Secondary school physics availability in an urban setting: Issues related to academic achievement and course offerings

Angela M. Kelly
Graduate Program in Science Education, Lehman College, City University of New York, 250 Bedford Park Boulevard West, Carman Hall 232, Bronx, New York 10468-1589

Keith Sheppard
Center for Science and Mathematics Education, Stony Brook University, Stony Brook, New York 11794-5233

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High school physics is a gateway course for post-secondary study in science, and an essential component in the formation of students' scientific literacy. The opportunity to study physics is not universally available for children in U.S. schools, particularly in urban areas. Restricted science opportunities result in inequitable participation and a barrier to future participation in STEM-related fields. Although the national trend in physics enrollment has recently shown an increase, the percentage of participation is much lower for students in urban schools. We examined the availability of physics in New York City, and whether access was related to academic achievement measures, such as prior science performance, and graduation and college attendance percentages. High schools that offered physics were compared to those that did not, and patterns in types of available physics courses were examined. The findings substantiate the compelling need to explore the barriers to increased physics access and participation for urban youth.
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I. INTRODUCTION

The availability of physics as a course option in United States urban secondary schools warrants close examination. The American Institute of Physics (AIP) has noted that "…introductory physics was almost universally available in our nation's high schools," although "in most places enrollment supported only one or two classes."[1] Similarly, the National Science Board reported that over 99% of high schools offered physics.[2] These reports of widespread availability of physics courses did not coincide with the experiences of the authors working with schools in New York City, where physics courses are not as widely available as the national statistics suggest.

Despite a robust and detailed annual school report system in New York State, data regarding enrollment in the sciences were not available from city and state agencies. Consequently, we sought to document and analyze the physics offerings and enrollments in New York City secondary schools. Additionally, the study examined academic performance measures that correlated to physics access, including science and mathematics achievement on standardized tests and college attendance and graduation percentages. (The former is the percentage of graduates planning to attend two- and four-year colleges, and the latter represents the percentage of students who had begun as first-year students and graduated from the same school; this number includes students who earned a GED or a diploma with or without a Regent's endorsement by passing five New York State standardized tests, one of which must be in a science).

In Ref. 3 the authors reported data on overall physics enrollment in the city and found that approximately 20% of New York City high school graduates have studied physics for at least one year. This figure is lower than the national average of approximately 33%.[1,2,4] The availability of physics courses was not equitably distributed; an overall 55% (163 of 298) of the surveyed city high schools did not offer any physics during the academic year 2004–2005.[3] These "nonphysics" schools enrolled 23% of the total secondary school population of the city (approximately 75 000 students). Four of the schools that did not offer physics reported that they usually did in alternate years, which did not significantly affect the reported results and statistical analyses. Our study is limited by the cross-sectional nature of the data collection—the results provide insight into physics access during one academic year in one city school district, which may or may not be representative of limitations in physics availability in other urban areas.

Three questions guided the study: How are physics offerings and enrollments distributed throughout New York City schools? Are there statistical correlations between physics availability and academic measures, such as mathematical proficiency, science achievement, graduation percentage, and the percentage of college bound students? Are there differences in these academic measures depending on the types of physics courses offered?

II. REVIEW OF CURRENT RESEARCH

Despite much concern about the quality and quantity of science education in the United States,[5] there has been recent positive news about enrollments in high school sciences. Transcript studies in 1990 and 2000 showed that the percentage of high school students taking chemistry rose from 45% to 63%, and physics rose from 21.5% to 33%.[2] Presently, almost all students in the U.S. graduate from high school having taken a biology course, and two-thirds complete chemistry and one-third physics. In 2006, for the first time ever, more than one million high school students were enrolled in physics.[6]

The approximately 3:2:1 enrollment ratio reflects the underlying organization of high school science in the U.S. Since the sciences were introduced into high school studies, they have been single year courses taught in a fixed order.[7]

Although there is considerable debate about the order in which the courses should be taught,[8,9] the predominant pattern is biology, followed by chemistry, and then physics. This ordering has acted as a filtering system; students enrolling in chemistry have usually completed biology, and students taking physics have traditionally completed both biology and chemistry. When coupled with state graduation requirements for science, the ordering of the sciences largely accounts for the reported general enrollment pattern.

Physics, as the last science course taken, is an elective subject and frequently acts as a measure of readiness for college science. Although the majority of states require three years of science for high school graduation, many competitive postsecondary institutions recommend the completion of four years of science, especially for future scientists, doctors, architects, and engineers.[10] A recent study identified taking physics and calculus courses in high school as the key to pursuing a STEM-related career and concluded that racial disparities in STEM degree attainment were partly due to course-taking patterns.[11] In another study of over 8000 science majors in college, Sadler and Tai[12] reported that more than 78% had taken high school physics. American College Testing determined that students who completed a biology, chemistry, and physics sequence were most likely to reach the science benchmark for college readiness (in contrast to just biology or biology and chemistry); students who meet or surpass the benchmark ACT science score of 24 (out of a possible 36) have a 75% chance of receiving a C or better in college science courses. Consequently, high schools that do not offer physics may inadvertently diminish college preparedness in STEM disciplines, thus constraining the postsecondary opportunities available to their students.

III. METHODOLOGY

This study was performed with data collected from the public secondary schools and the New York City Department of Education.[13] At the time of this study, New York City was the largest school district in the country with over a million students. Approximately 317 000 of these students attended 316 secondary schools. The racial composition of the student population was 38% Hispanic, 34% Black, 15% White, and 13% Asian. Most of the students in the city (69%) were eligible for free lunch, the graduation rate was 59%, and 8% of students were recent immigrants to the United States.[13]

Administrators at the New York City Department of Education were contacted to determine the optimal method for collecting the individual school information on physics enrollments. They reported that although general demographic data were available, enrollment data for the sciences were unavailable. Therefore, the information was collected directly from individual schools in the city.

Data were collected during the 2004–2005 academic year by contacting each of the city's secondary schools to request physics enrollment data, including the types of courses and the grades in which students could enroll. Ultimately, 298 of the 316 (94.3%) public secondary schools in the city completed the survey, verbally and/or in writing. The other 18 schools were representative of the overall sample in terms of size, demographics, and location within the five city boroughs. Descriptive statistics on demographics, graduation percentages, math and biology and chemistry standardized test scores (known as Regents exams), and percentage of college bound students were given in the Annual School Reports.[13] These variables were utilized as a comparative tool to determine the differences between the physics and nonphysics schools.

Students studying science in secondary schools in NYC take a variety of science courses. Biology (known as Living Environment) is the most common offering, followed by Earth Science, and then Chemistry; Physics is the least common. There are several levels of physics courses. For the purposes of this study the physics offerings were divided into Advanced Placement (AP) Physics, Regents Physics, and Non-Regents Physics (in order of decreasing difficulty). AP Physics, which is more advanced than Regents, is a college-level course that follows the curriculum established by the College Board[14] and may be either algebra-based with a broad focus (AP Physics B) or calculus-based with an in-depth treatment of fewer topics (AP Physics C). AP Physics, which is designed as a second year physics course, was offered in 20 (6.7%) of city high schools at the time of the study. Regents Physics is a college-preparatory physics course with a standardized culminating exam offered in 116 (39%) of the city high schools. Its curriculum is determined by the New York State Education Department.

Non-Regents Physics is more conceptually oriented course (for example, Hewitt's *Conceptual Physics*[15] or Eisenkraft's *Active Physics*[16] are used). Many schools in NYC have implemented this curriculum for 9th graders, although a few offered it for juniors and seniors. Non-Regents Physics was offered in 31 of the 298 (10.4%) high schools surveyed. This percentage reflected a positive trend in expanding physics access to a wider range of students. There were 2661 students in grades 9–12 studying some type of Non-Regents Physics during the school year. In six of the 31 Non-Regents Physics schools, Regents Physics was also offered, providing the opportunity for two years of physics study.

According to the City Council of New York's study on the state of science education in NYC,[17] "Physics First" approaches have shown promise in actively engaging students in physics in grade 9 and fostering interest in upper level science courses. This course provided more flexibility for school administrators; Non-Regents Physics is traditionally less mathematically challenging and does not require six instructional periods per week, as is the norm for Regents Physics. Several administrators commented that their students could not take Regents Physics because of inadequate mathematical preparedness, so they selected Non-Regents Physics as a more practical alternative.

IV. FINDINGS

A. The overall picture of physics availability

The general availability of physics in city schools is outlined in Table I. The data indicate limited physics availability in city school for all city boroughs. In each case the percentage of graduating seniors who had taken a physics course is below the national average of 33%, with 20% of city high school graduates taking a physics course before graduation. The borough with the least physics availability was the Bronx, which has the highest number of under-represented minorities (92% of the students) and the poorest students (77% qualify for free or reduced lunch). Just 15% of Bronx high school graduates had taken physics at the time of the study. The percentage of schools offering physics varied from 32% (Bronx) to 83% (Staten Island). With the exception of Staten Island, which has the lowest number of under-

Table I. New York City High School demographics and physics data by Borough (2004 and 2005).

Location	Mean school size	Total No. of HS students	% Black	% Hispanic	% Asian	% White	% Eligible free/reduced lunch	% Schools offering physics	% Graduating seniors who had taken a physics course
NYC	998 (n=298)	297,404	34	38	13	15	62	45	20
Bronx	693 (n=82)	56,826	34	58	4	4	77	30	15
Brooklyn	1092 (n=87)	95,004	56	29	6	9	62	39	21
Manhattan	708 (n=82)	58,056	32	45	11	12	65	52	28
Queens	1720 (n=41)	70,520	34	31	20	15	43	66	17
Staten Island	2213 (n=6)	13,278	19	17	8	56	25	83	24

represented minorities in the city, a significant number (55%) of city schools did not offer any physics courses.

Physics course-taking patterns showed some variance by borough (Table II). The majority of the city's physics students was enrolled in Regents Physics (77.1%), followed by Non-Regents (17.5%), and AP (5.4%). The percentage of Bronx students enrolled in Non-Regents Physics was greater than in other areas of the city; also, the percentage of Bronx students enrolled in AP Physics was much lower than in any other area of the city, which suggests that access to the most advanced physics study is restricted for the poorest students, who are overwhelmingly Black or Hispanic.

B. Mathematics and science performance and physics availability

Measures of academic performance were tested for differences between the physics and nonphysics schools (see Table III). Proficiency on SAT Mathematics and Regents Mathematics Exams was strong indicators of physics access. The average SAT mathematics score for those in schools that offered physics was 449, compared with 389 in schools that did not offer physics. Schools that offered Non-Regents Physics also reported higher SAT Math scores (442) than nonphysics schools, and schools with AP Physics had the highest scores (534). Similar results were obtained for the mathematics standardized state tests, with passing scores for 71% of the students who took the exam in physics schools compared to 53% of students who took the exam in nonphysics schools. AP Physics schools had a very high passing rate, at 85%. Non-Regents Physics schools had a passing rate of 63%, higher than both nonphysics schools and the citywide average of 61%. The passing score required for the state test was 65%.

The science achievement measures were biology and chemistry examination passing percentages (Table III). Physics schools had significantly higher passing percentages for both exams: 57% passed the biology exam, compared to 40% in nonphysics schools; 49% passed the chemistry exam, compared to 27% in nonphysics schools. AP Physics schools reported the highest passing rates for these tests, at 69% for Regents Biology and 63% for Regents Chemistry. Data on these academic indicators were not available for many of the Non-Regents Physics schools on the Annual School Reports.

C. Graduation rate and college attendance and physics availability

Table III indicates that the graduation percentage for schools that offered physics (64%) was higher than for schools that did not (47%). This difference also held for AP Physics schools (76%) and Non-Regents Physics schools (61%). The percentage of students planning to attend two-year or four-year colleges also was significantly different, with 74% of graduates from physics schools planning to attend college, compared to just 59% of graduates from nonphysics schools. AP Physics schools reported the highest graduation rate at 80%.

V. DISCUSSION

The availability of physics in New York City high schools reveals some troubling inequities. A significant number of students attend schools where there is no opportunity to take a physics course. The data show that poor and underrepresented minority students are much less likely to have access than other students, which suggests that policy makers should focus on improving physics availability when devel-

Table II. New York City physics course-taking patterns by Borough (2004 and 2005).

Location	No. of students in Regents Physics (% of total)	No. of students in Non-Regents (conceptual) Physics (% of total)	No. students in AP Physics (% of total)	Total No. of physics students
NYC	11,679 (77.1%)	2644 (17.5%)	821 (5.4%)	15,144
Bronx	1512 (66.7%)	695 (30.7%)	60 (2.6%)	2267
Brooklyn	3681 (72.6%)	998 (19.7%)	392 (7.7%)	5071
Manhattan	3134 (78.5%)	728 (18.2%)	129 (3.2%)	3991
Queens	2726 (90.5%)	161 (5.3%)	126 (4.2%)	3013
Staten Island	626 (78.1%)	62 (7.7%)	114 (14.2%)	802

Table III. Comparison of means of academic performance for schools that offered physics and those that did not offer physics (2004 and 2005).

Variable	Mean in schools that offered physics of any type ($n=134$)	Mean in schools that offered Non-Regents Physics ($n=31$)	Mean in schools that offered AP Physics ($n=20$)	Mean in schools that did not offer physics ($n=164$)	Mean in NYC schools overall ($n=298$)
SAT Math scores	449	442	534	389	431
% of students who passed Regents Math A exam[a]	71%	63%	85%	53%	61%
% of students who passed Regents Biology exam[a]	57%	N/A[b]	69%	40%	48%
% of students who passed Regents Chemistry exam[a]	49%	N/A[b]	63%	27%	37%
Graduation rate	64%	61%	76%	47%	59%
% of College bound graduates (both 2- and 4-year colleges)	74%	N/A[b]	80%	59%	66%

[a]The passing score for these exams is 65% or better.
[b]Many of these schools were new and did not yet have complete annual reports.

oping solutions for expanding representation in STEM-related fields. Although physics course-taking is just one measure of preparedness for postsecondary science study, its scarcity indicates a critical need for the improvement of secondary science education in urban schools.

In addition to the socioeconomic disparities related to physics access, our findings suggest three key issues: Academic performance indicators are significantly higher in schools that offer physics; (2) Non-Regents Physics, though available in only 31 schools, may be a practical alternative for broadening physics participation in urban schools; and (3) AP Physics, offered in just 20 schools, should be expanded to prepare more students for the rigors of postsecondary STEM study. Although the data suggest some correlation between physics access and student achievement, this correlation does not imply a causal relation. Rather, the overall picture of physics availability, as well as corresponding data on academic performance and course type, serves as a lens for examining potential ways for improving physics accessibility for all high school students.

Proficiency in mathematics and science on standardized assessments is often a prerequisite for entry into a high school physics course. It is problematic that there were significant statistical differences in science and mathematics performance between schools that offered physics and those that did not. It is unclear whether poor mathematical achievement was the primary factor contributing to limited physics availability, or whether a lack of high quality science might be indicative of a school's inadequacy in committing to rigorous standards. In any case, access to physics correlated strongly with higher academic performance. This correlation is further illustrated by data showing that students who attended schools offering physics were more likely to graduate and to plan to attend college. Greater effort on the part of school administrators and teachers is required to examine ways in which they might increase physics accessibility for a larger proportion of students, and this access should be explored in terms of how to better prepare students for the challenges of high quality secondary science and mathematics. This access might include after school and/or Saturday classes to strengthen science and mathematics skills, which could provide foundational knowledge for motivated students in low performing schools who wish to take physics.

Non-Regents Physics, which was offered in 31 of New York's 298 surveyed public high schools, offers great promise in expanding physics access to a greater portion of students. Although just 10% of the city's secondary schools offered Non-Regents Physics during the 2004–2005 academic year, students who attended these schools did slightly better academically than students in NYC schools overall and much better than students in nonphysics schools. This type of course does not have the mathematical demands of a traditional college-prep physics class but can provide a strong conceptual base for students who have insufficient backgrounds for a more rigorous course. Consequently, Non-Regents Physics may be a promising introduction to the traditional Regents Physics curriculum for some students. It may serve as a potential equalizer for physics access because it is a course in which larger numbers of students can gain exposure to physical phenomena, succeed without the pressure of standardized tests, and develop an interest in a science that has often been reserved for the academic elite. We do not suggest that this course replace mathematically based physics courses. Rather, it could be the first-year of a two-year physics sequence that would prepare traditionally underserved students for introductory college physics. This practice is not common, with only six of the 31 schools at the time of the study offering a two-year physics sequence.

Non-Regents Physics is an example of a "Physics First" approach because it is typically taught to younger students, emphasizes greater conceptual understanding of physical phenomena, and has less challenging mathematical applications. Increased availability of this form of physics study may be an important step in providing all high school students in New York City with the opportunity to study physics before they graduate.

AP Physics, a course that provides excellent preparation for those who major in a STEM discipline, was a rarity in the schools in this study, and it was usually offered in schools where students had demonstrated very high levels of academic achievement. Because this course provides a solid foundation for those who wish to study postsecondary physics and engineering, expanding AP Physics availability is a worthy long-term goal. Achieving this goal depends on providing a strong introductory physics course—a curriculum option that was unavailable for 75 000 city students at the time of the study. If more students study physics at the introductory level, there will be a greater pool of students prepared to succeed in AP Physics. Schools can also expand AP Physics availability by combining qualified students from

several schools into one class or partnering with neighboring colleges and universities to offer opportunities to enroll in credit-bearing college physics courses.

Although this study examined the physics course offerings and correlated academic achievement measures in an urban setting, it did not address issues that affect student choice in selecting physics nor administrative factors in deciding whether physics should be offered. Now that school reform has become a priority in the United States, particularly with regards to STEM education, new reforms and initiatives must advance the opportunities of all students to study physics. Urban science educators and policy makers can take the quantitative results of this and other studies to develop new models for curricular reform to expand access to high-quality advanced science and mathematics teaching and learning, with physics as the anchor for the successful expansion of diversified STEM participation.

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