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Museums, Zoos, and Gardens: How Formal-Informal Partnerships Can Impact Urban Students' Performance

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Abstract

In this paper we provide the first rigorous evidence of the impact of a partnership between public middle schools and informal science institutions (ISIs), such as museums and zoos, on student outcomes. This study focuses on Urban Advantage (UA), a program in New York City (NYC) that explicitly draws upon the expertise and resources of the city's ISIs, bringing these institutions together with NYC public schools to improve science education through intensive professional development, access to ISIs for teachers and students, and other science resources. We conclude that attending a UA school in eighth grade increases middle school science achievement, and there is some evidence that it may also increase the likelihood of passing standardized science exams in high school.

Keywords: science education, informal science institutions, urban education, professional development

I. Introduction

Students in urban school districts are often disadvantaged in many ways, and researchers devote considerable attention to understanding how and why inner-city students underperform relative to their suburban and rural peers. Despite the challenges urban settings present, cities can also offer unique educational opportunities for students. Among the often-overlooked resources available in large cities is the richness of the nonprofit sector, particularly informal science institutions (ISIs) such as museums, zoos, and gardens.

Urban Advantage (UA) is a program in New York City (NYC) that explicitly draws upon the expertise and resources of the city's ISIs, bringing these institutions together with NYC public schools to improve science education for students and teachers. UA differs fundamentally from traditional museum-to-school collaborations as it provides a hybrid model of formal-informal partnerships where the resources of institutions are selected, designed, and shaped specifically to align with the science curriculum of NYC's middle schools. This means that the partnership is more intensive than most programs that involve outside resources in schools, with a deeper relationship between the informal institutions, the department of education, and the schools. Additionally, since the program is designed specifically for the NYC schools, it is more closely tied to the science curriculum than typical programs that focus on general science enrichment.

In this paper, we estimate the impact of UA on middle school science achievement as well as on high school science outcomes, and our results provide the first rigorous evidence of the impact of a partnership between public middle schools and ISIs on student outcomes. In this paper, we estimate the impact of UA on middle school science test scores (the eighth-grade Intermediate Level Science exam) as well as on early high school outcomes, such as attending a

Science, Technology, Engineering, or Mathematics (STEM) high school, and taking and passing a science Regents exam in eighth or ninth grade.[1]

Results from the fixed effects models show that, on average, UA students do at least 0.041 standard deviations better than students at non-UA schools on the Intermediate Level Science (ILS) exam. As a falsification test, we estimate the impact of UA on ELA and math outcomes, and we find no impact. This indicates that UA has a positive impact on science specifically, and that the observed increase in science performance is driven by UA and not broader school improvement. Results from linear probability models demonstrate that UA may have a small positive impact on passing a science Regents exam in eighth or ninth grade, though the effects on taking a science Regents exam and attending a STEM high school and are null or slightly negative.

In the next section we describe the Urban Advantage program. Then we present an overview of previous research on the role of nonprofit organizations in improving education outcomes, including the role of ISIs in science education. Following we present our identification strategy and the data and measures. Finally, we present our results and then our conclusions.

II. Background

Urban Advantage was launched in September 2004 as a collaboration between eight NYC informal science 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 New York City Department of Education (NYCDOE) to provide teachers and students with opportunities to engage in authentic science practice. Grounded in the learning goals defined in the New York State Learning Standards for Mathematics, Science, and Technology, the UA program is focused on supporting teachers to help their sixth-, seventh-, and eighth-grade students carry out long-term scientific investigations, including the "science exit projects" that NYC eighth-graders are expected to complete before progressing to ninth grade.

The program provides 48 hours of professional development for teachers new to UA and ten hours each year for teachers continuing in the program. The professional development model is designed using an immersion-into-inquiry strategy, which emphasizes providing authentic hands-on learning experiences in science for teachers, the nature of scientific work, specific science content areas, and the essential features of inquiry in the form of long-term investigations. (National Research Council, 2000; Loucks-Horsley & Matsumoto, 2010). After choosing a UA partner institution to attend for targeted professional development, 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 and how to develop scientific explanations based on claims, evidence, and reasoning. As part of their training, 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 & Zeuli, 1999). Additionally, the UA program has developed a variety of classroom tools and resources for schools and families to support science learning outside of the classroom.

In addition to high-quality professional development, teachers also receive monetary and material support from UA. For example, Urban Advantage provides science kits with materials for UA schools, and it also gives teachers funds to purchase materials for their classrooms. Additionally, UA provides vouchers for teachers, administrators, students, and families to take trips to any of the eight partner institutions, and schools also receive vouchers for transportation. Schools use these resources in a variety of ways. For example, teachers may take students on field trips for free, parent coordinators may organize family field trips on the weekends, and teachers can distribute family vouchers to students, which allow the students to take family trips independent of the school.

In the 2011-12 school year, 24% of New York City's public middle schools [2]across all five boroughs (136 schools) participated in UA, and the program served 344 teachers and more than 35,000 students. With support from the American Museum of Natural History (AMNH), informal science education institutions and school districts in other cities have taken steps to implement programs based upon the UA framework in NYC, and a UA program launched in Denver in the 2010-11 school year.

In its early years, UA accepted teachers into the program on a volunteer basis; teachers learned about the program from their principals and from other teachers, and those who were interested self-selected into UA. Over time, the program has developed a more rigorous protocol for accepting both teachers and schools.[3] This is partly due to increased demand and partly due to budget reductions, which result from the fiscal constraints experienced by the New York City Council and NYCDOE, which fund the program. Rather than expand to provide the program to more schools, program staff have opted go deeper within already-participating schools, by opening the program to sixth-grade teachers and adding additional teachers per grade.

Professional development offerings have also evolved over time, as UA staff have developed more course offerings for continuing teachers, since participating teachers are likely to remain in the program for several years and over time, the balance has shifted from new teachers to more continuing teachers. These workshops are open only to teachers who have already participated in the professional development for first-year UA teachers and are designed to focus in greater depth on specific content related to the science exit project process and provide opportunities for experienced teachers to examine student work and assess students' thinking. To help ensure ongoing participation in the UA program, attendance at continuing teacher workshops is required for teachers to continue to receive resources and classroom materials provided by the program (Short, Elgendy, Roditi, & Holmes, 2012).

III. Review of the Literature

The Role of Nonprofits in Education

Nonprofits are organizations that use its surplus revenues to provide services and reinvest in itself rather than distribute profits or dividends to shareholders. In the U.S., many are organized as 501(c)3 tax-exempt organizations and as a whole are one of largest providers of social services in the nation. These organizations also have a long history of involvement in education. They have provided a variety of educational services such as drop-out prevention, tutoring, and mentoring; additionally, nonprofits have often provided literacy, vocational, and other programs that supplement what is available in schools. In the past decade, however, these organizations have played an increasingly larger and important role working within the education sector. In addition to more visibly working within or alongside public school systems, there is some evidence that nonprofits have also increased in size and quality (Paarlberg & Gen, 2009). Whereas early educational nonprofits were small parent-teacher organizations, many have become larger organizations, supported not only by parent dues but also by contributions from community and national foundations. Some of these organizations work to support individual schools (e.g., parent-teacher organizations), while others work to support entire school systems (e.g., local education funds), and others work to influence policy or train principals or teachers at the local, state or national level.

Nonprofits on the national level include foundations, such as the Bill and Melinda Gates Foundation, the Eli and Edythe Broad Foundation, and the Andrew Carnegie Foundation, which have provided funding for research, advocacy and service provision at the national, state and local level; New Leaders, Teach for America, The New Teacher Project, New Schools Venture Fund, the Education Trust, The After-School Corporation, The New York City Leadership Academy, and the Annenberg Institute for School Reform, which both provide funding for programs and/or are service-providers. These organizations train new and current school leaders, bring new teachers into hard-to-staff districts, provide resources for new school initiatives, and influence education policy. And many of these efforts have had visible impacts on the field (Author, 2004; Xu, Hannaway, & Taylor, 2011; author, 2012;) Nonprofits are also increasingly involved in running schools, both through standalone charter schools, charter networks, or education management organizations. Nonprofits have also been the largest provider of out-of-school time (OST) often running programs at schools or at locations close by, such as a park or community center.

Finally, an important, but little-acknowledged group of education nonprofits that works with schools includes museums (e.g., art, natural history), cultural institutions (e.g., orchestras, opera houses, theaters), and zoos, aquariums, nature centers, and gardens. Collectively referred to as informal education institutions, these nonprofit organizations have a history of working with schools as part of their public education mission. Informal science institutions (ISIs), such as museums, science centers, gardens, and zoos, are one particular type of informal education institution. These institutions were typically founded to provide engaging avenues for the general population to learn about science, and in more recent years they have emphasized the importance of science as the world becomes more technologically competitive. Currently, these ISIs create a world of rich learning experiences, which include social interaction and active exploration for people of all ages (Astor-Jack, Balcerzak, & McCallie, 2010).

Collaborations between ISIs and Schools

The traditional relationship between ISIs and schools has been limited, but many organizations, such as the National Research Council, National Science Teachers Association, National Science Board, Institute of Museum of Library Sciences, and the Center for Informal Learning and Schools, are formally recognizing the need for deeper collaboration between informal and formal science institutions (schools). Relationships between formal and informal science education institutions take various forms all of which seek to combine complementary aspects of formal and informal settings to maximize their benefits (Phillips, Finkelstein, & Wever-Frerichs, 2007; Adams, Gupta, & DeFelice, 2012). For example, because students attend school every day and typically receive science instruction in middle school every day, formal institutions are uniquely situated to provide consistent instruction in the framework of an organized, sequential curriculum; however, schools also operate under organizational constraints (e.g., relatively short class periods, large groups of students, testing requirements) that can make it difficult to present authentic, hands-on learning opportunities for students. Informal institutions, on the other hand, are designed to create engaging venues for students to *do* science and typically have excellent facilities and resources, but do not often have the benefit of structured, repeated visits from the same students.

Informal institutions have traditionally been sites for infrequent field trips, which are typically initiated by teachers to provide one-time enrichment activities for their students, and there has been relatively little continued collaboration between these institutions and schools in a systematic way. In recent years, however, the role of ISIs in education has been expanding. For example, ISIs are increasingly providing additional resources beyond single-day field trips, such as more formalized teacher and student programs. For teachers, ISIs frequently provide teacher residency programs, research opportunities, and professional development. These programs vary in their intensity, with some leading to official degrees or certification. For example, the American Museum of Natural History has its own Master of Arts in Teaching program, and the New York Hall of Science offers a state certification program in conjunction with The City College of New York (Saxman, Gupta, & Steinberg, 2010). For students, ISIs typically feature family outreach programs, camp-ins, activity kits, various activities and materials, and out-of-school time programs (Astor-Jack et al., 2010; Hein, 1998; Hofstein & Rosenfeld, 1996; Inverness Research Associates, 1996; Ramey-Gassert, Walberg, & 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 programs, workshops, materials, curricula, etc. for districts, schools, teachers, or students in the broad area of science education besides a one-day field trip" (Phillips et al., 2007).

Despite this expanding role of ISIs in the education sector, explicit partnerships between ISIs and schools are more the exception than the rule, and most interactions between schools and ISIs are informal and primarily dependent on the actions of individual teachers (Kisiel, 2010). Additionally, studies suggest that science museum resources are generally underused by the teachers and students they hope to serve; 53 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 indicated they turn away potential participants due to capacity constraints (Phillips et al., 2007). Research suggests that external factors such as rising costs and accountability concerns likely influence teacher and school participation (Anderson, Kisiel, & Storksdieck, 2006; DeWitt & Storksdieck, 2008).

Impact of Science Interventions

There has been little rigorous research examining the impact of science interventions on students' academic outcomes, and even less on formal-informal partnerships. Most quantitative studies of science interventions are descriptive or correlational, and qualitative work has focused on case studies. Descriptive studies have shown that gender, socioeconomic status, race, reading and math ability, and English language learner (ELL) status are important student-level predictors of science test scores (Maerten-Rivera, Myers, Lee, & Penfield, 2010). Evaluations of specific interventions tend to focus on small samples of students or use survey data to measure the intervention's success in educating students (as opposed to using test scores or other measures of academic achievement).

For example, one study of 404 middle and high school students finds that a joint program between a museum and an academic medical system (containing a museum exhibit and subsequent workshop) increased student interest in health-related careers (Bunce, Griest, Howarth, Beemsterboer, Cameron, & Carney, 2009). Another study of 444 middle school students finds that three online game sessions were able to increase students' science knowledge about exposure to toxic chemicals, as measured by pre- and post-tests (Klisch, Miller, Wang, & Epstein, 2012). Finally, an evaluation of a teacher-level intervention that provided a three-hour workshop and a kit of materials to middle school teachers for cancer education lessons reports that teachers perceived that their students gained knowledge from the unit (Burns, 2012).

There is little quantitative evidence on the impact of partnerships between schools and ISIs on student achievement, but studies suggest these collaborations may be more successful when school-based and informal educators are able to work together to provide cross-contextual learning experiences in both schools and ISIs. For example, one study concludes that 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).

Participation in informal science education has also been found to play a role in students' long-term career decisions, particularly among women and those from minority and low-income communities. Several studies find that by engaging students, encouraging authentic inquiry, building academic knowledge and skills, developing self-efficacy in science, decreasing external barriers and increasing supports, and exposing students to STEM careers, ISIs can make STEM careers an appealing and viable career choice (Dorsen, Carlson, & Goodyear, 2006; Darke, Clewell, & Sevo, 2002; Fadigan & Hammrich, 2004).

While these studies are helpful in understanding the implementation and success of certain science interventions, none examines student achievement directly, and most use only a small sample of students from a case study or small-scale intervention. This study contributes significantly to the literature by using rigorous methods and a large sample to estimate the impact of UA on an at-scale science intervention, and it is one of the first quantitative studies to examine formal-informal collaborations.

IV. Data and Measures

Our analysis draws on a rich student-level longitudinal database for NYC public schools and students from 2003-04 to 2009-10.[4] Every student record contains detailed demographic, program, and academic information including birthplace, race, gender, language ability, poverty (free/reduced-price lunch status), attendance rates, admit/discharge dates and codes, participation in special education and language programs, and standardized test scores. These data are combined with publicly available data from the *Annual School Reports* and *State Report Cards*, prepared annually by the NYCODE and the New York State Education Department (NYSED). In addition to the rich detail and breadth of our data, unique student identification numbers allow us to track students from their entrance in the NYC public school system until their departure. Our sample includes eighth-graders from 2004-2010, for a total of more than 400,000 student-year observations.

We measure short-term outcomes using the eighth-grade Intermediate Level Science (ILS) exam. New York State requires that all eighth-grade students take the ILS test, which 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 measure student performance on the ILS with a *standardized score* ("z-score"), a measure of relative performance standardized across students within a grade to have mean 0 and standard deviation 1. Students performing above (below) average relative to other students in their grade have positive (negative) z-scores.

We use several different measures for long-term outcomes. First, we examine students' academic performance using their likelihood of attending a STEM high school. 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 curricula these programs provide. For the purposes of this analysis, we define all-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. If UA 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.

Two other long-term outcomes we examine are taking and passing a science Regents exam (in our case, Living Environment and Earth Science) in eighth or ninth grade. We use this measure because students in New York have some choice about what Regents exams to take as well as when to take them.[5]

We measure UA program participation at the school level. Data constraints prevent creating a student-teacher match, so we estimate the impact of attending a UA school – not the impact of having a UA teacher. That is, we classify a school as being a UA school if at least one teacher in the school is in the UA program; thus, different schools will have different concentrations of UA teachers within the school. Because it is impossible to retract the treatment, we designate a school as being a UA school in every year after it joins the program, even if it is not currently participating in the program. Thus, once a school becomes a UA school, it is always a UA school for the purposes of our analysis. Note, however, that we only include UA schools that are in the program for at least two years, since the program is unlikely to be fully implemented until year two.[6]

V. Models

We estimate a series of models to assess the impact of attending a UA school on student outcomes. When we use the short-term outcome (student's standardized state science exam score[7],), these models are standard fixed effects models. For the long-term outcomes, though, we use linear probability models, as the outcomes are dichotomous.[8] Our initial specification models student outcomes as a function of only attending a UA school, and then we add year effects, student controls, and school effects. This model is as follows:

(1) $Y_{ijt} = \beta_0 + \beta_1 UA_{ijt} + \beta_2 ST_{it} + \gamma_t + \alpha_j + \varepsilon_{ijt}$

Here, Y is the outcome of interest for student *i* in school *j* in year *t*; UA is an indicator variable that takes a value of one if, in year *t*, student *i* attended a school *j* that was a UA school; ST is a vector of student characteristics in year *t*. Models also include year (γ) and school effects (α), and ε represents the remaining variation. Robust standard errors are appropriately modified to reflect clustering of students at the school level. In this specification, β_1 represents the impact of attending a UA school on student achievement, controlling for other characteristics of the student.

Because it is possible that schools positively select into UA (teachers in higher-performing schools choose to join the program), we include an indicator variable to control for performance in the year prior to joining UA. Thus, the second specification includes an indicator variable that takes a value of one if, in year *t*, student *i* attends a school *j* that is in the year prior to joining UA. This model is as follows:

(2) $Y_{ijt} = \beta_0 + \beta_1 \text{Pre}UA_{ijt} + \beta_2 \text{UA}_{ijt} + \beta_3 ST_{it} + \gamma_t + \alpha_j + \varepsilon_{ijt}$

Here, β_1 represents the difference between UA schools and non-UA schools in the year prior to joining the program, and β_2 is the impact of UA on student outcomes.

Finally, the third specification distinguishes between the first year a school joins UA and all subsequent years (the second year in the program and beyond). This takes into account the fact that programs are rarely fully implemented in the first year, as described above. Consequently, UA concepts and methods may not be implemented until at least the second year a school is in the program. The specification we use to model this relationship is below:

$$(3)\ Y_{ijt} = \beta_0 + \beta_1 \mathrm{Pre}UA_{ijt} + \beta_2 \mathrm{BaseYr}_{ijt} + \beta_3 \mathrm{PostYrs}_{ijt} + \beta_4 ST_{it} + \gamma_t + \alpha_j + \varepsilon_{ijt}$$

In this model, BaseYr is an indicator variable that takes a value of one if student *i* in year *t* attends a school *j* that is in its first of year of the UA program. PostYrs is an indicator variable that takes a value of one if student *i* in year *t* attends a school *j* that has been in UA for at least two years. Here, β_1 represents the difference between UA schools and non-UA schools in the year prior to joining the program, β_2 is the impact of UA during the first year a school is in UA, and β_3 is the impact of UA in all other years after a school joins UA.

VI. RESULTS

Table 1 provides descriptive statistics for the characteristics of the students at UA and non-UA schools in 2009-10[9]. UA schools are, in many respects, quite similar to other New York City public schools serving eighth-graders.[10] One consistent difference between UA and non-UA schools, however, is size; this is also the only statistically significant difference between UA and non-UA schools in 2009-10.

Across the years in our sample, the average size of a UA school ranges from about 650 students in 2006-07 to more than 1000 students in 2004-05; this is compared to between 400 and 800 for non-UA schools. In the 2009-10 academic year, the average enrollment at a UA schools was more than 700, compared to less than 600 at non-UA schools.

In some years, UA schools also show small differences in terms of the percentage of student demographic and academic characteristics. UA schools have a lower percentage of black and a higher percentage of Asian students compared to non-UA schools in 2007-08 and 2008-09. Additionally, in 2006-07 UA schools have greater percentages of students taking the math and science exams, and in 2009-10 UA schools have a greater percentage of their students taking the math exam. Finally, in 2007-08 and 2008-09, UA schools outperform non-UA schools on the English Language Arts (ELA) and math exams. Only in these years do we see a statistically significant difference in passing rates between UA and non-UA schools.

Across UA schools, as with city schools as a whole, there is wide variation in school characteristics. As the large standard deviations show, UA serves 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 student ethnicities.

Before turning to our empirical models, we first show descriptive evidence that UA schools outperform non-UA schools on the eighth- ILS exam. Figure 1 shows passing rates[11] on the 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 New York state 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. In 2007, 44.2% of eighth-graders at UA schools pass the science exam compared to 40.5% at non-UA schools (a gap of 3.7 percentage points).

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 & Stiegelbauer, 1991). It is reasonable to expect UA to take several years to develop into an effective program, and similarly it may take individual schools several years of UA participation before they implement the program effectively. By its third year of implementation, UA had a more developed and stronger program that included not only professional development, but also a set of developed materials and resources for teachers to use in the classroom. Additionally, teachers attend professional development sessions throughout the year in three different cycles, and so it may not be possible for teachers to fully implement UA until their second year as UA teachers. As teachers have more time to implement what they learn during professional development into their classroom practice, we begin to see improved student achievement across UA schools.

Short-Term Outcome: Eighth-Grade ILS Performance

Having provided descriptive evidence of the success of UA schools, we now turn to our empirical models to estimate the impact of UA on student outcomes. We first use a model that estimates the short-term impact of UA on eighth-grade ILS test scores. For these specifications, our analytic sample includes all eighth-graders who have scores on the ILS exam in 2003-04 to 2009-10 (the period corresponding to one year before the start of UA through the last year for which test scores are available).

As seen in Table 2, coefficients on the UA variable are not statistically significant in the most basic models, which control for only year effects (Model 1) and then add controls for student characteristics (Model 2). When we add school fixed effects, however (Model 3), there is a positive impact (0.04**) of attending a UA school; that is, comparing students in the same school (in years the school is and is not a UA school) reveals a positive impact of program participation. This result is robust to controlling for performance in the year before joining UA (Model 4), and as the coefficient on the PreYr variable is small and insignificant, we do not see evidence of positive selection into UA (at least on the basis of performance on the eighth-grade ILS).

As previously described, UA is not likely to be fully implemented in a school until at least the second year in which a school has officially been in the program. To model this appropriately, we distinguish between the first year a school is in UA and all subsequent years (Model 5). We find that UA does not have a statistically significant impact on ILS scores during schools' first year of implementation, but that the impact of UA in subsequent years is positive (0.06*). Model 6 augments this specification by including lagged math achievement in the model. This is not a true value-added model, as we do not have a lagged science test score (no science test is given in seventh grade); because math and science test scores are highly correlated, however, the lagged math score proxies for prior STEM performance. In this specification, the impact of UA is positive but not statistically significant. Again, we see no evidence of positive selection into UA.

Finally, in Model 7 we include interactions between attending a UA school and student characteristics (race, gender, poverty status) to determine if there are differential impacts of UA on different student groups. We find that while black students do worse than white students in science overall, UA has some impact on reducing the disparity between black students and white students. On average, black students at UA schools score .06 standard deviations higher than black students at non-UA schools. We find a similar effect for Asian students at UA schools, who perform .07 standard deviations higher than Asian students at non-UA schools. We also find, however, that female students at UA schools do significantly worse than their non-UA counterparts (0.03 standard deviations lower). We do not find any statistically significantly differences in the contribution that UA makes to the science achievement of Hispanic, white, or poor students.[12]

Though we see no evidence of positive selection into UA based on ILS test scores in the year prior to joining UA, it is possible that schools that are on a trajectory of improvement are more likely to choose to participate in UA. If this is the case, there may be reverse causality, with test score improvements predicting UA participation. If UA schools are improving overall (potentially as a result of whole-school reforms, other programs, or increased teacher effectiveness), we would expect to see similar positive "impacts" of UA on ELA and math test scores. As a falsification test, we perform the analysis from Model 5 using ELA and math test scores (z-scores) as dependent variables (Table 3), and we find UA has no effect on ELA or math test scores. This suggests that UA participation is not simply a proxy for overall school improvement and provides further support for our estimates of the impact of UA on science achievement.

Long-Term Outcomes: High School Outcomes

The results from the linear probability models are presented in Tables 4 and 5. Table 4 provides the full models for the impact of attending a UA school on the probability of attending a STEM high school. Note that the sample of students in these models, as with our previous models, includes students in eighth grade between 2004 and 2010; we follow these students to their ninth-grade schools to measure ninth-grade outcomes (type of school attended and Regents-taking and Regents performance). Thus, the long-term outcomes for students who were eighth-graders in 2010 are measured in 2011.Overall, there does not seem to be a systematic impact of attending a UA school on the probability of attending either an all-STEM or a partial-STEM high school. The first four columns show results for all-STEM high schools. As seen in columns 1 and 2, there are no statistically significant differences in the likelihood of attending an all-STEM school between students who attended a UA school and those who did not. After controlling for the year before joining UA (Model 3), attending a UA school is negatively related to attending an all-STEM school (-0.023*), but this effect disappears after controlling for eighth-grade school effects (Model 4). Overall, we find no evidence of a systematic impact of attending a UA school on attending an all-STEM high school.

Columns 5-8 show results for partial-STEM high schools, and here again there is no consistent impact. Results from Models 1-3 indicate that students who attend UA schools are slightly more likely to attend partial-STEM high schools than their non-UA counterparts (coefficients between 0.046* and 0.052*). Once we control for eighth-grade school effects, however, this result disappears, and the coefficient becomes negative and statistically significant, though quite small in magnitude (-0.009**).

Table 5 summarizes the coefficients on Post-UA for all the high school testing outcome variables. In the model that includes the eighth-grade school fixed effects, all coefficients are statistically significant, and most are positive. Students who attend UA schools are slightly less likely to take the Living Environment and Earth Science Regents exams, but they are more likely to pass these Regents exams.[13] We see a positive impact of attending a UA school in the 8^{th} grade on passing the Living Environment and Earth Science Regents at all three passing cut-points: 55, 65, and 85.[14] However, it should be noted that the coefficient on PreUA is also positive and significant, indicating that UA schools also have a slightly higher percentage of students passing these Regents in the year prior to joining UA. Since the passing score for the Regents is now 65, that UA schools are able to increase the percentage of students who are able to pass at 65 or higher, even slightly, is an important finding.

It is not entirely surprising that the effects of UA on long-term outcomes are inconsistent as many school-level factors that are not likely to be correlated with UA participation may be important to students' high school choices and testing outcomes. For example, school guidance counselors, parent coordinators, and other supports to eighth-grade students and parents can have great influence over the high school choice and placement process. Also, many middle schools tend to send students to a specific type of high school, and consequently act as de facto feeder schools for certain high schools. Thus, students may select into middle schools in part based on where they want to attend high school, which makes the middle school to high school transition endogenous.

In terms of Regents-taking behavior, there are several important factors that are not included in our models. First, because of the regulations around licensing and who is eligible to teach a Regents-level course, not all middle schools can offer science Regents exams to their students. This is a structural factor that is not likely to be influenced by UA participation.[15] Additionally, the high school attended has a role in the taking and passing of the Regents in the models, and this is unobserved in these models.

VII. Conclusion

Formal and informal institutions contribute differently to students' science learning in part because of structural/organizational 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 expect 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 et al., 2012). Rosser (1997) describes collaborations between in-school and out-of-school learning experiences as a “two-pronged approach to learning.”

Despite the growing consensus that collaboration between formal and informal education organizations is an important component of improving science education in the United States, there are still relatively few examples of ongoing, intensive collaborations between schools and informal science institutions, and there has been little research on the impact of such partnerships. This study provides the first estimates of the impact of a formal/informal science program on academic achievement and finds that exploiting the urban advantage with collaborations between formal and informal education institutions is an effective way to improve science education in urban schools.

In short, we find evidence that UA improves performance in science: student performance on the New York State eighth-grade science exam increases with the implementation of UA. Our estimated impact of 0.05-0.06 standard deviations reflect small improvement in science achievement; for comparison, results from the Tennessee STAR (student-teacher achievement ratio) experiment indicate that reducing class size from 22-26 to 13-17 students increased third-graders science test scores by 0.05 to 0.1 standard deviations (Konstantopoulos & Chung, 2009). No change is seen in student performance on ELA or math for eighth-grade students, suggesting the impact estimate is not merely reflecting coincident overall school improvement. Exploratory subgroup analyses find that the impact is largest for black and Asian students and is less successful for girls than boys. Additionally, we find that UA has no significant impact on whether a student attends a STEM high school, but there is evidence that students who attend UA schools are slightly less likely to take but are more likely to pass a science Regents exam in eighth or ninth grade.

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Table 1: **Mean characteristics of UA and non-UA Schools, 2009-10**

	UA	Not UA
Enrollment	**717**	**594**
	(425)	**(347)**
% Black	33.5	39.2
	(29.1)	(29.5)
% Hispanic	41.6	41.3
	(26.3)	(26.5)
% Asian	11.8	9.3
	(15.9)	(14.2)
% White	13.0	10.1
	(19.3)	(17.6)
% LEP	12.1	12.0
	(12.1)	(13.0)
% Free lunch	70.2	71.0
	(20.0)	(19.9)
% Taking reading exam	92.6	91.5
	(5.5)	(7.3)
% Taking math exam	94.9	93.9
	(5.1)	(7.0)
% Taking science exam	90.2	87.8
	(15.5)	(19.3)
% Passing reading exam	37.9	36.6
	(20.0)	(21.5)
% Passing math exam	49.9	47.6
	(21.9)	(22.6)
% Passing science exam	53.0	51.4
	(22.4)	(23.5)
% Manhattan	20.8	20.9
	(40.7)	(40.7)
% Brooklyn	30.2	34.7
	(46.1)	(47.7)
% Bronx	24.2	24.2
	(43.0)	(42.9)
% Queens	20.1	18.9
	(40.2)	(39.2)
% Staten Island	4.7	1.3
	(21.2)	(11.5)
N	149	297

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

Table 2: Impact of attending a UA school on eighth-grade ILS exam z-scores; 2004-2010

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
UA Any Year	0.06	0.01	0.04**	0.04*			
	(0.05)	(0.03)	(0.01)	(0.02)			
PreYr				0.02	0.01	0.00	0.01
				(0.02)	(0.02)	(0.02)	(0.02)
Yr Entered UA					0.04	0.03	0.01
					(0.02)	(0.02)	(0.04)
PostUAYrs					0.06*	0.04	0.030
					(0.03)	(0.02)	(0.04)
Black		-0.75***	-0.40***	-0.40***	-0.34***	-0.19***	-0.41***
		(0.04)	(0.02)	(0.02)	(0.02)	(0.01)	(0.02)
Hispanic		-0.55***	-0.23***	-0.23***	-0.23***	-0.10***	-0.24***
		(0.03)	(0.02)	(0.02)	(0.02)	(0.01)	(0.02)
Asian		0.09**	0.16***	0.16***	0.16***	0.01	0.15***
		(0.03)	(0.02)	(0.02)	(0.02)	(0.01)	(0.02)
Female		-0.06***	-0.07***	-0.07***	-0.07***	-0.04***	-0.06***
		(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
ELL		-0.91***	-0.81***	-0.81***	-0.81***	-0.40***	-0.81***
		(0.03)	(0.03)	(0.03)	(0.03)	(0.02)	(0.03)
Special Educ		-0.62***	-0.59***	-0.59***	-0.59***	-0.28***	-0.59***
		(0.02)	(0.01)	(0.01)	(0.01)	(0.01)	(0.12)
Poor		-0.14***	-0.09***	-0.09***	-0.09***	-0.05***	-0.09***
		(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Lag Z Math						0.56***	
						(0.01)	
UA*White							0.01
							(0.03)
UA*Black							0.06*
							(0.03)
UA*Hispanic							0.042
							(0.03)
UA*Asian							0.07*
							(0.03)
UA*Female							-0.03***
							(0.01)
UA*Poor							0.00
							(0.01)
Constant	18.73	12.65	41.43***	41.42***	45.91***	31.35***	44.95***
	(11.71)	(8.15)	(6.59)	(6.58)	(8.097)	(6.26)	(8.15)
Year FE	YES	YES	YES	YES	YES	YES	YES
School FE	NO	NO	YES	YES	YES	YES	YES
N	401270	401270	401270	401270	401270	401270	401270
R-Square	0.00	0.24	0.35	0.35	0.35	0.55	0.35

(1) *p<0.05, ** p<0.01, *** p<0.001
(2) Robust clustered standard errors in parentheses
(3) Year dummy not shown
(4) Not shown, analysis with Lagged Z Reading. Results are the same as model 7.

Table 3: Impact of attending a UA school on Eighth-Grade ELA and math, 2004-2010

	Math	ELA
Yr Prior UA	0.011	-0.001
	(0.024)	(0.017)
Yr Ent. UA	0.036	0.026
	(0.027)	(0.021)
Yr Post UA	0.014	0.022
	(0.031)	(0.023)
Black	-0.408***	-0.375***
	(0.022)	(0.023)
Hispanic	-0.270***	-0.275***
	(0.020)	(0.021)
Asian	0.407***	0.064**
	(0.027)	(0.022)
Female	0.027***	0.194***
	(0.004)	(0.004)
Poor	-0.074***	-0.119***
	(0.008)	(0.008)
Constant	21.546*	4.157
	(8.614)	(7.134)
Year FE	YES	YES
School FE	YES	YES
R-Square	0.33	0.32
N	425820	409572

(1) *p<0.05, ** p<0.01, *** p<0.001
(2) Robust clustered standard errors in parentheses
(3) Not shown Special Ed and ELL

Table 4: Impact of attending a UA school on the probability of attending a STEM high school

	All STEM				Partial STEM			
	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4
Yr Before UA			-0.016*	-0.004**			0.014	-0.009***
			(0.006)	(0.001)			(0.013)	(0.002)
UA	-0.008	-0.016	-0.023*	-0.002	0.051*	0.046*	0.052*	-0.009**
	(0.010)	(0.009)	(0.011)	(0.002)	(0.020)	(0.019)	(0.021)	(0.003)
Black		-0.061***	-0.062***	-0.034***		-0.053	-0.053	0.003
		(0.013)	(0.013)	(0.002)		(0.028)	(0.028)	(0.003)
Hispanic		-0.046***	-0.046***	-0.030***		-0.094***	-0.093***	-0.006*
		(0.012)	(0.012)	(0.002)		(0.025)	(0.025)	(0.003)
Asian		0.100***	0.100***	0.119***		0.005	0.005	0.002
		(0.016)	(0.016)	(0.002)		(0.026)	(0.026)	(0.003)
Female		-0.014***	-0.014***	-0.015***		0.002	0.002	0.006***
		(0.002)	(0.002)	(0.001)		(0.003)	(0.003)	(0.001)
Poor		-0.017***	-0.018***	-0.016***		-0.017*	-0.015*	0.007***
		(0.004)	(0.004)	(0.001)		(0.008)	(0.008)	(0.002)
Spec Ed		-0.046***	-0.046***	-0.037***		-0.005	-0.005	-0.003
		(0.004)	(0.004)	(0.001)		(0.005)	(0.005)	(0.003)
ELL		-0.072***	-0.072***	-0.061***		0.015	0.015	0.028***
		(0.008)	(0.008)	(0.001)		(0.009)	(0.009)	(0.003)
Constant	-13.873***	-11.576***	-9.395***	-7.804***	49.741***	51.488***	49.591***	40.319***
	(2.614)	(2.234)	(1.982)	(0.596)	(5.821)	(5.724)	(5.249)	(0.866)
School FE	NO	NO	NO	YES	NO	NO	NO	YES
R-Square	0.002	0.047	0.047	0.115	0.011	0.019	0.019	0.130
N	368854	368854	368854	368854	368854	368854	368854	368854

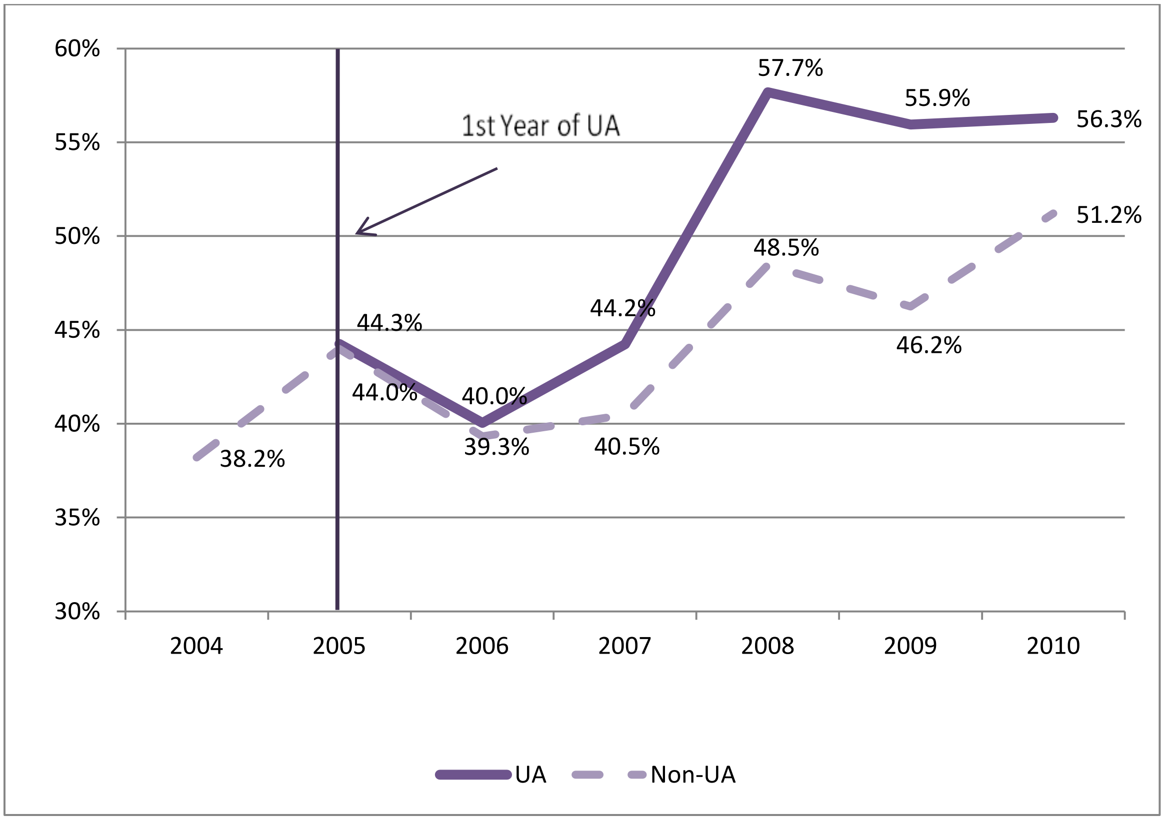
1) * $p<0.05$, ** $p<0.01$, *** $p<0.001$
2) Robust clustered standard errors in parentheses
3) Poor is equal to those eligible for free and reduced price lunch
4) N is all students who were present in NYC public schools in 8th and 9th grade
5) Time dummy not shown

Table 5: Impact of attending a UA school on the probability of taking and passing Regents exams in science

	Living Environment				Earth Science			
	Took Test	**Passed 55**	**Passed 65**	**Passed 85**	**Took Test**	**Passed 55**	**Passed 65**	**Passed 85**
Year prior to UA	-0.095***	0.031***	0.022***	0.013***	-0.089***	0.015***	0.012**	0.026***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.004)	(0.004)	(0.003)
Year in UA	-0.047***	0.014***	0.009**	0.012***	-0.020***	0.011*	0.013*	0.010*
	(0.003)	(0.002)	(0.003)	(0.003)	(0.003)	(0.005)	(0.005)	(0.004)
Black	-0.026***	-0.055***	-0.112***	-0.125***	-0.045***	-0.105***	-0.157***	-0.109***
	(0.003)	(0.002)	(0.003)	(0.003)	(0.003)	(0.004)	(0.005)	(0.004)
Hispanic	-0.031***	-0.029***	-0.073***	-0.110***	-0.031***	-0.051***	-0.094***	-0.083***
	(0.003)	(0.002)	(0.003)	(0.003)	(0.003)	(0.004)	(0.005)	(0.004)
Asian	0.050***	0.018***	0.041***	0.093***	0.001	0.034***	0.051***	0.070***
	(0.003)	(0.002)	(0.002)	(0.003)	(0.003)	(0.003)	(0.004)	(0.004)
Female	0.040***	-0.012***	-0.028***	-0.014***	0.020***	-0.032***	-0.046***	-0.025***
	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)	(0.002)	(0.003)	(0.002)
Poor	0.010***	-0.015***	-0.028***	-0.036***	0.000	-0.022***	-0.036***	-0.034***
	(0.002)	(0.001)	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)	(0.002)
Spec Ed	-0.094***	-0.194***	-0.276***	-0.103***	-0.053***	-0.231***	-0.259***	-0.075***
	(0.003)	(0.003)	(0.004)	(0.002)	(0.003)	(0.006)	(0.006)	(0.002)
ELL	-0.070***	-0.171***	-0.247***	-0.113***	-0.050***	-0.168***	-0.193***	-0.070***
	(0.003)	(0.003)	(0.003)	(0.002)	(0.003)	(0.005)	(0.005)	(0.003)
Constant	-19.348***	-4.700***	-30.620***	-38.809***	99.184***	-19.676***	-46.375***	-55.972***
	(0.928)	(0.714)	(0.954)	(0.883)	(0.822)	(1.548)	(1.785)	(1.655)
School FE	YES	YES	YES	YES	YES	YES	YES	YES
r2_a	0.056	0.099	0.150	0.195	0.102	0.124	0.174	0.185
N	36	259131	259131	259131	368721	121259	121259	121259

1) * p<0.05, ** p<0.01, *** p<0.001
2) Robust clustered standard errors in parentheses
3) Control variables not shown are: Year

Figure 1: Unweighted mean achievement, eighth-grade Intermediate Level Science exam



Note: This figure uses student-level data, and thus shows the percent of all students in UA schools and all students in non-UA schools that pass the eighth-grade ILS in each year.

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[1]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 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.

[2] Middle schools are defined as all schools with an eighth grade.

[3] UA does not accept all schools or teachers who apply to be in the program. Current UA schools as well as schools that are hoping to join the program submit applications to UA, and UA program staff consider factors such as how many teachers in the program have been or are planning to participate in UA, how frequently schools have been or anticipate being able to use vouchers to attend ISIs.

[4] The database is housed at author and is updated annually with data from New York City Department of Education (NYCDOE).

[5] 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 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.

[6] We drop 62 schools from the sample, as these schools are only in UA for one year.

[7]The standardized score, or "z-score," is a measure of relative performance standardized across students within a grade to have mean 0 and standard deviation.

[8] Long-term outcomes include attending a STEM high school, taking a science Regents exam in eighth or ninth grade, and passing a science Regents exam in eighth or ninth grade. Outcomes are described further in the Data section.

[9] Results for all years are similar and available from the authors.

[10] 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.

[11] A school's passing rate is the percentage of eighth-grade students who scored a 3 or 4 on the ILS.

[12] We also find no differences for special education or LEP students; results are not shown here but are available from authors.

[13] This result is not contingent upon taking the exam. That is, the sample of students used for the models estimating likelihood of passing the exam includes all students who are in the NYC public schools in both eighth and ninth grades, not just those who take the exam in one of these years.

[14] Prior to 2005, students were required to earn a score of 55 or higher to count a Regents exam toward earning a Local Diploma, while 65 was the score needed for Regents and Advance Regents Diplomas. Now earning a Regents Diploma is the minimum requirement, so 65 is the lowest passing score. Achieving an 85 on a Regents exam is used as a cutoff for admission to certain selective colleges and universities.

[15]For a student to be eligible to take a specific science Regents exam, the teacher must be certified in that content area. That is, only teachers certified in earth science can teach an Earth Science Regents course; only teachers certified in biology can teach a Living Environment Regents course. If a middle school science teacher is only certified in general science or a general middle school instruction, her students are not eligible to take a the Earth Science or Living Environment Regents exam.

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