

Short- and long-term impacts of an informal STEM program

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During the middle school years, interest in Science Technology Engineering and Math (STEM) falls off, especially among Black and Latinx students and women. In underserved districts, a small percentage of students graduate prepared for college and even less are prepared for undergraduate STEM coursework. Beginning in the 2009-10 academic year, we implemented an informal STEM program for upper elementary and middle school students from a nearby underserved district. Students chose from STEM offerings including hands-on engineering and computer technology courses, coding courses, and physics courses taught through hands-on activities and video games. We found that participants are similar in ethnicity, poverty, and residency, but outperform non-participants in a variety of New York State standardized measures of achievement while participating in the program and years after leaving. For example, program participants outperform non-participants in high school assessments in physics, chemistry, and math. They are also over-represented in advanced science classes, and in receiving diplomas with advanced designation - a key indicator of preparedness to pursue a STEM major in college.

I. INTRODUCTION

This paper investigates the longer term impacts of the Urban Scholars Program (USP), an informal Science Technology Engineering and Math (STEM) program for middle school youth. USP is designed to promote interest and engagement in STEM subjects before and through the middle school years when interest and participation is known to decline[1–5]. This paper studies the STEM course-taking of USP participants during high school and also looks at subsequent graduation rates.

Underrepresented youth rarely join the flow of courses leading to high school STEM course-taking. For physics in particular, there are many barriers to accessing high school physics courses for underserved students, which is a needed preparation to pursue a STEM undergraduate degree. Barriers include poor math preparation, missing prerequisite courses, lack of support from school counselors, lack of student interest, and a host of other factors including ethnicity, socioeconomics, and gender [6–9].

Generating interest and awareness at a young age and sustaining it through middle school is critical for augmenting the number of under-represented students entering STEM fields. This interest can lead students to do well enough in their introductory coursework to pursue the advanced high school courses needed to pursue a STEM major in college.

If USP is effective, we expect to see short term impacts while participants are in middle school, as well as longer term outcomes during their high school years. In particular, we expect to see USP participants enrolling in advanced high school STEM courses and graduating at higher rates.

II. DESCRIPTION OF URBAN SCHOLARS PROGRAM AND STUDENT POPULATION

The Urban Scholars Program (USP) is part of the Siena College Informal STEM Center and serves approximately 60 underrepresented 5th - 8th grade students each year. Students participate in morning and afternoon group meetings, take two classes, and eat lunch on campus.

The program meets 14 Saturdays for approximately 70 contact hours annually. Students take up to six different courses during this time period. Courses are 4-6 Saturdays in length.

Prior to 2009, the program at the campus was focused on general liberal arts topics including dance, music, writing, photography, etc., with very few STEM classes offered. In 2009-10, one STEM class, robotics, was offered by the first author. In the 2010-11 academic year, the program shifted to have a physics and STEM focus as the first author, a physicist, and the advisor for pre-service teachers in physics, became more involved in the program. In 2010-11, 6 different STEM classes were offered. Three were physics-related including a robotics class focused on torque and speed, a circuits class, and a renewable energy class. A class on programming in Scratch and two additional technology classes were also offered.

A typical physics class is led by an upperclassman in physics planning to become a teacher. Mentors in the class are undergraduate physics students. One or more physics courses are offered in every session of the program. While physics is a theme in the program, many other STEM courses are offered to show the connection between the STEM content areas. Coding classes, problem-solving classes, hands-on classes, and gaming classes are also offered every session. Examples include physics in Minecraft, renewable energy systems, coding with Construct2, Lego robotics, chemistry lab, painting with gouche, FLOSS Desktops for Kids, augmented reality, math mysteries, and many more. Although

Urban Scholars is primarily a STEM program, a few non-STEM classes like painting, and cooking are offered so that many interests are recognized.

III. METHODOLOGY

A. Data Collection

We provided the participating school district with a list of participants as well as their attendance and course-taking in the program. The district provided aggregated data on numbers of participants in a variety of advanced high school STEM courses, and graduation rates for participants and non-participants.

Following FERPA guidelines, all school district data used in this report were provided in aggregate form. Analyses focused on group comparisons between program participants and their peers.

B. Participating Students

The school district served by the program is classified as a high-needs, low resource capacity district with 58% of students considered economically disadvantaged (eligible for free and reduced-price lunch), and a low graduation rate compared to state graduation rates. 78% of USP program participants are African American or Latinx as compared to 65% in the district. Participants were very similar to non-participants in the poverty levels of the neighborhoods in which they live. Students are recruited into the program in 5th and 6th grades and most students (93%) begin as 5th or 6th graders. Students in 5th - 6th grades comprise 41% of the participants and 7th-8th graders comprise 59% of the participants. Most students (92%) participate for 2 or more years, equating to 28 Saturdays and approximately 140 contact hours. Of those, 26% participate for 3 years and 21% participate for 4 or more years.

C. Cohorts and Analysis

The long-term impacts of the shift to a STEM-focused program are first seen in 2012-13. This is the year when 8th grade students who participated in the program in 2009-2010, are juniors in high school and are eligible to take upper level science and math electives beyond those required for graduation. The impacts for 7th graders are first seen in 2013-14, the impacts for 6th graders are first seen in 2014-15, and the impact for 5th graders are seen in 2015-16 and 2016-17, as shown in Table I. High school impacts are defined as advanced STEM course-taking in math and science during participants' junior or senior year of high school, and rates of graduation with advanced designation. Additional USP in-

formation about the high school cohort is included in Table I.

5th graders, who began in USP during the 2009-2010 year when the program focused on physics and STEM, did not graduate from high school until June 2018. Graduation data for these students were not available for this publication. However, course taking data were available, and are reported.

To determine whether students participating in the program were representative of the population of the high needs district, we compared Northwest Evaluation Association (NWEA) math conditional growth percentile of USP participants to non-participants. NWEA scores indicate performance in the form of a percentile for comparison to a national average [10].

We report New York State English Language Arts (ELA) and Mathematics assessments. These tests are administered annually in grades 3-8. They measure how well students are mastering the New York State learning standards and indicate whether students are on track to graduate from high school.

TABLE I. Informal program information for students taking high school physics courses

HS year	No. of students	Years in USP	Grade during USP	% 5th-6th graders	Avg. # USP STEM classes taken
2012-13	4	1.3	8th	-	no class data
2013-14	7	2.1	7th-8th	-	5
2014-15	5	2.6	6th-8th	60	6
2015-16	13	2.0	5th-8th	73	7
2016-17	22	1.3	5th-8th	70	7

IV. RESULTS AND DISCUSSION

We examined whether students in the program were representative of students in the district and not high-performing or STEM-focused students. The year before participation, they were compared to a control group from the district in terms of ethnicity, poverty level, and Northwest Evaluation Association (NWEA) scores, which indicate performance in comparison to a national average. Students in the program were somewhat more ethnically diverse with higher levels of poverty than district students. NWEA scores before participation in the program were not significantly different between participants and non-participants ($p < .10$). Both groups scored in the 47th percentile as compared to the NWEA norm group. Overall, Urban scholar program (USP) participants enter the informal STEM program at Siena College performing at the same level as students in the district, and somewhat below a matched sample from the NWEA norm group.

During and years after their participation in the program, USP participants outperform students in their district in a number of ways. Table II summarizes shorter term impacts

such as NYSED English Language Arts (ELA) and Math Assessments for when they participated in the USP program. We also report longer term outcomes such as the graduation rates, rates of advanced designation diplomas (see New York State Education Department (NYSED) requirements,[11]), pass rates on high school assessments in science and math. The table also summarizes the number of students taking advanced science and math courses. The number of students taking physics courses, AP physics courses, and math at the pre-calculus level and above are reported for 2013-2017.

During their participation in the program, USP participants are more proficient on New York State ELA and math assessments than their district peers. Several years after leaving the program, they continue to outperform their peers. In 2017, 50% of USP graduates graduated with advanced designation, as compared to 22% of district students. USP students pass high school math and science exams at a higher percentage than non-participants ($p < .001$). For USP, the percentage of participants graduating with advanced designation nearly doubled since our shift to a physics and STEM emphasis, while the percentage of students in the district graduating with advanced designation remained relatively constant at 20% of their graduating population.

In Table II, the number of advanced science and math courses that students from the program take is shown for 2013-17. The trend is that more students in USP are taking courses that prepare them for college, and potentially for a STEM major. Science courses that were included in the analysis are physical science, and life science courses beyond those required for a NY state diploma. Some examples include chemistry, physics, environmental science, IB and AP science courses, and electives such as introduction to nanoscale science and engineering. Advanced math courses include algebra 2, pre-calculus, calculus, AP calculus, and AP statistics.

To successfully pursue a physics degree in college, most students take at least one physics course, and some advanced math classes (e.g. pre-calculus and calculus) in high school. At the bottom of Table II, the number of students taking physics and advanced math courses (pre-calculus, calculus, AP calculus and AP statistics) are listed. USP students are over-represented in these advanced courses. For example, in 2017, 104 students from the school district took the NYS Regents exam in physics. 15% were USP participants, however, participants represent less than 5% of the school population. This over-representation in particular courses has an effect on their graduation rates. Of the USP students graduating in 2015 and 2016, 43% graduated with advanced designation.

Physics is typically taken in high school in 11th or 12th grade. As shown in Table II, four USP students took a physics course in 2013. The number of USP students who took high school physics increased to 13 in 2016 and 26 in 2017. The majority of these students started the program in 5th or 6th grade as shown in Table I, and had more opportunities to take physics and STEM courses in USP.

The number of years a student participated in the program

TABLE II. HS Graduation and pass rates, and the number of students taking science and math courses for a potential undergraduate STEM major

		2013	2014	2015	2016	2017 †
Graduation Rate	USP*	93 - 100% ‡§				
	District	60% ‡				
Advanced designation	USP	16%	6%	42%	36%	50%
	District	20%	18%	22%	18%	22%
Science & Math HS Assessments Pass Rate	USP	62%				
	District	42%				
ELA MS Pass Rate	USP	32%				
	District	16%				
Math MS Pass Rate	USP	25%				
	District	11%				
No. Science courses	USP	28	24	33	48	52
No. Math courses	USP	15	23	18	21	35
No. Physics courses	USP	4	8	8	13	26
No. Math \geq Pre-calc	USP	1	6	4	6	11

Note: *Urban Scholars Program (USP)

†End of the academic year, i.e. 2013 represents 2012-13

‡Combined 2016 and 2017 graduation rates are reported as complete data isn't available for earlier years for USP participants.

§Two participants currently coded as long-term absentees may be recoded when more information about them becomes available.

rose from 1.3 to 2.6 and then declined back to 1.3, though the number of students taking physics increased. This led us to examine the number and types of classes students chose in the informal STEM program. While class data wasn't recorded in 2013, the number of STEM classes (compared to other classes) increased to 7 in 2016 and 2017, totaling between 56 and 84 hours of STEM instruction, depending on whether the class was offered during a 4-week or 6-week session.

V. CONCLUSIONS AND FUTURE WORK

We examined USP participants and their high school records. We discovered that many were successfully prepared for challenging STEM coursework in their high school, and many are on track for high school degrees with advanced designation, particularly the first 2 cohorts of 5th-6th graders. These students began in USP during the 2009-2010 academic year, and had the opportunity to participate fully in the program while it had a physics and STEM focus.

With the inclusion of STEM expertise and leadership to the USP program in 2009, a change of focus to STEM topics, and an attraction of STEM undergraduate mentors provided USP participants with the opportunity to engage in a multitude of

real-world STEM experiences, and the opportunity to work alongside young, passionate STEM role models.

In designing STEM experiences, we found it useful to provide a multitude of supports, and a variety of courses. It is too soon to tell if this strategy will lead to concrete suggestions about how to increase the number of under-represented students in STEM coursework. At this point, the approach taken in USP looks promising. For example, after having identified a group of successful participants prepared to enter undergraduate programs in STEM, we found that those who were encouraged to take more of our challenging STEM classes were also more likely to take more challenging high school STEM courses. Though it has become a STEM program, we didn't eliminate all of the liberal arts courses. This provides opportunities that support student interests other than STEM, but also provides exposure to STEM topics for these students. We have not studied the impact of undergraduate STEM mentors on USP participants.

While we believe that the college STEM role models have an impact on the young USP participants, participation in the program may strengthen the resolve of these mentors to persist in their own STEM major. Anecdotally, we've seen undergraduate students change their major, because they became immersed in STEM by mentoring and leading classes in the program. Similarly some USP students who have aged

out of the program continue in the program as mentors, further supporting them in their high school years. It may be that these growth experiences as leaders in our program help them to redefine their identities as STEM people. There is more to the story that we have yet to understand. For example, what other supports in high school pushed these USP participants, but not other USP participants, to continue taking STEM courses?

FERPA guidelines can be seen as a barrier to linking student data in school to their extracurricular experiences. Very little research on out-of-school programs links a program's activities to school outcomes. However, cooperation and data sharing can go in both directions to make the most of data collected by programs and data available through schools. Tracking long-term program effects requires support for such collaboration through the commitment of expertise and financial resources.

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