The Effect of Ninth-Grade Physics in One Private School on Students' Performance on the Mathematics Section of the PSAT

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ABSTRACT

Germantown Friends School (GFS) in Philadelphia introduced ninth-grade physics (replacing ninth-grade biology) in 1999. I have studied the effect of this change on the mathematical performance of students on standardized tests taken late in the eighth grade and early in the tenth grade. I examined data for six classes, three that did not have ninth-grade physics and three that did have it, including in the survey only students who were enrolled at GFS in the eighth, ninth, and tenth grades. There were no significant differences in the performance of the six classes on the Quantitative Ability sub-test of the CTP III test in the eighth grade. However, all three classes that had ninth-grade physics performed significantly better on the mathematical section of the PSAT in the tenth grade than did the three classes that did not have ninth-grade physics. This result is not entirely surprising, since the ninth-grade physics course, despite its conceptual focus, did make use of some algebra and a small amount of geometry.

INTRODUCTION AND METHODOLOGY

In the fall of 1999, Germantown Friends School (GFS) "inverted" its upper-school science sequence from biology-chemistry-physics to physics-chemistry-biology, joining about 150 other schools which, at that time, had opted for "physics first"[1]. Although the arguments in favor of the inverted sequence[1-8] are persuasive, they are based more on the intellectual logic of the sequence than on measured outcomes. I do not know of any quantitative studies that explore the effects of teaching physics in the ninth grade. I set out to explore one small facet of the GFS change—how replacing biology by physics in the ninth grade affects the math skills of the students.

Setting

The students attending this K-12, co-educational, private day school are from Philadelphia and surrounding suburbs. Although many are from middle-class and upper-middle class families, the school provides numerous scholarships and financial aid opportunities to qualified students who exhibit financial need. The students in eighth grade through twelfth grade are placed in distinct math courses based on ability grouping, but the science curriculum maintains heterogeneous groupings. The total school enrollment is approximately 900 students. There are about 80 to 88 students in each eighth-grade class, and 88 to 98 in each ninth- and tenth-grade class. During eighth grade through twelfth grade, the enrollment in each section of a course is typically 16 to 20. The school is located in a lower-middle class urban community, and is academically competitive. Graduates are often accepted into highly selective colleges and universities.

Faculty members do not need to be certified in order to teach at the school, but more than two-thirds of them have an advanced degree.

The Physics Course

Since physics was introduced to the ninth grade, all of the ninth grade math and physics teachers have met a number of times to discuss their respective courses. Although no joint lessons have been presented to students, the teachers use these conversations to learn what vocabulary is being introduced to the students. These discussions also provide the teachers with information concerning what skills and tools are being enhanced in each course and what background knowledge would most aid students in each class. This collaboration has been quite informal, but it has improved communication and coordination between the science and math departments. Additionally, math teachers have made efforts to use the equations and concepts of physics in their classrooms and they continue to occasionally borrow physics equipment for demonstrations and classroom exercises.

This introductory physics course uses the third edition of Paul Hewitt's *Conceptual Physics* and the accompanying *Concept-Development Practice Book*. In the three-year period 1999-2002, five different teachers taught this course but they followed similar approaches and focused on many of the same topics. The course is hands-on and is not a memorization intensive course. The students study motion in one and two dimensions, Newton's laws, momentum, energy, circular motion, center of gravity, rotational mechanics, wave motion, sound, and light. In some years, the students have also been able to explore areas of electricity, magnetism, and optics. The emphasis is on conceptual comprehension of the material, but there is frequent quantitative work performed in lecture and the laboratory that complements the information being studied. The mathematics used is algebra and some topics from geometry. Students are not expected to carry out derivations or solve multi-step problems of the kind that are common in higher-level courses.

An annual event that takes place in this course is the Physics Olympics. For this assignment, students spend at least three weeks in the spring applying their knowledge of physics to one of a handful of construction assignments that aim to solve a problem under certain constraints. Projects in the past have included a gravity powered car, an elastic powered airplane, a light and strong tower made of index cards, a mousetrap powered car, an egg drop, and a car that must travel forwards and backwards. Each group works on one of the projects and ultimately competes against others who worked on the same event. Projects are judged based on criteria supplied to students before they began construction. Students must also write journals and reflection papers relating their design to physical principles and concepts studied in the year or learned through independent research.

Methodology of This Study

Each student in the school completes a Comprehensive Testing Program III (CTP III) Level F test during the spring of eighth grade. This standardized test is published and distributed by the Educational Records Bureau and is composed of eight sections that assess performance in verbal and quantitative areas. The Quantitative Ability section is similar to, but not at the same depth as, the mathematics portion of the PSAT and SAT 1.

Scores are reported in percentiles relative to the national performance of eighth graders. In the fall of tenth grade, many students choose to take the PSAT. These scores are reported in percentiles relative to the national performance of college-bound juniors.

Percentile scores on the Quantitative Ability subtest of the CTP III were collected for the graduating classes of 2000 through 2005. The participants in this study were enrolled at GFS during eighth, ninth, and tenth grades. Students who did not take both the eighth grade CTP III test and tenth grade PSAT were omitted from the study. For the classes of 1999-2002, biology was offered in the ninth grade; for the classes of 2003-2005, physics was offered. For the latter three classes, the few students who did not take ninth-grade physics were omitted from the study. The CTP III data served as a baseline to see if all six classes had comparable quantitative skills at the end of eighth grade. After statistical analyses established that the six classes' scores were comparable, I analyzed these same students' scores on their tenth grade PSATs. For the three classes that did not have physics, I used statistical tests to determine whether these three classes had comparable grades on the math portion of the PSAT. I then compared these data with the PSAT performance of those members of the next three classes who had studied physics to see if statistically different results were observed.

RESULTS

Table 1 shows students' performance on the Quantitative Ability subtest of the eighth grade CTP III test, and the sample size, for the six graduating classes of 2000 to 2005.

A chi-square test for the mean scores listed in Table 1 gives the results χ^2=0.107, df = 5, and p < 0.005. This means that there is a greater than 99.5% likelihood that the deviations that occur among the six years can be attributed to chance[9]. Therefore, the chi-square statistical test implies that it is highly probable that the observed fluctuations among the six graduating classes are not unexpected and all six classes have similar quantitative abilities at the end of eighth grade.

Between the eighth-to-tenth-grade experiences of the first three classes (graduating in 2000-2002) and the latter three classes (graduating in 2003-2005), the change from biology to physics was the only significant change in the curriculum or academic program.

The average percentile performance of each class, during its sophomore year, on the quantitative portion of the PSAT is listed in Table 2.

A chi-square test for the PSAT scores between 2000-2002 resulted in χ^2=0.203, df = 2, and p = 0.90. This implies that there is a 90% chance that the variations in the scores during this time period are explained by chance. Therefore, the graduating classes of 2000, 2001, and 2002 can be viewed as having similar quantitative skills during the fall of tenth grade.

The scores from the classes of 2000-2002 were combined together to establish a larger data set of students' performances on the PSATs prior to the placement of physics in the freshmen year. These values were compared with the data collected for each year after the change in the science curriculum. The aggregate percentile performance of the pre-inversion classes and each post-inversion class is noted in Table 3. A two-sample t-test related the pre-inversion and post-inversion sets, and the results are listed in Table 4.

Table 4 shows that for the class of 2003, the results are significant at the $p < 0.1$ level and the data for the classes of 2004 and 2005 are significant at the $p < 0.005$ level. This means that there is a less than 10% chance that the increase observed for the class of 2003 relative to the pre-inversion classes occurred by chance. Similarly, there is less than a 0.5% chance that the increase noted for the classes of 2004 and 2005 relative to the pre-inversion years was a result of chance. This data indicates a strong association between physics in the freshmen year and improved test scores on the mathematics' portion of the PSATs for students at Germantown Friends School.

SUMMARY AND DISCUSSION

For the six-year span of this study, all of the eighth-grade classes had comparable quantitative abilities as measured on the standardized test. Before ninth-grade physics was introduced, students' scores on the math portion of the PSAT in tenth grade remained relatively constant from year-to-year. Placing physics in the ninth grade curriculum coincided with an observed improvement in the mean performance on the math section of the PSAT. It is highly likely that chance does not account for this improvement. The improvement was less marked for the first class to take physics (class of 2003) than for the next two classes (classes of 2004 and 2005). This could be associated with who taught the course and how, since the teachers were not the same for all three of these years.

Although this paper discusses a circumscribed study consisting of a small sample at a specific school, it is important because despite all the discussions and papers regarding 'physics first' I have been unable to find any quantitative studies that analyze the effects of teaching physics in the ninth grade. This paper does not definitively prove that the physics course is solely responsible for raising students' performance on standardized assessments of quantitative ability, but this change in performance has a strong correlation with the curricular changes made in our science sequence.

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TABLES

Table 1: Performance of each grade on quantitative portion of the CTP III test

Year of Senior Graduation	2000	2001	2002	2003	2004	2005
Mean CTP III Quantitative Percentile	92.2	90.2	88.4	89.4	91.0	89.1
Sample Size (n)	64	41	49	66	68	65

Table 2: Performance of each grade on mathematics' portion of the PSAT

Year of Senior Graduation	2000	2001	2002	2003	2004	2005
Mean PSAT Mathematics' Percentile	69.8	64.6	66.4	71.6	75.3	75.7
Sample Size (n)	64	41	49	66	68	65

Table 3: PSAT performance of pre-inversion classes and each post-inversion class

Year of Senior Graduation	2000-2002	2003	2004	2005
Mean PSAT Mathematics' Percentile	67.3	71.6	75.3	75.7
Sample Size (n)	154	66	68	65

Table 4: T-test results comparing post-inversion PSAT scores for each class with pre-inversion scores

Year of Senior Graduation	2003	2004	2005
p-value	0.0935	0.0035	0.0036
t-value	-1.32	-2.72	-2.71
Degrees of freedom	218	220	217

ENDNOTES

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9. Due to a one-time change, the CTP III test for the graduating class of 2003 was administered during the first month of their ninth grade year. These fall ninth grade percentile scores are relative to other students taking the exam in the fall of their freshmen year. Since these fall normed percentile scores are statistically similar to the scores of the other five classes who took the test in eighth grade, all six classes' performance can be compared relative to each other.