of Educational Process reported national averages for 8th grade math and science proficiency at 56% and 51%, respectively. New Jersey's average math and science proficiency scores were 58% and 52%, respectively (National Assessment of Educational Progress, 2019). These scores can arguably be increased with STEM intervention programs, as academic performance has shown improvement with furthering student interest through STEM intervention programs, especially in the field of mathematics (Gerber, 1996).

Out-of-school STEM intervention activities, such as club activities, museum trips, camps, and outdoor field trips, can help improve STEM literacy (Mohr-Schroeder et al., 2014; Sahin et al., 2014). These activities cannot replace classroom learning but can provide opportunities for students to explore subject matter and cultivate interests in an informal, constructive way (Lunenburg, 2010). A study conducted by Nugent et al. (2010) assessed the impacts of a STEM-based robotics summer camp on middle school adolescents across several locations in Nebraska; students who participated in

the 40-hour camp performed significantly better in engineering, programming, and geospatial skills post-camp assessment than the control group. Males in the study scored nearly three times higher in the pre- and post-assessments than the female participants, showing that while there was improvement in both sexes, gender can still play a significant role in STEM education (Nugent et al., 2010).

Female adolescents in particular can benefit from STEM intervention programs. A substantial amount of research has been conducted to investigate the role of gender in STEM education, with emphasis on the positive role of STEM intervention programs on female youths (Archer et al., 2014; Kim et al., 2018; Mosatche et al., 2013; Falco and Summers, 2019; Weisgram and Diekman, 2015). While the ages of participants greatly vary amongst the studies available, literature on the impact of a STEM intervention program on girls aged 10-13 is limited. This age range is of great importance, with evidence of gender stereotypes in STEM fields becoming less prominent from early childhood to early adolescence, attracting more female students (McGuire et al., 2020). This group also represents a cohort that is most open to careers in science, with studies showing a loss of interest in STEM subjects in high school (Sadler et al., 2012). Therefore, we aim to address this literature gap in our study, emphasizing whether these intervention programs may improve the desire not just to attend college but to major in STEM subjects.

STEM educational interventions can also be considered beneficial to help "facilitate the access and success of women, minorities, low-income, and first-generation students in these fields" (Rincon and George, 2014). Females and minority groups are historically underrepresented in STEM, and this effect is particularly pronounced in the Black and Hispanic communities (National Science Foundation, 2019). Yeager et al. (2017) found that racial and ethnic minority students aged 11-14 may feel discrimination and other biases from the institution they attend. This impression could contribute to discontent in STEM and trends of low rates of college graduates in STEM fields from underrepresented minority (URM) groups; in 2016, URMs comprised nearly 30% of the total population but only represented 21% of science and engineering degrees (Kiuru et al., 2017; National Science Foundation, 2019). Addressing children's needs in middle school, a point at which researchers identify as critical in a child's life regarding career direction, can help support interest in STEM (Archer et al., 2012; Jackson et al., 2011).

Parents also play a critical role in student engagement in STEM fields. Ing (2013) studied 7th graders as they moved through the education system until 12th grade and found parent involvement to be a significant motivator in STEM persistence. Parents and peers were considered significant factors in children seeking information on future careers (Kracke, 2002). These principles can follow into adulthood; engineering students participating in a study assessing reasons for choosing a STEM major cited their parents as a reason to choose their study area (Hall et al., 2011). If the parents are unsupportive, they can implicitly and explicitly pass on beliefs of gender roles in STEM, swaying their children in the same direction (Tuijl and Molen, 2016). If the parents support STEM education, they can increase the probability of their children's engagements in technology and engineering, particularly with female adolescents and high school students (Heddy and Sinatra, 2017). Parental support can also be especially impactful for black students. In Black families, Moore (2006) found a significant positive relationship between mother support of math and sciences, but not from the father. The large role that parents play in a child's life, whether they provide implicit or explicit opinions concerning engagement in STEM, can be significant in understanding student drive to attend college as a STEM major.

Peers may also play a role in STEM persistence and desire to pursue a STEM career. There has been a documented direct positive correlation between best friends in adolescence and similar career choice as adults, emphasizing the importance of peers in long-term career choices (Kiuru et al., 2012). Girls may also benefit more from peer support than boys; female adolescents who have a favorite STEM subject who are exposed to other girls with favorite STEM subjects are more impacted by their peers than boys in the same classes who show no such influence (Raabe et al., 2019).

Parental and peer support, age, and ethnicity all play a role in adolescents' desire to major in a STEM-related field in college. In this study, we assess the role that STEM extracurricular intervention programs have on the desire to attend college and major in a STEM field with respect to the aforementioned variables. In Summer 2019, the Assimilating Computational and Mathematical Thinking into Earth and Environmental Science (ACMES) Science, Technology, Engineering, Mathematics, and Computing (STEM+C) team at Montclair State University (MSU) provided a free summer day camp to students entering grades 6-8. Three different weekly sessions were offered to interested students. Participants engaged with doctoral-level students and faculty from the Computer Sciences and Earth and Environmental Sciences departments to learn coding and earth sciences throughout the week of attendance. This paper uses pre- and post-survey data to understand the role of parents, peers, demographics play in affecting student interest in attending college to major in STEM disciplines.

METHODS

Weekly Activities. Participants followed a schedule in which they were taught JavaScript and Python coding languages during the morning session. Attendees learned to

create shapes using programming language, with the coding sessions culminating in animating the shapes created. Their post-lunch schedules included sessions encompassing earth sciences, microbiology, and civil engineering design and execution using teamwork and engineering principles, among other activities. Surveys were administered on Monday mornings before camp activities started and on Thursday afternoons after learning sessions were completed. The survey questions were posed to obtain data on demographics, attitudes towards science, technology, engineering, and mathematics, and opinions on STEM subjects needed for their desired careers, regardless of whether the desired career was based in STEM.

Survey Analysis. Respondents were asked to respond with level of agreement to presented statements using a Likert-scale response set, where (1) indicated strong agreement with the statement, (2) indicated agreement, (3) indicated neither agreement nor disagreement, (4) indicated disagreement, and (5) indicated a strong disagreement. The difference between each respondent's pre- and post-survey data was calculated with the cleaned, coded, and transformed data then entered into a statistical analysis program. Two logistical stepwise regressions were performed. Stepwise regressions can be less sensitive to datasets with a large variation in cell size, but because our data was simplified to assess change in opinion, multi-layered variation was not a consideration (Arnocky and Stroink, 2011). Similar to data in Arnocky and Stroink (2011), missing values were minimal. If, however, a value was missing from a survey question, the corresponding answer from the respondent's pre- or post-survey was deleted from the dataset. An ordinal logistic model was used to process the Likert-scale data. The ordinal logistic model uses analogous logistic curves with separate intercepts (SAS Institute, 2018):

$$P(y \leq k) = F(\alpha k + \beta X) \text{ for } k = 1, \ldots, r-1 \quad (1)$$

$$F(x) = \frac{1}{(1+e^{-x})} = \frac{e^{x}}{(1+e^{x})} \quad (2)$$

where P is the probability function, y is the dependent variable, k is the number of levels, α is the intercept for number of levels, and β is the coefficient for the X, which is the independent variable for Eq (1). In Eq (2), F is the function for the logistic cumulative distribution function. A stepwise regression was then performed for each question to be investigated, with the model determining significant variables.

The first regression focused on the role of family as the dependent variable. Dependent covariates included reasons for participation, demographic background, as well as changes in data from the following statements: "Someday when I tell others about my career, they will respect me for doing scientific work," "Scientists make a difference in the world," and "Having a career in science would be challenging."

The second regression was performed to assess links between demographics and change in desire to attend college and major in a STEM field. The dependent variables were the statements "I will graduate with a college degree in a major area needed for science," with independent variables including potential reasons to attend the camp (their peers were attending, their parents/guardians encouraged them, they wanted to know what college looked like, they wanted to learn about STEM), desire to have a career in science, and whether or not their families encouraged them to study science.

RESULTS

Descriptive Profile. Respondents were asked to provide information about their backgrounds (see Table 1). Overall, there was considerable variation in the ethnic background of camp attendees. Camp attendees were primarily of Asian and Hispanic heritage (19% each), followed by those of mixed background. Caucasians and students identifying as "Other" each composed 13% of attendees. Black students only made up 3% of the total population. Male students outnumbered female students at a 2:1 ratio.

Respondents were also asked to choose up to two reasons why they participated in the camp (see Table 2). Of the rea-

Table 1. *Demographic characteristics of respondents.*

Variable	Frequency
Ethnicity and ID number	
Caucasian – 91	13%
Asian – 92	19%
Black – 93	3%
Hispanic – 94	19%
Native American – 95	8%
Mixed – 99	16%
Other – 100	13%
Prefer not to answer – 101	8%
Gender	
Male	68%
Female	32%
Other	0%
Prefer not to answer	0%
Age	
10	8%
11	44%
12	24%
13	24%
Grade	
6	46%
7	32%
8	22%

Table 2. *Breakdown of desire to participate in the ACMES STEM+C camp.*

Reason to Participate in Camp	Frequency
My parents told me I had to participate.	36%
I was selected by my teacher/school.	8%
I want to learn more about STEM for myself.	46%
I want to participate because my friends are participating.	11%
I want to know what college looks and feels like.	16%
I am participating for fun/personal enjoyment.	38%

sons provided, most students indicated personal agency in attending camp; 46% wanted to learn more about STEM for themselves, while 38% participated for fun or personal enjoyment. Parents pushed 36% of students to partake in camp, while most students who finished the camp and completed the post-survey (64%) entered willingly.

Logistic Stepwise Regression Model. In the first logistic stepwise regression model, we examined the relationship between the family encouraging the study of science and reasons for participating, demographic information, if they felt scientists were respected, whether or not scientists made a difference in the world, and if they felt a career in science would be challenging (see Table 3).

In our sample population, respondents who answered that they did not join camp because their friends were joining camp could have answered so for several reasons; however, the reasoning behind this would require further investigation. Ethnicity of participants also played a role in the regression model. In the scenario where Caucasians, Asians, and those who preferred not to disclose their ethnic backgrounds were compared to those identifying as Black, Hispanic, American Indian, Mixed, or Other, there was also a significant relationship to feeling as though the families encouraged the study of science. Racial-ethnic minorities, such as those from the Black, Hispanic, and Native American populations, are underrepresented in STEM (NSF, 2019). This is mirrored in our regression model. In our study population, the underrepresented minority students did not feel that their families actively encouraged studying the sciences.

Using the JMP Profiler to break down the results of the regression further to assess how the different variables interacted with each other, we discovered that respondents who felt that they strongly agreed (rather than maintain a neutral response or negative response) with the statement, "Scientists make a meaningful difference in the world," were 38% more likely to positively indicate that their families supported them studying science. If they gave a more neutral or negative response regarding the difference scientists made, they were 68% likely to answer that their families did not encourage them to study science. Using the same technique to gauge the response between respondents' feelings about careers in the sciences being challenging, we found that students who overall agreed with the statement were 85% likely to disagree with the statement of family encouragement in the sciences. In contrast, students who disagreed with a career in the sciences to be challenging were 85% likely to respond that their families did not encourage them to study science.

A second regression was performed to understand the relationship between the role of respondents' families and the desire to graduate from a college and major in a science field (see Table 4). In this regression model, the dependent variable, "I will graduate with a college degree in a major area needed for a career in science," was run against several covariates independently from the first model. The variables "I want to participate in camp because my friends are participating" and "My family encourages me to study science" were significant in this regression. The stepwise function compared different groupings of responses, with two significant comparisons under the variable in which families

Table 3. *Parameter estimates for the ordinal logistic regression fit for "My family has encouraged me to study science."*

Term	Estimate	Std Error	ChiSquare	Prob>ChiSq
Intercept [-1]	1.295	0.987	1.72	0.189
Intercept [0]	4.483	1.314	11.63	0.001*
I want to participate in camp because my friends are participating [0].	-2.906	1.064	7.46	0.006*
Ethnicity Grouping 1: {92&91&101-93&94&99&100&96}	1.229	0.468	6.87	0.008*
Ethnicity Grouping 2: {92-91&101}	0.717	0.649	1.22	0.269
Some day when I tell others about my career, they will respect me for doing scientific work. Grouping 1: {1&2-3&4&5}	-0.120	0.465	0.07	0.795
Some day when I tell others about my career, they will respect me for doing scientific work. Grouping 2: {1-2}	-1.275	0.693	3.39	0.065
Scientists make a meaningful difference in the world. {1-2&3&5}	1.982	0.691	8.22	0.004*
Having a career in science would be challenging. Grouping 1: {1&2-3&4&5}	-1.187	0.587	4.09	0.043*
Having a career in science would be challenging. Grouping 2: {1-2}	-0.828	0.564	2.15	0.142

Table 4. *Parameter estimates for the ordinal logistic regression fit for "I will graduate with a college degree in a major area needed for a career in science."*

Term	Estimate	Std Error	ChiSquare	Prob>ChiSq
Intercept [-1]	-2.329	1.221	3.64	0.056
Intercept [0]	3.341	1.332	6.29	0.012*
I want to participate in camp because my friends are participating [0].	2.203	0.858	6.58	0.010*
Gender [1]	-1.797	0.715	6.31	0.012*
I would like to have a career in science Grouping 1: {1&2&3-4&5}	-2.726	1.122	5.90	0.015*
My family encourages me to study science Grouping 1: {1&2&3&4-5}	-2.846	1.169	5.92	0.014*
My family encourages me to study science Grouping 2: {1&2&3-4}	4.813	1.906	6.37	0.011*
My family encourages me to study science Grouping 3: {1-2&3}	-1.449	0.754	3.69	0.054

encourage students to study science. The first significant sub-variable (Grouping 1) grouped responses 1, 2, 3, and 4, which range from "strongly agree" to "disagree," against "strongly disagree," to compare the stronger held feeling against the other responses. The second significant sub-variable (Grouping 2) grouped responses 1-3 and compared it against only "disagree." Overall, if students answered that they "strongly disagreed" that their families supported their studying of the sciences, they were unlikely to see any real change in opinion regarding their desire to major in science. However, if students only "disagreed," there was an 86% chance that they would see improvement in desire to graduate with a major in STEM.

The model output from Grouping 1 behaved much differently than the model output for Grouping 2, and they further differed when gender was included in the model. Male respondents who strongly disagreed that their families encouraged them to study science but who wanted to have a career in science were only 14% likely to show improvement in opinion regarding graduation from college and majoring in science. Female respondents who wanted a career in science but strongly felt that their families did not encourage studying science remained resilient, with results showing nearly 86% improvement in opinion regarding the possibility that they would still want to graduate college and major in science.

Model 2 shows some variation between the genders in our sample population. Male respondents who disagreed with the statement of family encouragement in science and indicated they wanted a career in science were not at all likely to pursue it in college. However, male respondents who did feel supported by their families to study science showed a 99.5% improvement between the pre- and post-survey in opinion towards graduating with a major in science. Female respondents who did not feel that their families supported them but wanted a career in science showed a 32% likelihood of improvement in opinion compared to their counterparts with family support, who showed a dramatic near 100% improvement in opinion.

DISCUSSION

Results from model 1, in which we assess the relationship between family support of studying science and different covariates, shows that for our sample population, friends also attending camp were not prioritized as a reason to attend the STEM camp. This result suggests that other factors can be more influential on adolescents aged 10-13. Ethnicity, however, plays a larger role in respondents' feelings of familial support in studying the sciences. Those who identified as Asian, Caucasian, or preferred not to answer showed similar answering patterns, while those who identified as part of underrepresented groups showed similar answering patterns. Although Asians are considered minorities, they are considered well represented in the STEM fields (Castro, 2018). Our Asian and Caucasian population indicated they felt supported by their parents, while the population from Black and Hispanic backgrounds did not feel their parents supported studying STEM. This is somewhat mirrored in similar studies; Moore (2006) found that his study population of Black students felt more supported by their mothers than their fathers, but this is inconclusive in our study and would require further investigation.

There is a significant need to address this intergenerational trend and make STEM more appealing and welcoming to children from underrepresented minority groups. When breaking down the results further, we see that there is a direct relationship between family support of studying science and opinion on the impact that scientists make in the world; those who felt that their families encouraged them to study science were nearly twice as likely to believe scientists made meaningful differences in the world. The relationship between parental support and opinion of the sciences is significant. Parents can potentially improve their children's interest in STEM by actively improving their own awareness of STEM issues and engaging in STEM activities with their children to prepare their children for long-term success in STEM subjects (Watson et al., 2020).

Our second model shows variation between the different groups of respondents concerning the intention to graduate

from college with a degree in a subject area needed to pursue a career in science. The role of family was included in this regression model to assess how strong the relationship was compared to that of the camp (indicated by the change between the pre-post survey response to "I would like to have a career in science"), gender, and the role of friends in participating in the camp. Respondents significantly indicated a negative response to the impact of friends in the decision, which came as a surprise considering the influence that peers can play on the lives of adolescents.

Gender was also significant in our model, with girls more positively influenced by the intervention than the male participants. Girls who felt that they were supported by their families to study science were also more likely to show improvement in feeling that they wanted to pursue a career in science. The nearly 86% improvement in opinion regarding the possibility that they would still want to graduate college and major in science perhaps suggests in the instances that their families don't support their STEM education at home, STEM intervention programs like the ACMES STEM+C Summer Camp might play a larger role. In this study, there was only a 14% increase in male pre-post opinion regarding the desire to pursue STEM subjects in college, compared to the 86% increase in female pre-post positive change in opinion. With more support from STEM intervention programs, girls may be more inclined to continue in STEM fields.

The ACMES STEM+C Summer Camp was an interactive STEM intervention program that excited participants by engaging them in STEM-based activities throughout the week of attendance. The program had targeted students aged 10-13 from all backgrounds to encourage diverse attendance. Attendees received hands-on training in programming and coding, soils science, microbiology, civil engineering construction, ecology, and GIS exposure with doctoral-level faculty and students. This exposure to different STEM-based activities, along with their own individual characteristics—ethnicity, parental support to study the sciences, gender—positively contributed to the desire to continue with STEM into adulthood.

Similar STEM intervention summer camp programs should intentionally engage more female and underrepresented minority adolescents in their programs, as these programs can help improve opinion towards attending college and majoring in a STEM-based field. Administrators of other similar STEM intervention programs can use the results of our study to help decide and prioritize which participants would best benefit from such programs and how to serve students who may be interested in STEM but not receive as much support from their families.

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ABBREVIATIONS

ACMES: Assimilating Computational and Mathematical Thinking into Earth and Environmental Science; MSU: Montclair State University; STEM: Science, Technology, Engineering and Mathematics; STEM+C: Science, Technology, Engineering, Mathematics, and Computing

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