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The Impact of Attending an Engineering Program on Underrepresented Middle School Students' Interest in STEM (RTP)

Mrs. Natasha Wilkerson, Texas A&M University

Natasha Wilkerson is a Ph.D. student in Curriculum & Instruction with an emphasis in engineering education at Texas A&M University. She received her B.S. in Aerospace Engineering and her M.S. in Curriculum & Instruction from Texas A&M University. She is the President of the Cosmic Leap Foundation, Director of Space Club, and Co-Founder of Vivify, LLC.

Impact of Afterschool Engineering on Underrepresented Middle School Students

Introduction

Despite widespread efforts to increase access to science, technology, engineering, and math (STEM), women and racial minorities continue to be underrepresented in these fields. More women than men are enrolled in college, but women only represent 20% of those awarded computer science degrees in 2018, a decline from 27% in 1998 [1]. Racial minorities, including Hispanic or Latino, Black or African American, and American Indian or Alaska Native, make up about a third of the population in the United States, but these groups were only awarded 24% of science and engineering bachelor's degrees [1]. This lack of representation may be linked to a decline in interest in STEM starting at age 11 [2]. A look at gender differences found that middle school girls are much less likely to report interest in a STEM career than boys [3]. To counteract this decline in interest, researchers have found a link between consistent engagement in an afterschool STEM program with an improved interest in STEM [3] [4]. However, attendance in an out-of-school (OST) program is often sporadic [5], and the duration of programs varies widely [6]. Further investigation is needed on the amount of exposure to OST STEM as a predictor of interest in STEM, with gender as a moderator. This study explores this relationship by examining a middle school STEM afterschool program serving a traditionally underrepresented group, low-income Hispanic students.

Literature Review

The following describes studies investigating early interest in STEM as a predictor of persistence, the role of OST on STEM interest, and the role of gender as a moderator.

Early Interest in STEM

To explore potential causes for the underrepresentation of women and minorities in STEM, researchers have investigated the link between early interest in STEM and later persistence in STEM fields. For example, a longitudinal study examined whether interest in science during middle school predicted obtaining a bachelor's degree in science [7]. The analysis involved 3,359 students who indicated an interest in science in 1988 as eighth-graders and received a bachelor's degree by 2000. Using nested multinomial logistics modeling that accounted for demographics, achievement scores, academic characteristics, and parent background, researchers compared eighth-graders who expected to pursue science with those not interested. The model showed a statistically significant difference between groups with eighth-grades reporting science interest to be 3.4 times more likely to earn a physical science or engineering degree ($b = 1.23$, $SE = 0.24$, $p<0.001$). These results highlight that early interest in science appears to be a statistically significant predictor for persistence in a STEM pathway.

A follow-up investigation in 2010 involved 116 scientists and science graduate students to explore childhood experiences that may have impacted their persistence in STEM [8]. A majority of participants described their interest in science took place before middle school, and 40% said

their initial experiences were related to an education-based experience like a science competition. While this study is limited to the perspective of the participants already in a science field, the results of this study and the previous longitudinal analysis suggest an early interest, often developing in an educational setting, maybe a significant predictor of persistence in STEM.

The Role of Out-of-School Programs on STEM Interest

A potential key player in developing an early interest in STEM is OST programs. With 73% of OST programs now offering STEM activities, these have the potential to reach underrepresented groups [5]. Additionally, OST activities involve engaging, hands-on, exploratory, and project-based learning experiences that may increase interest in STEM pathways [9]. This potential was explored in a large-scale evaluation of 158 STEM-focused OST programs on their impact on interest in STEM [6]. The study involved a large sample of students in grades 4 - 12 participating in OST STEM programs. A one-time retroactive survey found participants reported statistically significant interest in STEM careers based on participation in an OST program. This study shows promise for the impact of OST programming on STEM interest.

Not all studies, however, support a link between OST and increased interest in STEM. For example, a randomized experimental study investigated the effects of a 2-week summer science camp on middle school girls' affinity toward science [10]. While the treatment group reported a statistically significant increase in science attitude, there was no statistically significant change in science interest for treatment or control groups. This 2-week program can be compared to the research on a 6-to-12-week OST program [4]. Analysis of pre and post surveys found that treatment and control groups were similar in initial science interest. However, non-participants reported a statistically significant *decrease* in interest while the STEM participants showed no statistically significant change in interest. This study suggests that without intervention, students in middle school generally start to lose interest in STEM, a finding supported by other researchers [2]. Perhaps a measure of success for OST programs is maintaining interest in STEM.

Gender as a Moderator of STEM Interest

With women being underrepresented in STEM fields, gender is generally considered a factor in influencing STEM interest. A survey of 1,200 middle school students found that while 26.1% of boys selected STEM occupations as a top choice for a career, only 12.4% of girls chose a future career in STEM [3]. However, female participants enrolled in an OST program were statistically significantly more likely to aspire for a STEM career compared to those not enrolled indicating the potential impact of OST activities on STEM interest.

However, a review of gender as a moderator on STEM interest has mixed results. The large-scale survey by Allen et al. did not find a statistically significant main effect of gender on self-reported STEM career interest for participants in OST STEM [6]. This was also supported by a 2017 meta-analysis, which did not find gender or race as statistically significant moderators of OST on STEM interest [11]. However, the authors argued that this lack of significance was likely misleading as most studies did not disaggregate groups by race and gender.

Program Duration on STEM Interest

While gender as a moderator of OST on STEM interest still needs further investigation, studies generally find a positive impact of OST programs on STEM interest. However, largely missing from the literature is the effect of program duration and frequency of participation on interest. As noted, the study of a 2-week STEM camp did not show any statistically significant difference in STEM interest among treatment and control groups [10], but a 6-to-12 week intervention was found to counteract a decrease in interest [4].

While increasing the frequency and duration of OST programming to improve or maintain STEM interest seems like an obvious solution, limited access to quality STEM programs, especially for underrepresented groups, is a challenge. OST programs vary widely in duration [6], and competing activities and other barriers, such as transportation, result in sporadic attendance [5]. Therefore, an important consideration is how much exposure to STEM is required to affect a student's interest in STEM.

Present Study

Building on previous research on OST programs and STEM interest, this study explores the relationship between the frequency of attendance on interest in STEM for underrepresented groups. The program of study, Space Club, is a year-long STEM afterschool program composed of low-income and Hispanic middle school students. Both boys and girls are enrolled in the program allowing for an investigation of gender as a moderator on the relationship between the amount of participation and interest in STEM.

Space Club is an afterschool STEM program developed by Communities In Schools of San Antonio (CIS-SA), a non-profit organization in San Antonio, Texas. The mission of CIS-SA is to "surround students with a community of support, empowering them to stay in school and achieve in life" (CIS-SA). CIS-SA Site Coordinators are placed in targeted campuses to provide tailored support for at-risk children, including access to educational and community resources such as academic assistance, food packs, counseling, and enrichment to support the development of academic and life skills. In 2014, CIS-SA added Space Club programming to their list of enrichment services to engage youth in a program that promotes engineering and scientific literacy alongside social and emotional learning.

Targeting youth at risk of dropping out of school, Space Club involved a unique partnership between a mental health professional, teachers who contributed classroom content and management, and engineering mentors who added technical depth. Students participated in weekly engineering design challenges aligned to science and math standards that covered topics such as rocketry, robotics, and chemistry with connections to STEM careers and current events in space exploration. Space Club also involved team activities, mentoring, and goal setting to build a foundation of engineering habits of mind that improve student confidence, increase persistence, and improve academic performance. The program culminated in a district-wide competition where students worked in teams to design a colony on Mars that featured engineering design, science research, architecture, and mental health solutions. Teams presented to local STEM professionals and were joined by families at an award ceremony. The program ended with a trip

to NASA Johnson Space Center, where many students left their neighborhoods for the first time to explore mission control and astronaut training facilities.

Participation in Space Club was voluntary, but students were incentivized to attend by requiring 80% attendance of Space Club meetings to be eligible to attend the field trip to NASA. Attendance records were kept by staff who also administered a pre and post-survey measuring STEM interest. These records formed the data used in this study to determine how the amount of attendance in a STEM program impacted interest in STEM.

The following research questions were addressed in this study:

1. After controlling for initial STEM interest, do students who attend more hours of Space Club have a higher post STEM interest?
2. After controlling for initial STEM interest, does gender moderate the relationship between hours attending Space Club and post STEM interest?

Methods

Participants

Data collection occurred during the 2018 - 2019 school year. Through convenience sampling based on prior engagement with Space Club, four urban middle schools located in a low-income and predominately Hispanic community in San Antonio, Texas participated in the study. All participating schools had been implementing Space Club for the previous four years, and the STEM program had become an established component of the district's efforts to create a pipeline toward their STEM Early College High School.

Registration to join Space Club opened in September, and any sixth, seventh, or eighth-grader at the four participating middle schools was invited to register, free of charge. While 301 students initially registered and completed a pre-survey, data for this study only included the 145 Space Club students who completed both the pre and post-surveys. Table 1 details the self-reported demographics of the included sample. As Space Club was a recurring program each year open to all grades, 32% of students had participated in Space Club the previous year.

Table 1
Student Demographics

Characteristic	n	%
Gender		
Female	57	39
Male	88	61
Race/Ethnicity		
Latino or Hispanic	135	93
White, Caucasian (non-Hispanic)	5	3
African American, Black	3	2
Asian, Asian-American	2	2
Grade Level		
6th	71	49
7th	47	32
8th	31	21

Procedures

During the first two Space Club meetings in October 2018, all participants were asked to complete a pre-survey using computers in the library. The survey was administered over two weeks to capture the most students. The survey was accessed via a web link provided by the PEAR Institute. Space Club instructors read a provided script stating the purpose of the survey and ensuring students recognized that participation was voluntary. No names or other identifying information was collected except for a student ID number provided by the school. The administration took about 10 minutes and involved students answering 44 multiple-choice questions.

Space Club programming ran weekly from October 2018 through May 2019. To capture attendance, Space Club instructors asked students to sign in during Space Club meetings. Staff input attendance information into an online database. Records were kept during the school year and captured attendance at all Space Club meetings, field trips, and other events. The same survey was administered to any remaining Space Club students in May.

Measures

The pre and post-survey administered to students was the Common Instrument Suite for Students 3.1 (CIS-S) developed by The PEAR Institute: Partnerships in Education and Resilience [12].

This survey, totaling 44 questions, captured STEM interest, enjoyment, career interest, career knowledge, and identity. However, this study focuses on the first ten questions based on the survey developed by Noam et al. measuring interest in science across various informal settings [13]. Researchers undertook three testing phases, including stability over time, internal structure, and construct validity. For this study, Space Club students were involved in a more general STEM program that included technology, engineering, and mathematics in addition to science. Therefore, any mention of "science" in the 10-item survey was replaced with "STEM." For example, "I get excited about science" was replaced with "I get excited about STEM." Possible options included, Strongly Disagree = 1, Disagree = 2, Agree = 3, and Strongly Agree = 4. No items were reverse-scored.

Reliability analysis of the STEM interest subscale was conducted on participants' post STEM interest scores and found acceptable (Cronbach's alpha = 0.83). Therefore, an average of 10 scores was used to indicate STEM interest. A high score was interpreted as indicating a student had a high interest in STEM, while a low score would indicate low interest in STEM. For the participants in the study, the initial STEM interest scores were moderately high (N = 145, M = 3.24 out of 4.00), and variability was relatively low (SD = 0.40). The post-test scores were similar, with a little more variability (N = 145, M = 3.22, SD = 0.63).

Variables

Other variables of interest were gender and hours attending Space Club. As reported in Table 1, 39% of students were girls compared to 61% of boys. In the regression analysis, dummy coding was used for measuring the effect of gender with female students as the reference group. For hours, Space Club programming was offered 76 hours throughout the year, and participants attended an average of 62.73 hours. Variability in attendance was high (SD = 12.29). This variable, as well as the initial STEM interest scores, were mean-centered to allow for easier interpretation of the intercept.

Plan of Analysis

Using STATA, a regression analysis will be performed using a sequential model-building approach to address each research question. For the first research question, which explores the relationship between hours and post STEM interest, accounting for initial STEM interest, the final model is $\text{PostSTEMInterest}_i = \beta_0 + \beta_1(\text{c\_PreSTEM}_i) + \beta_2(\text{c\_Hours}_i) + \varepsilon_i$, with initial STEM interest and hours centered around their means. In this model, β_0 indicates the predicted post STEM interest score for a student who attends an average amount of Space Club and has an average initial interest in STEM. β_1 is the relationship between initial interest and post interest in STEM after accounting for hours attending Space Club, and β_2 is the relationship between hours and post STEM interest after accounting for initial interest in STEM.

The second research question aims to explore if gender moderates the relationship between hours and post STEM interest after controlling for initial STEM interest. Before conducting a moderated regression analysis, we will check for homogeneity of regression slopes between initial STEM interest and gender. If gender is not found to affect the relationship between initial STEM interest and post STEM interest, the final moderated regression model will build from the

previous model by adding gender and the gender x hours interaction: $PostSTEMInterest_i = \beta_0 + \beta_1(c\_PreSTEM_i) + \beta_2(c\_Hours_i) + \beta_3(Gender_i) + \beta_4(GenderxHours_i) + \varepsilon_i$. For the gender variable, girls are the reference group. In this model, β_0 indicates the predicted post STEM interest score for a male student who attends an average amount of Space Club and has an average initial interest in STEM. β_1 is the relationship between initial interest and post interest in STEM for a male student with average attendance. β_2 is the relationship between hours and post STEM interest for a male student with an average initial interest in STEM. β_3 is the difference in post STEM interest between male and female students who have an average initial interest and average attendance. β_4 is the difference in the relationship between hours in Space Club and post STEM interest, for an average initial interest, for a male versus female student.

Results

The purpose of this study is to examine the relationship between hours of attendance in an afterschool STEM program and post STEM interest after accounting for initial interest in STEM. The study also explores if this relationship was moderated by gender for the middle school participants. The variables under study are described in Table 2, which shows a positive and statistically significant correlation between initial STEM interest and post interest in STEM. Hours and post STEM interest have a positive correlation, but this is not statistically significant. Additional descriptive statistics are provided in Table 3, showing the variables of interest as a function of gender. Boys start with a slightly higher initial interest in STEM compared to girls and increase in this interest at post-test. Girls actually decrease on post STEM interest scores compared to initial interest despite attending slightly more hours of STEM programming.

Table 2

Summary of Descriptive Statistics and Correlations for Post STEM Interest, Initial STEM Interest, and Hours in Space Club (N =145).

Variables	1.	2.	3.
1. Post STEM Interest	1.00		
2. Initial STEM Interest	**0.65*** **	1.00	
3. Hours in Space Club	**0.10**	**0.024**	1.00
M	***3.22***	***3.24***	***62.73***
SD	***0.63***	***0.40***	***12.29***

*p<.05, **p<.01, ***p<.001

Table 3

Summary of Descriptive Statistics for initial STEM interest, post STEM interest, and hours as a function of gender

		Initial Interest		*Post Interest*		*Hours*	
Gender	*N*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Male	**88**	**3.27**	**0.39**	**3.30**	**0.59**	**61.38**	**13.62**
Female	**57**	**3.21**	**0.42**	**3.11**	**0.67**	**64.82**	**9.63**

A check on the homogeneity of regression slopes predicting post STEM interest was conducted prior to the nested regression analysis. The omnibus test for the moderation effect was not statistically significant, $F(1, 141) = 0.09$, $p = 0.76$, $\Delta R^2 = 0.0004$. The interaction term was also not statistically significant, $b_3 = -0.06$, 95% CI [-0.46, 0.34]. Therefore, when evaluating gender, we can assume homogeneity of regression slopes for the relationship between initial STEM interest and post STEM interest.

To answer the research questions, a nested regression analysis was conducted that predicted post STEM interest from pre STEM interest, hours attending, gender, and the interaction of gender and hours. The results of this moderated regression analysis are shown in Table 4. Looking at the omnibus statistics, the final model with all parameters was statistically significant $F(4, 140) = 29.11$, $p < 0.001$, $R^2 = 0.45$. However, the majority of the variability was explained by the initial STEM interest, $\Delta F(1, 143) = 106.41$, $p < 0.001$, $R^2 = 0.43$. Adding hours as a predictor did not explain a statistically significant amount of the variability in the model, $\Delta F(1, 142) = 1.78$, $p = 0.18$, $\Delta R^2 = 0.0071$. Therefore, in addressing the first research question, hours was not a statistically significant predictor for post STEM interest.

Table 4

Summary of the moderated regression analysis predicting STEM post interest from initial STEM interest, gender, hours in Space Club, and gender x hours interaction.

Source	*SS*	*df*	*MS*	*F*	R^2
Initial STEM Interest	**24.29**	**1**	**24.29**	**110.41*** **	**0.43**
Hours	**0.41**	**1**	**0.41**	**1.86**	**0.0099**
Gender	**0.75**	**1**	**0.75**	**3.41**	**0.010**
Gender X Hours	**0.40**	**1**	**0.40**	**1.82**	**0.0071**
Residual	**31.09**	**140**	**0.22**		

*p<.05, **p<.01, ***p<.001

A closer look at the parameters is found in Table 5. In this model, 3.30 was the predicted post STEM interest score for a male student who attends an average amount of Space Club and has an

average initial interest in STEM. For a male student with average attendance, a 1-point increase in initial STEM interest predicted a 1.01 change in post STEM interest, a statistically significant relationship, b_1 = 1.01, 95% CI [0.81, 1.20]. All other parameters were not found to be statistically significant. The parameter for hours, $b_{2,}$ showed a small, not statistically significant negative relationship between hours and post STEM interest for a male student with an average initial interest in STEM. Looking at the effect of gender, boys with average initial STEM interest and attendance are expected to have a 0.13 higher post STEM interest score, but this was not a statistically significant difference. Finally, the interaction term was not statistically significant but showed that boys with average initial STEM interest and attendance are expected to have a more strongly positive relationship between hours and post STEM interest.

Table 5

Summary of Moderated Regression coefficients predicting post STEM interest from initial STEM interest, gender, hours, and gender x hours interaction.

Source	*B*	*S.E. B*	*95% CI [LL, UL]*		*β*
Intercept	**3.30**	**0.43**	**2.45**	**4.15**	
Initial STEM Interest	**1.01**	**0.098**	**0.81**	**1.20**	**0.64**
Hours	**-0.003**	**0.0065**	**-0.015**	**0.010**	**-0.049**
Gender	**0.13**	**0.082**	**-0.034**	**0.29**	**0.10**
Gender X Hours	**0.01**	**0.0075**	**-0.0047**	**0.025**	**0.17**

The second question was focused on the moderating effect of gender. As stated, the interaction term was not statistically significant, and adding moderation to the regression model did not statistically significantly explain more variability in post STEM interest when controlling for initial STEM interest ($\Delta F(1, 140) = 1.82$, $p = 0.18$, $\Delta R^2 = 0.0071$).

In conclusion, this study did not find a statistically significant relationship between hours spent in a STEM program and post interest in STEM after controlling for a pre STEM interest. The effect of gender on this relationship was also not found to be statistically significant in explaining post STEM interest.

Discussion

Prior studies have shown that participation in an OST STEM program results in an increase of interest in STEM [6] [11]. However, this study did not replicate these findings for low-SES, Hispanic, middle school students in an afterschool year-long STEM program. Participation in the program did not seem to have any statistically significant impact on post STEM interest. While no control group was present, other studies have found that students generally lose interest in STEM in middle school [2], and maintaining the same level of interest is an improvement over the control group [4].

The study also investigated the effect of gender, as middle school girls have a lower interest in STEM fields on average compared to boys [3]. However, gender did not moderate the relationship between hours and post STEM interest, which was also reflected in the meta-analysis by Young et al. [11]. In fact, our study found that girls actually had a lower post STEM interest score on average compared to their initial score at the beginning of Space Club.

A decline in interest for girls may reflect some of the study's limitations, including several threats to internal validity. For example, the survey was administered in October and then again in May, and external events are likely to impact student interest in STEM. Questions in the survey asked generally about attitudes towards STEM, such as, "I get excited about STEM." While the facilitator prompts students to relate these questions to Space Club, the students may have other influences on this interest, such as activities in a science class. The timing of the survey was also a factor, as the 44-question post-test was administered in May right around standardized state testing, which may have influenced students' attitudes about taking another multiple-choice test. Space Club is also an elective program that leads to selection bias in the sample.

Additionally, "STEM" was not a word often used in Space Club, and participants may not have equated Space Club activities with "STEM" activities. Validation of the inferences from the CIS-S survey tool was based on the use of "science" in the questions, and it is unclear how students interpreted "STEM." Answering the questions may be a reflection of the individual subjects (science, technology, engineering, and math) or the integration of topics. Another limitation was an over 50% loss of participants from pre to post-testing. Future studies may consider providing shorter post-test surveys throughout the year to capture more participants and minimize the influences of factors such as testing.

Another consideration is the desired STEM interest in students. Students in this study had generally high initial interest in STEM ($M = 3.22$ out of 4.00), indicating they agreed with most of the statements. Space Club was a voluntary program; therefore, students already interested in STEM are probably more likely to register. Perhaps more important is that an increase in already high STEM interest scores is maintaining an interest in STEM throughout the school year. Chittum et al. found similar results where participation in an OST STEM program did not change interest in STEM, but non-participants in a control group showed statistically significant decreases in interest [4].

An ongoing STEM program such as the weekly Space Club program in this study has the potential to maintain STEM interest for middle school students, which is cited as a critical time for later STEM persistence [7]. Future studies can investigate the minimum dosage to maintain interest in middle school, especially with an addition of a control group. This study also did not consider the type of STEM activities throughout Space Club. Additional research can explore which activities and frequencies are most important in maintaining or improving interest in STEM.

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