Can Formal-Informal Collaborations Improve Science Literacy in Urban Middle Schools? The Urban Advantage Middle School Science Initiative in New York City

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Abstract

Informal science education institutions have been identified as critical partners as they seek to support the science efforts of school systems that have increasingly focused their attention on reading/language arts and math. The current study reports on the findings of the evaluation of Urban Advantage, a partnership program designed to improve middle school students' understanding of scientific inquiry through collaborations between the New York City Department of Education (NYCDOE) and eight informal science education institutions in New York City (NYC). The program is focused on enhancing the science content knowledge of middle school science teachers and addressing the academic needs of middle school students by creating opportunities for them to learn science using the resources and expertise of NYC's science rich cultural institutions. We examine whether the Urban Advantage (UA) program has led to increased student achievement on the New York State 8th grade Intermediate Level Science (ILS) assessment for participating schools and students and on early high school outcomes, such as attending a Science, Technology, Engineering, or Mathematics (STEM) high school or taking a science Regents exam in 8^{th} or 9^{th} grade. Our study is one of the few to estimate the impact of a formal-informal science program on academic achievement.

We find that controlling for performance of students in the year prior to joining UA, students at UA schools, on average, do at least 0.041 standard deviations better than students at non-UA schools, while no significant differences are found for either ELA or math. Additionally, the results from the linear probability models find that UA also contributes to post-8^{th} grade outcomes, including the probability of attending a STEM high school and taking and passing a high school science Regents exam.

Introduction

Today, no work could be more important or timely than re-envisioning the approaches, leadership, and methodologies for educating U.S. children in science. Within the formal education sector, researchers have pointed to the importance of supporting students' college- and career-readiness by more closely aligning K-12 education standards with the knowledge and skills they will need to succeed in introductory college-level science courses (The College Board 2009). At the same time, informal science education institutions (ISEs) are seeking to support the science efforts of school systems that have increasingly focused their attention on reading/language arts and math. These ISE institutions have been identified as critical participants in helping students succeed in science, "premised on the notion that their emphasis on phenomena-rich, learning-driven interactions with science resonates with the notion of inquiry underlying K-12 science education reform" (National Research Council 2009).

This study reports on the results of one such collaboration – the Urban Advantage collaboration developed between the American Museum of Natural History (AMNH), its partner institutions, and the New York City Department of Education (NYCDOE). We examine whether this partnership has led to increased student achievement on the 8th grade science exam for participating schools and students. Additionally, we examine whether or not the program has any impact on early high school outcomes, such as attending a STEM high school or taking a New York State Science Regents exam in 8th or 9th grade, which can give students an early jump on finishing high school in four years.

Our study also provides the first estimates of the impact of a formal/informal science program on academic achievement. In short, we find evidence that the UA program improves performance in science: student performance on the NYS science exam increases with the implementation of UA and the magnitude of the difference between UA and non-UA schools increases over time. Little change is seen in student performance on ELA or math for 8th-grade students, suggesting the effect is not merely reflecting coincident overall school improvement. Additionally, we find that participating in UA also contributes to post-8th-grade outcomes. The biggest impact is on the likelihood of taking the Living Environment Regents in 8th or 9th grade. This could have huge implications for a student's high school career as research has shown that students who take a science Regents early on are more likely to take additional Regents compared to those who wait to take the required Regents.

New York City is an ideal setting to conduct this study. Not only is it home to the largest system of schools in the U.S., with over one million students and more than 1,600 schools, it is also home to a number of ISEs that can provide valuable learning opportunities to complement those taught at school or to provide resources in areas that schools cannot. While no research site is completely comparable to all places, our findings are relevant to other contexts, as NYC schools, students, and institutions provide valuable insight into the issues and constraints faced by other large urban areas. Contrary to common belief, NYC is not wholly dissimilar from other urban districts. Indeed, while some areas of the city (Times Square and the Financial District, for example) are quite unique, much of NYC is representative of other urban settings around the country (Queens and Staten Island, for example). Importantly, NYC public schools educate children who are similar to urban school children elsewhere, and the sheer size of the public school population provides large samples of students in various underrepresented subgroups, enabling nuanced analyses that would be impossible to conduct elsewhere. A disproportionately large number of the nation's students are educated in urban school districts, and to many people these are areas of particular concern and provide useful lessons that can be broadly applied.

Background

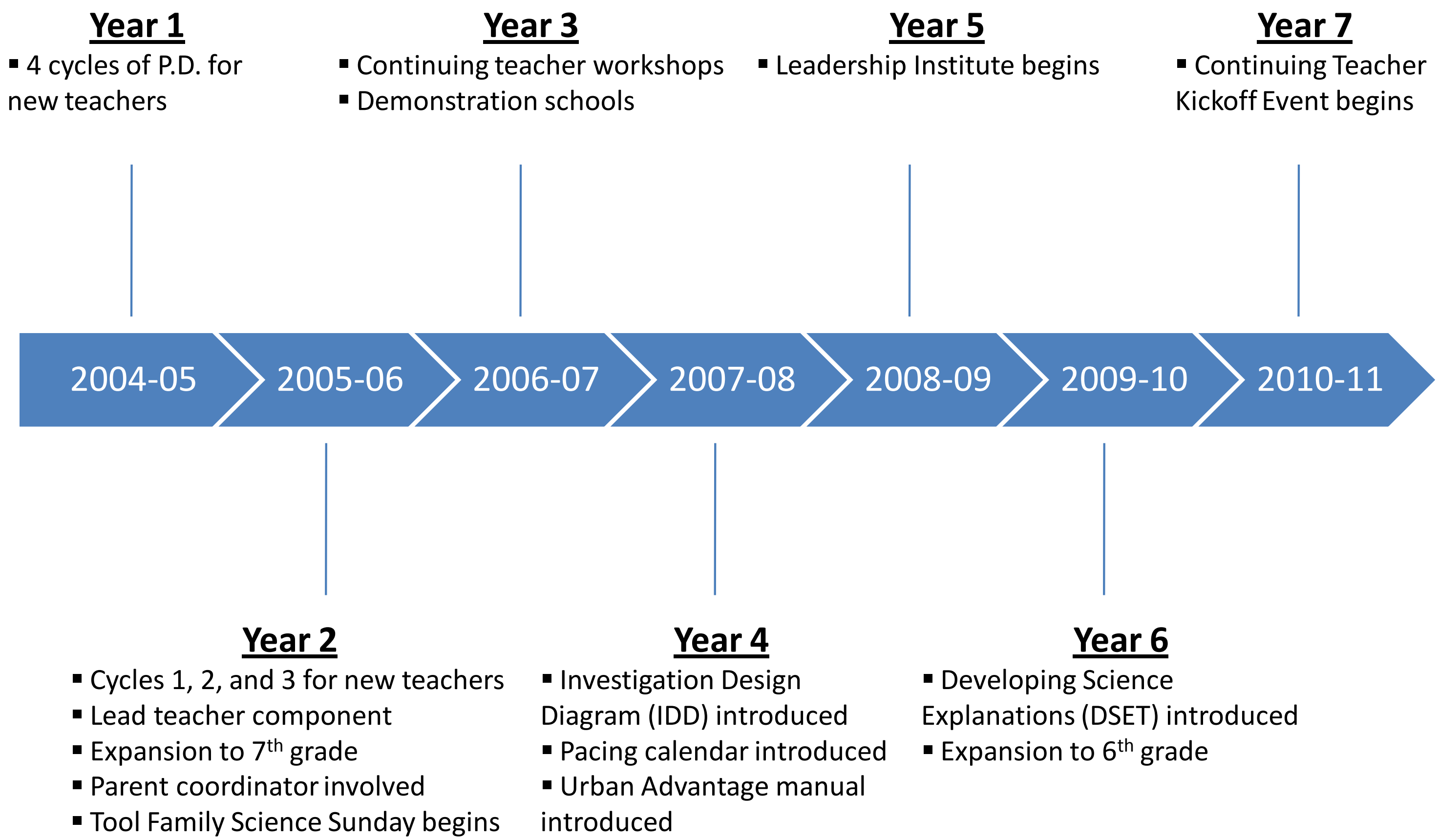
Launched in 2004 as a collaboration between eight NYC ISE institutions (the American Museum of Natural History, Brooklyn Botanic Garden, New York Botanical Garden, New York Hall of Science, Queens Botanical Garden, Staten Island Zoological Society, and the Wildlife Conservation Society's Bronx Zoo and New York Aquarium) and the NYCDOE, the UA program both students and teachers with opportunities to engage in authentic science practice. Taking part in the scientific process – designing and conducting investigations in which they pose scientifically oriented questions, prioritize evidence, and develop logical explanations – is a prerequisite to understanding science (The College Board 2009; National Research Council 2005; National Research Council 2007). Grounded in the learning goals defined in the New York State Learning Standards for Mathematics, Science, and Technology, UA is focused on supporting teachers to help their 6th, 7th, and 8th grade students carry out long-term scientific investigations, including the "science exit projects" NYC 8th graders are expected to complete before progressing to 9th grade.

The name "Urban Advantage" reflects the partners' belief that it is an advantage to live in an urban setting with so many science-rich cultural institutions and nature facilities. UA differs fundamentally from traditional museum-to-school collaborations as it provides a hybrid model for civic engagement where the resources of institutions are selected, designed, and shaped to align specifically to the science curriculum of NYC's middle schools.

UA provides 48 hours of professional development for new teachers and ten hours each year for continuing teachers.[1] The professional development model is designed using an immersion into inquiry strategy (Loucks-Horsley et al. 2009). Professional development emphasizes authentic hands-on learning experiences in science, the nature of scientific work, specific science topics, and the essential features of inquiry in the form of long-term investigations (National Research Council 2000). After choosing a UA partner institution to participate in professional development with, teachers learn how to plan effective field trips, embed resources in instruction, use UA-provided equipment and resources, and teach students the components of experimental design as well as how to develop scientific explanations based on claims, evidence, and reasoning. Teachers conduct their own scientific investigations, learning first-hand what it means to "do science," which is consistent with the teacher-as-learner model of professional development (Thompson and Zeuli 1999). Additionally, over the course of its existence, the UA program has developed a variety of classroom tools and school and family related resources to support outside-of the-classroom science learning (See Figure 1).

[1] These are teachers who are new to the UA program, not new to the profession of teaching.

Figure 1: Urban Advantage Timeline



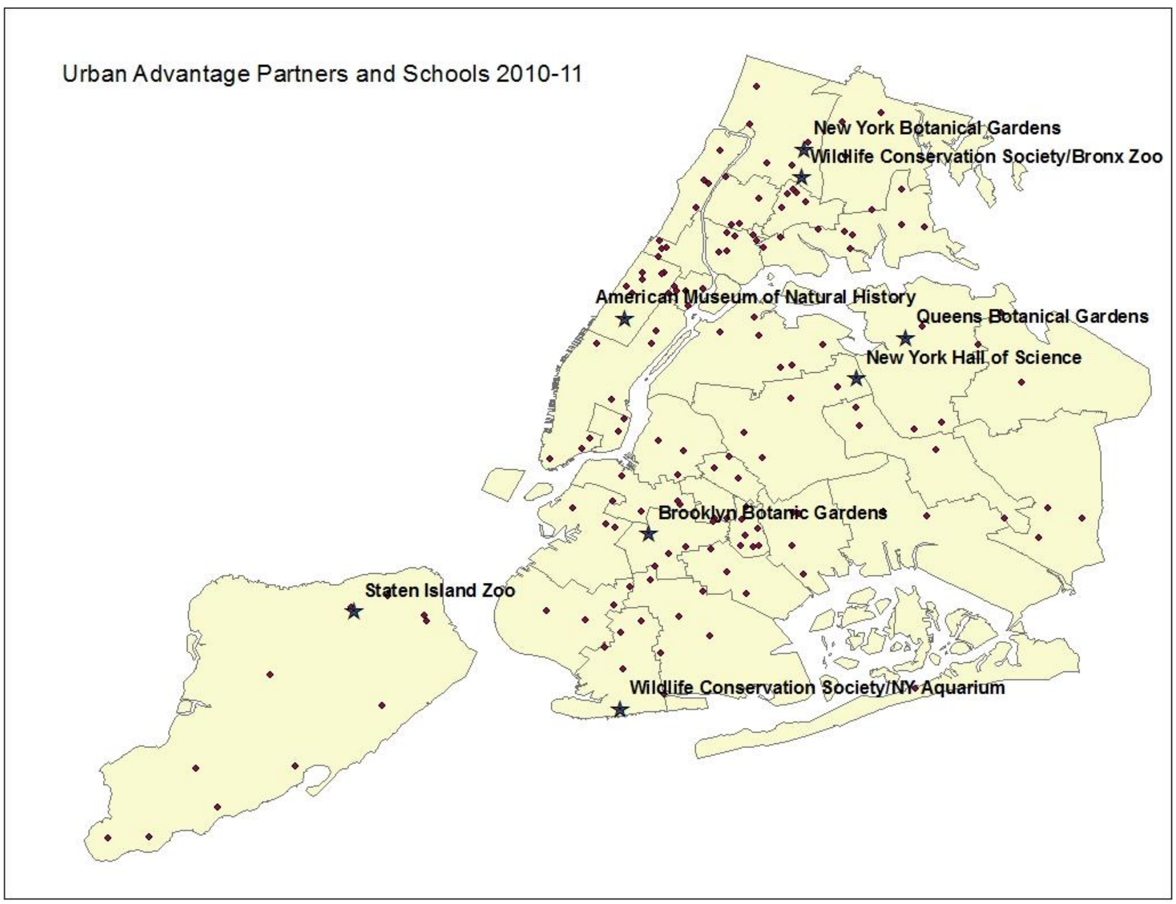
In existence for eight years, UA served 344 teachers and over 35,000 students and their families in 136 middle schools—about 24% of New York City's public middle schools in the 2011-12 school year (Table 1). And as Figure 2 shows, both the UA partner institutions and the participating schools are located across all five boroughs. With support from the Museum, informal science education institutions and school districts in other cities have taken steps to implement programs based upon the UA framework in NYC, with a UA program launched in Denver in the 2010-11 school year.

Table 1: Growth of UA, 2004-05 to 2011-12

	2004-05	***2005-06***	***2006-07***	***2007-08***	***2008-09***	***2009-10***	***2010-11***	***2011-12***
# schools	*31*	*111*	*129*	156	147	174	156	137
New teachers	*62*	*133*	*116*	127	61	182	86	63
Continuing teachers		*62*	*94*	129	196	204	285	280
Total teachers	*62*	*195*	*210*	256	257	386	371	343
Students	*5,500*	*18,722*	*21,016*	*27,541*	24,793	37,582	37,822	35,824

In its early years, teachers and schools self-selected into UA. Over time, the program has developed a more rigorous protocol for accepting both teachers and schools. This is partly due to increased demand and partly due to budget reductions as a result of the fiscal constraints experienced by the New York City Council and NYC Department of Education, which fund the program. Rather than expand to provide the program to more schools, program staff have opted to grow within already participating schools, opening the program to 6th-grade teachers and hoping to attract more than one teacher per grade. Additionally, UA staff have developed more professional development offerings for continuing teachers since the balance of participants has shifted from new to continuing teachers over time. These workshops are designed to focus in greater depth on specific content related to the science exit project process and provide opportunities for experiences teachers to examine students work and thinking. These sessions were open only to teachers who had already participated in new teacher professional development. To help ensure ongoing participation in the UA program, attendance at continuing teacher workshops was required for teachers to continue to receive resources and classroom materials provided by the program (Short et al. 2012).

Figure 2: Urban Advantage Partner Institutions and Schools



Review of the Literature

The Importance of Science Education

While the 2001*No Child Left Behind* (NCLB) Act only required students to exhibit proficiency in math and reading**,** proficiency in science is also fundamentally important to our functioning in the 21st century. Numerous studies have found that the emphasis on reading and math has led to a narrower curriculum, with subjects such as science and social studies receiving less attention or even being cut altogether (Froschauer 2006; Griffith and Scharmann 2008; McMurrer 2008; Common Core 2011). For example, Griffith and Scharmann (2008) examined the impact of *NCLB* on elementary school science education and found that more than half of teachers had cut time from science instruction in order to focus on math and reading for *NCLB* requirements. In 2006-07, *NCLB* requirements were amended to include mandated testing in science—one assessment per grade span (3–5, 6–9, and 10–12) (Guilfoyle 2006). However, studies show that science continues to be marginalized. A report by the Center for Education Policy found that 80% of school districts increased instruction for English Language Arts and 63% of school districts increased instruction for math at least 75 minutes per week. When this occurred, 53% of districts decreased science instruction at least 75 minutes per week (McMurrer 2008).

The further marginalizing of science comes at a time when students have been showing a growing aversion to science, leading the scientific community to become concerned that there will be fewer scientists entering the field in the future. This concern has led to efforts to encourage more students to take higher-level science courses. Researchers have found a variety of reasons students choose not to take elective courses in science, including student attitude and perceptions about science, teacher characteristics, student characteristics, home and school environment, learning environment, and academic ability (Cavallo and Lauboch 2001; Myers and Fouts 1992; Gallagher 1994; Fraser 1994).

In order for students to take and excel in higher-level science courses, a focus on science in the middle grades is necessary. The middle school years have been shown to be an especially important time to grab students' attention for science learning, as researchers see middle school science as a "gateway" for high school science courses (Snead and Snead 2004), and claim students who are unsuccessful in the middle grades avoid science and math courses as they grow older (Steen, 1987). Additionally, strong science instruction in the middle grades has been found to impact science persistence in high school (Gallagher 1994).

Second, strong science instruction in the middle grades has been found to impact science persistence in high school (Gallagher 1994). For example, in a 1994 study linking middle school achievement to science persistence in high school, Gallagher found that inquiry-based science instruction had a strong predictive value—more than double that of instruction that emphasized facts and principles. Gallagher stated, "Inquiry seems to lead to later enrollment in higher levels of science" (Gallagher 1994, 732).

Third, *NCLB* requires high school students to take at least one state science exam before graduation. There is no specific standard regarding which year in high school they must take this exam; however, it is to a student's advantage to take a science exam early in his high school career. The longer students wait to take the test, the fewer chances they have to pass and graduate in a timely manner. Additionally, the earlier students take a science exam, the more high-level science courses they will be able to take throughout their high school career.

The Need for Collaboration

Participation in informal science education has also been found to play a role in student's long-term career decisions by further engaging students, encouraging authentic inquiry, developing academic knowledge and understandings, developing self-efficacy in science, decreasing external barriers and increasing supports, and exposing students to STEM careers, particularly among women and those from minority and low-income communities (Dorsen, Carlson, and Goodyear 2006, Clewell and Darke 2000; Fadigan and Hammrich 2004).

Formal and informal institutions contribute differently to students' science learning in part because of structural differences. Schools are not designed for ongoing, authentic science investigations, as they must operate within the constraints of a school setting and generally have fewer science-specific resources. As such, it is unrealistic to encourage formal education to model itself after informal education; rather, a comprehensive science education is achieved through collaborations among many different types of institutions, both formal and informal (Adams, Gupta, and DeFelice 2012). Rosser (1997) describes collaborations between in-school and out-of-school learning experiences as a "two-pronged approach to learning." Many science education groups agree: the National Research Council, National Science Teachers Association, the National Science Board, and the Institute of Museum and Library Science all assert that collaboration between schools and informal science institutions is important.

Relationships between formal and informal science education institutions take various forms, all of which seek to combine complementary aspects of formal and informal settings, maximizing their benefits (Phillips, Finkelstein, and Wever-Frerichs 2007; Adams, Gupta, and DeFelice 2012). Beyond single-day field trips, most ISEs have both teacher and student programs. For teachers, ISEs frequently provide teacher residency programs, research opportunities, and professional development; for students, ISEs typically feature family outreach programs, camp-ins, activity kits, and various activities and materials (Astor-Jack, Balcerzak, and McCallie 2010; Hein 2001; Hofstein and Rosenfeld 1996; Inverness Research Associates 1996; Ramey-Gassert, Walberg, and Walberg 1994; Kisiel, 2010). In the Centre for Informal Learning and Schools' survey of 345 informal science institutions, 73 percent reported providing "support in the way of programmes, workshops, materials, curricula, etc. for districts, schools, teachers, or students in the broad area of science education besides a one-day field trip" (Phillips, Finkelstein, and Wever-Frerichs 2007).

Unfortunately, these ISE-based resources tend to be underutilized. Fifty-three percent of the informal institutions responding to the Centre for Informal Learning and Schools' survey reported that their programs could handle more participants than they currently serve, while only 24 percent indicate they have to turn away potential participants due to capacity constraints (Phillips, Finkelstein, and Wever-Frerichs 2007). Collaborations between formal and informal education institutions may help increase the utilization of existing informal science resources. In fact, the key goal of partnerships between formal and informal settings is to support cross-contextual learning. As articulated by Voss (2011), rich cross-contextual learning experiences are more than simple field trips; in addition to students traveling to informal institutions, informal educators may travel to schools to provide informal-style learning opportunities in the formal school context. Cross-contextual learning events tend to be most successful when they truly span both formal and informal settings. For example, it is beneficial when school-based and informal educators work together to plan learning experiences and when formal educators introduce concepts prior to informal learning, facilitate students' reflection of informal learning experiences, and assess the learning that takes place in informal settings (Voss 2011).

Data

Our analysis draws on a rich student-level longitudinal database for NYC public schools and students from 2003-04 to 2009-10. Student data include socio-demographic characteristics (age, gender, race/ethnicity, birthplace), educational needs (special education, limited English proficient, eligibility for free lunch), and standardized test scores (statewide English and math tests in grades 3-8 and science tests in grades 4 and 8).

Table 2 provides the descriptive statistics for the characteristics of the students at UA and non-UA schools. UA schools are, in many respects, quite similar to other New York City public schools serving 8th graders.[2] The one consistent difference we found between UA and non-UA schools is size. On average, UA schools are larger than non-UA schools, ranging from over 1,000 students in 2004-05 (not shown) to almost 600 in 2007-08, compared to between 400 and 800 for non-UA schools. Additionally, UA schools have a lower percentage of black and a higher percentage of Asian students compared to non-UA schools in this year. Finally, in 2009-10, UA schools outperform non-UA schools on the English Language Arts (ELA) and math exams. Only in this year do we see a higher percentage of students at UA schools meeting the standards on both exams compared to students at non-UA schools. Across UA schools, as with city schools as a whole, there is significant variation in school characteristics. As the large standard deviations show, UA serves students in schools that vary in size from very large to very small, from a student body where all are eligible for free lunch to those where only a small proportion are eligible, and from schools where the majority of students are black or Hispanic to those with a more balanced mix of students of different ethnicities.

[2] New York City schools have a variety of grade span configurations that include grade 8. Some schools are traditional middle schools that serve grades 6-8, while others may be K-8 or 6-12.

Table 2: Mean Characteristics of UA and Non-UA Schools, 2006-2010

	2006		2007		2008		2009		2010	
	UA	Not UA	UA	Not UA	UA	Not UA	UA	Not UA	UA	Not UA
	N=86	N=325	N=116	N=321	N=129	N=301	N=123	N=406	N=149	N=297
Total Enrollment	**720**	**553**	**657**	**502**	**635**	**487**	**724**	**605**	**717**	**594**
	(475)	**(404)**	**(439)**	**(369)**	**(446)**	**(338)**	**(439)**	**(345)**	**(424)**	**(347)**
Percent Black	36.9	39.31	35.2	40.59	**32.8**	**40.75**	34.3	39.0	33.5	39.2
	(27.8)	(29.18)	(27.5)	(29.83)	**(28.3)**	**(29.46)**	(29.4)	(29.2)	(29.1)	(29.5)
Percent Hispanic	40.7	40.62	43.1	39.95	42.9	40.32	41.1	41.2	41.6	41.3
	(25.0)	(26.45)	(26.2)	(26.33)	(26.4)	(26.30)	(26.0)	(26.4)	(26.3)	(26.5)
Percent Asian/Other	10.0	8.24	9.7	8.44	**11.6**	**8.19**	12.2	9.1	11.8	9.3
	(14.8)	(12.76)	(15.1)	(12.88)	**(16.4)**	**(12.92)**	(18.9)	(13.5)	(15.9)	(14.2)
Percent White	11.7	11.23	11.5	10.45	12.4	10.26	12.3	10.7	13,0	10.1
	(18.6)	(18.43)	(19.8)	(17.65)	(19.3)	(17.52)	(19.0)	(18.2)	(19.3)	(17.6)
Percent ELL	11.3	10.68	11.7	10.48	12.4	10.71	11.8	11.7	12.1	12.0
	(10.4)	(11.16)	(12.3)	(12.55)	(12.0)	(11.32)	(10.0)	(12.5)	(10.4)	(13.0)
Percent Free Lunch	69.3	69.19	62.6	67.50	63.6	67.07	69.2	70.0	70.2	71.0
	(24.4)	(23.11)	(29.1)	(26.63)	(26.9)	(25.61)	(21.1)	(20.3)	(20.0)	(20.0)
% Proficient ELA	42.2	32.9	42.4	42.4	**52.1**	**47.6**	40.3	42.2	37.9	36.6
	(49.8)	(21.6)	(21.5)	(21.3)	**(22.0)**	**(21.3)**	18.3	(20.91)	(1.64)	(1.25)
% Proficient Math	45.0	41.7	51.5	50.8	**66.2**	**61.2**	47.1	49.3	49.9	47.6
	(20.6)	(22.7)	(23.2)	(23.5)	**(23.1)**	**(23.6)**	(20.3)	(23.05)	(1.79)	(1.31)
% Proficient Science	38.5	39.4	41.01	42.6	53.3	48.7	50.5	46.7	53.0	51.4
	(22.5)	(24.3)	(22.2)	23.0)	(20.7)	(23.6)	(21.2)	(23.8)	(1.85)	(1.39)

Standard deviations in parentheses
Bold indicates differences are statistical significant at .05 level or less
% Proficient is the percent scoring in levels 3 or 4

Estimation Strategy

First, we characterize the observable differences between students in UA and non-UA schools. Differences in the student populations mean that descriptive comparisons in performance between UA and non-UA schools will be biased. For example, if low-performing students are more likely than other students to attend UA schools, even if these students experience gains at the UA schools, they may still continue to perform at lower levels than their non-UA school counterparts. If this is the case, the average performance of these UA schools compared to the rest of the schools will be lower, although the effect of UA is positive. Second, we use quasi-experimental techniques to estimate UA's total effect on several student achievement outcomes in middle school by controlling for these observable variables, including prior test scores. As a first step toward modeling the effect of UA on performance, we develop a set of models of student achievement that link a student's performance (measured by his or her score on the ILS) to an indicator variable indicating whether the middle school the student attends is a UA school, as well as a set of observable variables capturing student socio-demographic and educational characteristics to control for student characteristics and achievement. We model the equation as follows:

$$(1)\ Y_{ijt} = \alpha_0 + \alpha_1\, PreUA_{ijt} + \alpha_2\, UA_{ijt} + \alpha_3\, ST_{ijt} + \varepsilon_{ijt}$$

where Y is the outcome of interest (science z-score) , for student *i* in school *j* in year *t*, PreUA is an indicator that takes a value of 1 if, in year *t*, student *i* attended a school *j* that is in the year prior to joining UA; UA is an indicator variable that takes a value of 1 if, in year *t*, student *i* attended a school *j* that was a UA school; ST represents a set of student characteristics; and α_2 captures the difference in scores between students who attend UA schools and students who do not, controlling for student characteristics and past performance. ε represents the remaining variation. Robust standard errors are appropriately modified to reflect clustering of students at the school level. In this specification, the estimated coefficient on the UA dummy variable indicates the extent to which UA adds education value to their students, controlling for other sources of student achievement.

To test our long term outcomes we use linear probability models. Our basic model is

(2) $Y_{ijt} = \alpha_0 + \alpha_1\, AlwaysUA_{\,ijt} + \alpha_2\, PostUA_{\,ijt} + \alpha_3 ST_{\,ijt} + \varepsilon_{\,ijt}$

where Y is the outcome of interest (such as the probability of attending a STEM high school), for student *i* in school *j* in year *t*; AlwaysUA is an indicator that takes a value of 1 if, in year *t*, student *i* attended a school *j* that has always been a UA school, PostUA is an indicator variables that takes a value of 1 if, in year t, student *i* attended a school *j* that was a UA school; ST represents a set of student characteristics; and α_2 captures the difference in scores between students who attend UA schools and students who do not, controlling for student characteristics and past performance. ε represents the remaining variation. Robust standard errors are appropriately modified to reflect clustering of students at the school level. In this specification, the estimated coefficient on the AlwaysUA dummy variable indicates the extent to which attending a UA schools again adds education value to their students, this time at the high school level, controlling for other sources of student achievement.

Outcome Variables

Short-Term Outcomes

8th grade Intermediate Level Science and item-level analysis

We test two outcomes measured in the 8th grade. New York State requires that all 8th-grade students take the Intermediate Level Science Test. The test consists of approximately 80 questions in three sections: multiple choice, open-ended, and performance-based questions. The test covers three standards: scientific inquiry, living environment, and physical setting. We provide a measure of overall 8th-grade test performance using z-scores to provide the comparative performance of students at UA and non-UA schools. Additionally, because UA focuses on inquiry-based learning, we also conduct an item-level analysis on each of the three standards. By considering student performance on each standard separately, we can examine whether UA students performed better on scientific inquiry than non-UA students.

Unfortunately, our item-level analysis is complicated by the unavailability of comparable scale scores that were used for the overall test score. New York State does not provide scale scores for the three separate standards and we are only able to compute raw scores for each standard. Additionally, when computing the raw scores, some of the individual items are included on one or more scales, therefore, the total of the three scales do not add up to the total raw score. Therefore, to test our results we conducted the item-level analysis on two different measures. We created z-scores using the total raw score for each standard and a measure based on the percent of the questions answered correctly.

Long-Term Outcomes

New York State Science Regents

The analyses outlined above focuses on same-year effects of Urban Advantage, asking whether UA students perform better on the ILS exam overall and on the subset of inquiry-specific questions in that year. In order to capture longer-term outcomes, we have modeled students' likelihoods of taking and passing a science Regents exam in 8th or 9th grade as a function of attending a UA school. We use this broader measure because students in New York can decide which Regents exams they want to take as well as when to take them.[3]

[3] In addition to fulfilling credit requirements, high school students in New York State must take and pass a certain number of Regents Exams in order to graduate. While the requirements vary by the year of entrance, students generally must take and pass

Attending a STEM school

We also assess the impact of UA on the likelihood of attending a STEM high school. If Urban Advantage fosters a greater appreciation for and understanding of science, then it is possible that UA students will be either more interested in STEM schools, more qualified to attend them, or both.

In New York City, many high schools offer multiple specialized academies students can choose from, such as health professions, technology, law, journalism, computer science, humanities, and performing arts. Schools vary both in terms of how many specialized tracks (if any) they offer and what types of curriculum these programs provide. For the purposes of this analysis, we are defining STEM schools as those that offer *only* science-rich academies- that is, all students in the school are in a science-specific program. We define partial-STEM schools as those schools that offer both science-based academies and non-science academies to students.

Results

8th Grade ILS

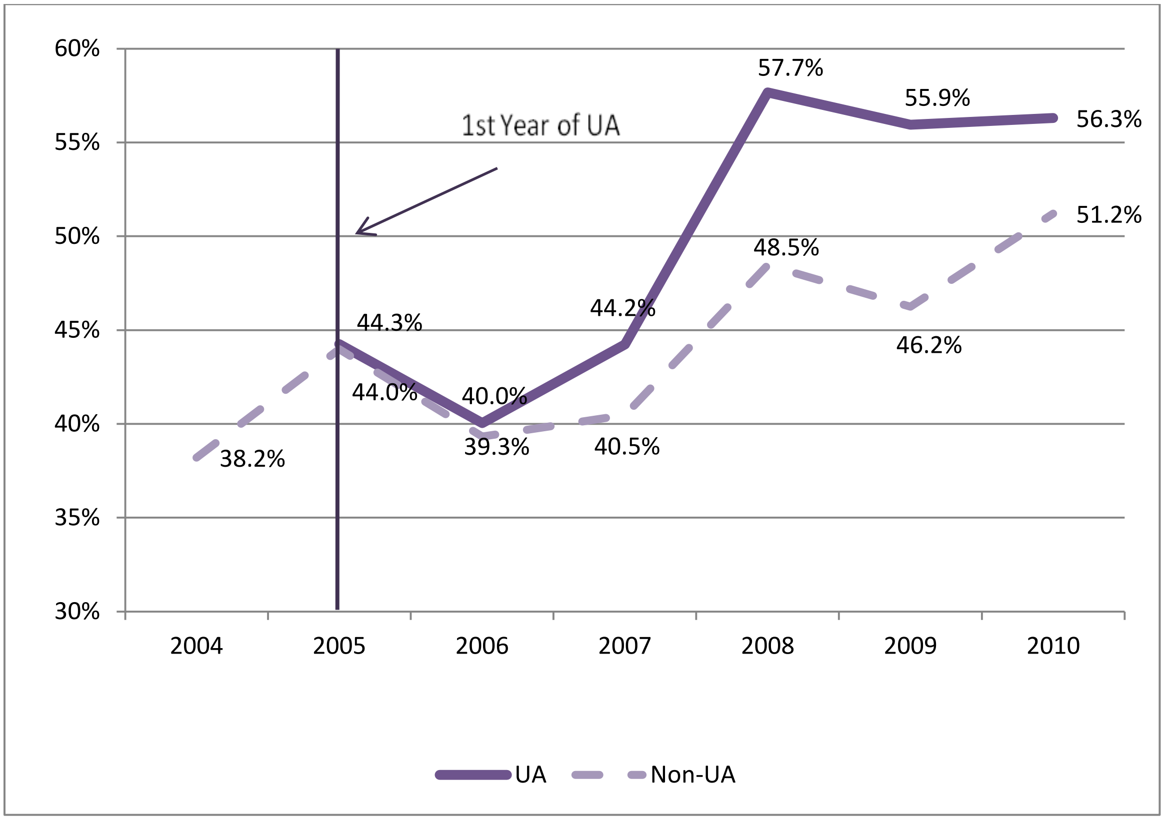
Figure 3 shows the distribution of eighth-grade students scoring in levels 3 or 4 (passing) on the New York State (NYS) Intermediate-Level Science (ILS) Test from years 2003-04 (one year prior to the inception of UA) through 2009-10. Note that in 2003-04, less than 40% of NYC eighth-graders were proficient in science, considerably less than the NYS average of 86%.

In the first two years of UA, there are no significant differences in student performance between UA and non-UA schools. However, in the third year differences begin to emerge, with students at UA schools outperforming students at non-UA schools on the ILS exam. At UA

one science Regents to obtain a high school diploma. There are no mandated years when students are eligible or required to take a specific exam, but they typically take the exam at the end of the related course. Typically, students will take the Earth Science or Living Environment Regents in the 8th or 9th grade. Because the graduation requirements reward passing but do not penalize failing, it is in a student's best interest to take and pass these exams earlier than later.

schools, 44.2% of eighth-graders pass the science exam compared to 40.5% at non-UA schools% (a gap of 3.7 percentage points).

Figure 3: Unweighted Mean Achievement, 8th Grade Intermediate Level Science



This finding is consistent with the school improvement literature that argues three years is the minimum amount of time needed to see results from interventions (Fullan and Stiegelbauer 1991). UA began in 2004-05 with a four-cycle professional development plan (Figure 3). By the third year of implementation, UA had a well-developed and stronger program that included not only professional development, but a set of developed material and resources for teachers to help them in the classroom. As teachers had more time to implement what they learned during professional development into their classroom practice, we begin to see improved student achievement across UA schools. It is also possible, however, that the schools selecting to become UA schools in those years are those entering with higher scores on science, math and

English Language Arts compared to schools who do not choose to participate in UA. As Table 3 shows, though, there are no statistically significant differences between UA and non-UA schools in the year prior to joining the program.

We next estimate a series of ordinary least square regression models that compare performance among 8th-grade students attending UA and non-UA schools after controlling for observable differences between students. We include only those schools that participate in UA for at least two years.

Our analytic sample includes all 8th-graders who have scores on the ILS exam from 2003-04 through 2009-10 (corresponding to one year before the start of UA through the last year for which test scores are available). Our dependent variable is a *standardized score* (“z-score”) on the 8th-grade ILS exam. Z-scores are standardized across students within a grade to have a mean of 0 and a standard deviation of 1. Students performing above (below) average relative to other

Table 3: Mean Characteristics of UA and Non-UA Schools, Year Prior to Joining UA

	2004		2005		2006		2007		2008		2009	
	UA	Non-UA	UA	Non-UA	UA	Non-UA	UA	Non-UA	UA	Non-UA	UA	Non-UA
N of Schools	31	289	61	291	43	366	42	244	7	227	24	238
Total Enrollment	**1079**	**851**	851	784	611	586	580	539	738	667	519	621
	(434)	**(468)**	(500)	(439)	(426)	(425)	(439)	(390)	(647)	(373)	(328)	(375)
% Black	41.84	36.47	34.05	38.67	37.65	38.95	36.95	39.41	33.89	38.52	35.74	38.17
	(28.1)	(28.1)	(26.2)	(29.5)	(29.3)	(28.9)	(29.4)	(29.3)	(34.0)	(29.3)	(26.7)	(29.4)
% Hispanic	35.10	39.91	42.81	39.56	42.21	40.45	43.27	40.48	35.56	41.18	46.87	40.74
	(22.9)	(25.4)	(26.3)	(25.7)	(27.5)	(26.0)	(25.4)	(26.4)	(23.2)	(26.4)	(23.0)	(25.9)
% Asian/Other	13.26	9.67	10.20	9.42	7.16	8.77	10.32	8.61	12.56	9.14	7.13	10.37
	(19.6)	(12.1)	(12.9)	(13.0)	(12.0)	(13.3)	(14.2)	(13.4)	(14.5)	(14.1)	(9.7)	(14.9)
% White	9.82	13.96	12.94	12.34	12.53	11.18	8.87	10.95	17.78	10.71	10.48	10.64
	(18.2)	(19.6)	(19.3)	(19.1)	(22.1)	(18.0)	(13.3)	(18.5)	(19.1)	(18.0)	(14.4)	(17.7)
% ELL	10.26	10.60	11.68	10.59	10.79	10.80	11.29	10.74	9.67	11.23	10.56	12.02
	(7.8)	(10.6)	(10.7)	(10.4)	(9.9)	(11.1)	(10.2)	(12.7)	(4.2)	(11.7)	(10.1)	(11.7)
% Free Lunch	75.37	71.10	69.20	68.66	63.30	69.90	64.76	66.29	55.89	66.30	72.48	69.98
	(21.8)	(23.5)	(21.7)	(22.5)	(23.1)	(23.3)	(30.2)	(27.1)	(31.5)	(25.8)	(15.8)	(20.4)
% Prof. ELA	33.17	39.42	50.94	46.94	36.11	40.14	42.32	42.37	58.41	48.75	43.17	41.71
	(16.6)	(20.5)	(19.9)	(21.3)	(20.4)	(21.3)	(19.1)	(21.6)	(18.9)	(21.6)	(22.1)	(20.2)
% Prof. Math	38.10	43.63	48.49	45.07	36.34	43.08	53.53	50.71	73.27	62.42	48.64	48.77
	(17.4)	(20.6)	(21.7)	(22.3)	(23.2)	(22.2)	(21.2)	(23.6)	(18.7)	(23.5)	(25.6)	(22.3)
% Prof. Science	38.23	45.03	46.88	45.17	36.61	39.52	43.00	42.05	47.57	50.16	45.34	47.86
	(20.9)	(24.8)	(23.9)	(23.8)	(23.0)	(24.0)	(19.6)	(24.6)	(27.7)	(22.7)	(28.4)	(23.0)

Standard deviations are in parentheses
Bold indicates differences are statistically significant at .05 level or less
% Proficient is the percent scoring in levels 3 or 4

students in their grade have positive (negative) z-scores. Model 1 controls for performance in the year prior to joining UA, while Model 2 breaks down the UA indicator more finely into the first UA year and years post UA-entry. Models 1 and 2 include student-level covariates ST_{it} that include whether a student is black, Hispanic, Asian, female, eligible for free or reduced-price lunch, limited English proficient, or in special education. Model 3 includes interactions between UA and student demographics.

As seen in Table 4, after standardizing the science test scores across the city and controlling for differences in student characteristics and student performance in the year prior to joining UA, students at UA schools perform .041 standard deviations higher than students at non-UA schools (Table 4, column 1). When we also control for the first year of participating in UA, students at UA schools do even better in the years post UA entry: performing .056 standard deviations higher than students at non-UA schools (Table 4, column 2).

While black and Hispanic students do worse compared to white students in science, we do find that UA has some impact in reducing the disparity for black students. In general, black students at UA schools score .062 standard deviations better than black students at non-UA schools (Table 3, column 5). We find a similar effect for Asian students at UA schools, who perform .066 standard deviations better than Asian students at non-UA schools. We also find, however, that female students at UA schools do significantly worse compared to their non-UA counterparts (0.033 standard deviations worse). We do not find any statistically significantly differences in the contribution that UA makes to the science achievement of Hispanic, white, poor, special education, or LEP students.[4]

As a check to see if students at UA schools are generally higher performing than students at non-UA schools, we ran the same analyses using ELA and math z-scores as the dependent

[4] Special education and LEP coefficients not shown in Table 4 but are available from authors.

Table 4: OLS Regression Science Z-Scores, Urban Advantage, 2005 through 2010

	Science		Math	ELA	Science
	Model 1	**Model 2**	**Model 2**	**Model 2**	**Model 3**
	β/se	**β/se**	**β/se**	**β/se**	**b/se**
Yr Prior UA	0.002	0.011	0.011	-0.001	0.010
	(0.018)	(0.021)	(0.024)	(0.017)	(0.021)
UA in Any Year	0.041*				
	(0.016)				
Yr Ent. UA		0.044	0.036	0.026	0.013
		(0.024)	(0.027)	(0.021)	(0.038)
Yr Post UA		0.056*	0.014	0.022	0.030
		(0.028)	(0.031)	(0.023)	(0.037)
Black	-0.397***	-0.397***	-0.408***	-0.375***	-0.411***
	(0.017)	(0.017)	(0.022)	(0.023)	(0.017)
Hispanic	-0.226***	-0.226***	-0.270***	-0.275***	-0.235***
	(0.015)	(0.015)	(0.020)	(0.021)	(0.015)
Asian	0.162***	0.162***	0.407***	0.064**	0.145***
	(0.019)	(0.019)	(0.027)	(0.022)	(0.021)
Female	-0.072***	-0.072***	0.027***	0.194***	-0.062***
	(0.005)	(0.005)	(0.004)	(0.004)	(0.005)
Poor	-0.092***	-0.092***	-0.074***	-0.119***	-0.092***
	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)
UA*White					0.012
					(0.028)
UA*Black					0.062*
					(0.030)
UA*Hispanic					0.042
					(0.027)
UA*Asian					0.066*
					(0.032)
UA*Female					-0.033***
					(0.008)
UA*Poor					0.002
					(0.014)
Constant	41.407***	45.897***	21.546*	4.157	44.951***
	(6.584)	(8.097)	(8.614)	(7.134)	(8.153)
School FE	YES	YES	YES	YES	YES
R-Square	0.35	0.35	0.33	0.32	0.35
N	401270	401270	425820	409572	401270

(1) * p<0.05, ** p<0.01, *** p<0.001
(2) Robust clustered standard errors in parentheses
(3) Year dummy not shown

variables. No significant differences are found for math or ELA (Table 4, columns 3 and 4). This provides evidence that UA has significant impacts for students on the eighth-grade science exam.

The results for the item-level analysis of the three standards are inconsistent (Table 5). The models using the z-scores are mostly negative and inconsistent, except for the PostUA variables on the inquiry standard which is significant but still negative. The percent answered correctly are all positive and statistically significant for the three standards, although UA and Year Entered UA are not significant for Physical Environment. The magnitudes across the standards are similar for the z-scores and the percent answered correctly.

High School Outcomes

Table 6 provides descriptive statistics for the 252,129 students with both 8^{th}- and 9^{th}-grade data who are included in the high school analysis. These students are overwhelmingly minority, with 32% black, 39% Hispanic, 17% Asian, and 13% white students. The sample is also largely poor, as 88% of the students receive free or reduced-price lunch. About 10% of students in the sample are limited English proficient and about 8% receive special education services. Turning to our outcomes of interest, approximately 10% attend a STEM high school, 60% took the Living Environment Regents, and 11% took the Earth Science Regents.

Roughly 31% of these students attended UA schools in 8^{th} grade. The UA sample has fewer blacks and more Asians and whites than the non-UA sample. Additionally, a higher percentage of those who attended UA schools took the Living Environment Regents compared to those at non-UA schools. No significant differences were found for pass rates or taking the Earth Science Regents between students attending UA and non-UA schools in 8^{th} grade.

The results from the linear probability models are presented in Tables 7 and 8. Table 7 provides the full models for the impact of attending a UA school on the probability of attending a

Table 5: OLS Regression, Item – Level Analysis

	Zscores						% Answered Correctly					
	Inquiry		Physical		Living Environment		Inquiry		Physical		Living Environment	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
	β/se	β/se	β/se	β/se	β/se	β/se	β/se	β/se	β/se	β/se	β/se	β/se
PreYear	0.03	-0.05	0.03	-0.02	0.01	-0.03	-0.84	3.29***	-2.75***	-0.04	-0.92	0.73
	(0.03)	(0.03)	(0.02)	(0.03)	(0.02)	(0.03)	(0.91)	(0.83)	(0.74)	(0.79)	(0.58)	(0.69)
UA	-0.01		0.02		0.01		2.38**		0.04		1.07*	
	(0.03)		(0.02)		(0.02)		(0.75)		(0.64)		(0.48)	
Yr. Enter UA		-0.06		-0.02		-0.02		5.56***		0.80		2.31***
		(0.03)		(0.03)		(0.03)		(0.85)		(0.78)		(0.63)
Post UA		-0.10**		-0.04		-0.05		6.86***		3.71***		2.87***
		(0.04)		(0.03)		(0.03)		(0.86)		(0.76)		(0.70)
Constant	0.34***	0.37***	0.46***	0.48**	0.41***	0.43***	70.92***	68.89***	62.51***	61.15***	65.23***	64.41***
	(0.020)	(0.02)	(0.019)	(0.02)	(0.02)	(0.02)	(0.46)	(0.51)	(0.44)	(0.51)	(0.40)	(0.46)
FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
r2_a	0.30	0.30	0.33	0.33	0.31	0.31	0.30	0.30	0.33	0.33	0.32	0.32
N	400923	400923	400923	400923	400923	400923	400923	400923	400923	400923	400923	400923

(1) * p<0.05, ** p<0.01, *** p<0.001
(2) Robust clustered standard errors in parentheses
(3) Year dummy not shown
(4) Control variables not shown are: Black, Hispanic, Asian, Female, Poor, Special Education, LEP

Table 6: Descriptive Statistics, High-School Outcomes, 2005-2009

	Full Sample	**UA**	**Not-UA**
	N=252,129	N=79,090	N= 173,039
	Mean	Mean	Mean
UA	31.37 (0.46)		
% Female	50.69 (0.50)	50.14 (0.50)	50.94 (0.50)
% Black	32.38 (0.46)	27.97 (0.45)	34.40 (0.48)
% Hispanic	38.96 (0.48)	38.56 (0.49)	39.14 (0.49)
% Asian	16.74 (0.37)	20.05 (0.40)	15.22 (0.36)
% White	13.31 (0.34)	14.7 (0.35)	12.66 (0.33)
% Poor	87.88 (0.33)	82.62 (0.38)	84.62 (0.36)
% LEP	9.54 (0.29)	9.93 (0.30)	9.36 (0.29)
% Special Education	8.06 (0.27)	8.18 (0.27)	8.01 (0.27)
Attended a STEM High School	9.83 (0.30)	9.72 (0.30)	9.87 (0.30)
Took Living Environment in 8th or 9th Grade	60.33 (0.49)	67.39 (0.47)	57.10 (0.50)
Pass Living Environment with 55 or higher	86.92 (0.34)	87.58 (0.33)	86.60 (0.34)
Took Earth Science in 8th or 9th Grade	10.60 (0.31)	10.94 (0.31)	10.44 (0.31)
Pass Earth Science with 55 or higher	76.93 (0.42)	77.50 (0.42)	76.67 (0.43)

Table 7: Linear Probability Models: Probability of Attending a STEM School

	Model 1	Model 2	Model 3	Model 4
	b/se	**b/se**	**b/se**	**b/se**
Always UA	0.007	0.000		
	(0.016)	(0.015)		
Post UA	-0.001	-0.009	0.014***	0.008*
	(0.010)	(0.009)	(0.003)	(0.004)
Black		-0.057***	-0.032***	0.001
		(0.013)	(0.009)	(0.007)
Hispanic		-0.037**	-0.028***	-0.007
		(0.013)	(0.008)	(0.007)
Asian		0.112***	0.127***	0.103***
		(0.017)	(0.014)	(0.011)
Female		-0.015***	-0.016***	-0.011***
		(0.002)	(0.002)	(0.002)
Poor		-0.064***	-0.043***	-0.025***
		(0.007)	(0.005)	(0.004)
Special Ed		-0.044***	-0.035***	0.013***
		(0.004)	(0.003)	(0.002)
LEP		-0.069***	-0.060***	0.007
		(0.008)	(0.006)	(0.004)
Lag_ZMath				0.086***
				(0.005)
Constant	0.098***	0.189***	0.147***	0.103***
	(0.008)	(0.019)	(0.009)	(0.007)
School FE	NO	NO	YES	YES
R-Square	0.00	0.05	0.12	0.17
N	252129	252129	252129	252129

1) * p<0.05, ** p<0.01, *** p<0.001
2) Robust clustered standard errors in parentheses
3) Poor is equal to those eligible for free and reduced price lunch
4) N is all students who were present in NYC public schools in 8th and 9th grade

STEM high school. As seen in columns (1) and (2), there are no statistically significant differences in the likelihood of attending a STEM school between students who attended a UA school and those who did not. However, after including school fixed effects for the 8th grade school (columns 3 and 4), students who attended UA schools in 8th grade were 1.4 percent more likely to attend a STEM school for 9th grade than those who didn't attend a UA school. After controlling for 7th grade math scores though, the difference was less than 1% and statistically significant at the .05 level. There was no statistically significant difference in the likelihood of attending a partial STEM school (results not shown).

Table 8 summarizes the coefficients on Post-UA for all the high school outcome variables. Attending a UA school has the largest impact on whether a student takes the Living Environment Regents in the 8th or 9th grade: students at UA schools are 25.5% more likely to take the Living Environment Regents than those at non-UA schools.   The impact on taking the Earth Science Regents is considerably smaller (only 3.9%), which is not surprising, considering that only about 11% of students in the sample took this exam during the 8th or 9th grade. Attending a UA school also contributed to higher pass rates at 55, 65, and 85 for both Regents, except for passing with a 55 on the Living Environment Regents, which was not statistically significant.

Table 8: Probability Coefficients, High School Outcomes

	Model 3	Model 4
	β/s.e	β/s.e
Attending a STEM School	0.014*** (0.003)	0.008* (0.004)
Attending a Partial STEM School	NS	NS
Taking Living Environment Regents in 8th or 9th Grade	0.255*** (0.012)	0.246*** (0.012)
Passing Living Environment Regents	NS	NS
Passing Living Environment Regents with 65 or higher	0.040*** (0.006)	0.032*** (0.006)
Passing Living Environment Regents with 85 or higher	0.062*** (0.005)	0.054*** (0.005)
Taking Earth Science Regents in 8th or 9th Grade	0.039*** (0.007)	0.033*** (0.007)
Passing Earth Science Regents	0.029*** (0.0006)	0.012* (0.0006)
Passing Earth Science Regents with 65 or higher	0.059*** (0.007)	0.037*** (0.008)
Passing Earth Science Regents with 85 or higher	0.062*** (0.005)	0.054*** (0.005)
School Fixed Effects	YES	YES

1) * $p<0.05$, ** $p<0.01$, *** $p<0.001$
2) Robust clustered standard errors in parentheses
3) Control variables not shown are: Black, Hispanic, Asian, Female, Poor, Special Education, LEP, and for Model 4 lagged_zmath.

While the magnitudes of the other results were smaller, we also find that attending a UA school increases the likelihood of passing the Living Environment or Earth Science Regents and attending a STEM high school.

Conclusion

Our study provides the first estimates of the impact of a formal/informal science program on academic achievement. In short, we find evidence that UA improves performance in science: student performance on the NYS science exam increases with the implementation of UA and the magnitude of the difference between UA and non-UA schools increases over time. Little change is seen in student performance on ELA or math for 8th-grade students, suggesting the effect is not merely reflecting coincident overall school improvement. Exploratory subgroup analyses suggest the impact is largest for black students and is less successful for girls than boys. Additionally, we find that UA also contributes to post-8th-grade outcomes. The biggest impact is on the likelihood of taking the Living Environment Regents in 8th or 9th grade. This could have huge implications for a student's high school career as research has shown that students who take a science Regents early on are more likely to take additional Regents compared to those who wait to take the required Regents.

UA's framework has been influenced by research on science teaching and informal science education. Of particular importance is the work of the Museum Learning Collaborative (Leinhardt, Crowley, and Knutson 2002; Schauble, Leinhardt and Martin, 1998) which illuminated how and when students and teachers can learn with objects and through conversation. Science educators aim to teach students the basic disciplines, concepts, and processes of scientific thinking, to develop a scientifically literate citizenry, and to help prepare the next generation of scientists and engineers. Recent publications (National Research Council 2005; National Research Council) indicate that if students are to understand science, they must have opportunities to do science.

Local, state, national, and international science standards all recommend inquiry as a method to approach science instruction (American Association for the Advancement of Science, 1993; National Research Council, 1996; New York State Education Department, 2010; New York City Department of Education 2011). However, much of the current science instruction in schools in the United States does not utilize inquiry, and instead takes a more simplistic approach (National Research Council 2009). Indeed, a study by Weiss et al. (2003) of high school science classrooms found that only 2% of the classrooms observed focused on scientific inquiry. When teachers do utilize inquiry methods, though, these methods have been found to be useful for facilitating student learning (Rushton et al. 2011).

While schools traditionally do not utilize inquiry methods, many informal science institutions embrace this form of instruction. Informal science institutions are also believed to help make science learning “personally relevant and rewarding” (National Research Council 2009, 1). Although schools and informal science institutions approach science differently and play different roles in students’ lives in regard to science instruction, there is a growing body of literature that points to the benefits of collaboration between formal and informal science institutions. For example, a National Research Council report (2009) on learning science in informal environments showed that informal science learning experiences impact children’s interest in science and recommended a collaboration between formal and informal education institutions to increase students’ science learning. Additionally, the National Science Board’s 2007 report on needs in STEM education encourages collaboration between formal and informal science environments in order to improve teacher professional development and science curricula (National Research Council 2009). Research shows that informal science institutions can be effective resources for hands-on science learning for students and increased science pedagogical content knowledge for teachers (Aquino, Kelly and Bayne 2010). Other studies have shown that in many circumstances, field trips can be a beneficial addition to science instruction, though they have often been underused as teaching tools (DeWitt and Storksdieck 2008).

These studies point to the role UA can play in helping science teachers improve their inquiry methodology and ultimately affect student learning. The collaboration between formal (schools) and informal (museums, zoo, botanic gardens) institutions in promoting inquiry-based science education is a key component of UA, along with professional development, field trips and materials. While the results of our study do show increased student achievement for students at UA schools, they do not bear out increased achievement on the inquiry standard. However, this may be a measurement issue. It is possible either the way inquiry is measured on the test or the way we are measuring the standard in our analysis hinders our finding more conclusive results.

The results of this analysis give support to the call by the National Research Council and others for an increased role of informal institutions in science learning both for students and teachers. However, these institutions cannot work alone. Strong partnerships between the institutions within each community and between the institution and the school district(s) in which they work (and in most cases, consistent funding sources) must be in place to enable these programs to grow and flourish and to provide students with the resources they need to develop as scientists.

However, more research is needed. One limitation of this study is that it compares students at UA schools to students at other schools who did not receive the treatment. Further research must be done to compare the outcomes of students who are taught by teachers receiving professional development through UA with the outcomes of other students in the same school whose teachers do not participate in UA. Unfortunately, until the data systems of the public schools have the capabilities to match students to classes and teachers, and to verify that this data is correct, we are limited to these more global types of analyses.

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