The Role of High-School Physics in Preparing Students for College Physics

By Philip M. Sadler and Robert H. Tai

It is a rare high-school teacher who does not view his or her physics course as being helpful in preparing students for college physics, yet many college physics professors question the worth of taking physics in high school. Studies have documented both the dissatisfaction of college professors with the knowledge and abilities of high-school graduates and the success that high-school teachers feel in preparing students for college. 1-4 At the summer 1996 AAPT paper session, blood pressure was palpably soaring as these two groups debated this issue. The stakes are high. Nationally, over 650,000 students each year take high-school physics5 and success in college physics (taken by one-third million students) often is a prerequisite for many programs, including pre-med and engineering. 6

Several studies have reported on the relationship between college physics and high-school preparation. 2,7-10 All have shown that in introductory college physics courses, students who have studied physics in high school have performed better than their classmates who have not (although the strength of the relationship varies among the studies). So, it seems that this is a well-researched matter with fairly consistent results. Yet, there is something troubling about each of these studies.

Few alternative hypotheses were explored. Perhaps only suburban students, or those with highly educated parents take physics in high school. The success of these students in college physics may be more closely related to such demographic variables than to taking a high-school course in physics. Moreover, all the previous studies were undertaken at a single college or university. Since high-school teachers do not know which college their students will attend, a more generalizable result would be obtained by studying this issue at many institutions. To this end, we launched a study to determine the degree to which demographic variables and past high-school courses relate to success in first-semester college physics courses.

Methodology

To select a sample of college courses, we drew at random the names of 100 physics professors from a commercial mailing list. We hoped for a diverse group of institutions. Thirty-eight of these professors were identified as teachers of an introductory physics course; only 30 were teaching such a course in the fall of 1994 when we carried out the study. Six refused to participate, five more withdrew later because of lack of time or reported student reluctance to participate. Nineteen participated, a rate of 63% of the potential 30. They represented 19 courses at 18 colleges with 1933 students. There were nine public state and eight private institutions, plus one national military academy. Fifteen were universities, three were four-year colleges. Course sizes ranged from 21 to 292 students with a mean of 97 students.

We prepared a student questionnaire through interviews with college faculty, students, and high-school teachers. A pilot study in a local college helped us refine the range and possible answers to questions. We produced forms that could be scored by computer. The survey was designed to test many of the same variables of earlier studies, but we extended our questions to identify demographic variables and the different experiences that students had in their physics courses. We report here only on the course-taking and demographic issues.
We chose college grades as the most accessible and universal measure of student success in college physics. We feel this gauge reflects the values and beliefs of individual college professors better than any test we could devise. The 57-item survey was given to students during class time and student grades were later reported by the professor. The forms were coded and checked for accuracy.

Data and Analysis

Professors graded their students using a variety of schemes, so grades were all translated to a comparable 100-point scale. Students came from a wide variety of backgrounds. Most went to public school (84%). White students made up 78% of the sample, those with Asian backgrounds, 11%. African American and Latino students each represented 4% of the sample, and Native Americans 0.5%. Two-thirds of the students in the sample identified themselves as male. Roughly a third hailed from suburbs, while a quarter each were from small cities or small towns. Fourteen percent were from large cities and only 6% from rural areas. The majority (63%) of students had taken calculus in high school and 87% previously took both chemistry and biology. The high-school GPA of students (based on last science, math, and English courses taken) was $89 \pm 8$ (± one SD). Students' parents varied in their level of education. Sixty percent of the students' fathers had four or more years of college; this was true of 45% of mothers. Only 4% of students had mothers or fathers who had not completed high school.

Almost all students came from high schools offering physics (94%), yet only 82% took a high-school course in physics. Of the 293 students without high-school physics, 52 came from schools in which physics was not offered. Roughly half of the students in the sample took "regular" high-school physics. About one-sixth each took AP, honors physics, or none at all. Only 12 students identified their high-school course as primarily for non-science students. Most students who took physics had a one-year course, although 13% of the sample had two or more years of high-school physics. These students were twice as likely to take AP physics in their second year than a non-AP course.

Previous studies found support for several variables contributing to success in introductory college physics courses. Hart and Cottle found a 6-point difference between students who had taken high-school physics and those who had not. Our sample shows a difference of only 2.4 points between these two groups. Hart and Cottle also found that students with a grade of B or better in their last high-school math class scored 6 points higher out of 100 (converted from 0.6 on a 4-point scale) than students with a grade of C+ or lower. The mean grade of those students in our study receiving a B or better in high-school math was 5 points higher than those receiving lower grades. Afters replicated Hart and Cottle's study with 161 students. Again, students with a high-school physics course outperformed those without by 6 points on a 100-point scale, about half a full grade level.

Comparing means is a first step in analyzing the relationship between variables. Although it may seem reasonable to attribute the difference in mean grade to a particular variable, other factors may be better predictors of performance. By exploring many alternative hypotheses, we can build models that identify which sets of variables account for the most variance. Multiple regression is a tool for building models that can best explain the variation in college performance using several variables. This method also allows the calculation of the statistical significance of each of these variables in addition to its strength. We built three models in reverse stepwise fashion starting with all variables and removing those that were the least significant until all had a statistical significance of $p \leq 0.05$ (Table I). Excluded variables were tested at each step, one at a time, and the stepwise reduction iterated until no further variables met the required conditions.

Results should be interpreted as a way of explaining the variation in student grades within each college. Model A sets the baseline for variance. The college a student attends is used as a control variable, since some schools graded harder than others. Model B accounts for whether or not students took high-school

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physics. Students who have taken high-school physics do 2.4
points better in college courses.

Model C adds several demographic variables and the
amount of explained variance doubles. Students from private
high schools did slightly worse than those from public schools.
White and Asian students performed better than Native Ameri-
can, Black, or Hispanic students. Those students with well-edu-
cated parents also did better. Students in suburban schools
appear to have a slight advantage. These results relate to the
socioeconomic status of students. Students who took a college
course from someone of the same gender got a boost in grades,
as did those who had good grades overall in high school, and
especially those who took a high-school calculus course. Gender
of the students did not prove to be a significant variable. Girls
did as well as boys in their college courses if we take into account
the demographic variables.

The contribution of taking high-school physics shrinks to
1.24 points in this model. The probability of this being the
result of a random fluctuation is $p = 0.049$, just on the edge
of statistical acceptability. Students in this study were asked
to predict how much high-school physics improves grades in
college. The mean response was 7.8 points, six times larger
than the effect found. High-school physics has a weight of
less than half of taking a high-school calculus course.

**Discussion**

This study attempts to characterize the relationship be-
tween demographic variables, taking high-school physics,
and later performance in introductory college physics. Inclu-
sion of demographic variables reduces the apparent effect of
earlier study of physics on later college performance.

Colleges that advise against or restrict enrollment in phys-
ics courses based upon prior enrollment in high-school phys-
ics should reconsider their policies. Students with strong
academic backgrounds in high school and with a previous
calculus course perform well in college physics without
having taken the subject in high school.

Our study failed to find a strong relationship between
college physics grades and taking physics in high school.
Although preparation for future college coursework is em-
phasized by most high-school physics teachers, it is not the
only goal espoused. Many teachers view their course as a way
to connect students to the world in which they live, to help
them become science “fans” following science in the press,
or to even the inequities among genders or races concerning
experiences in science. We believe, based on this work, that
promoting a high-school physics course as preparation for
college physics is not justifiable. This may seem counter to
the anecdotal reports from college students who return to
praise their high-school courses. Views of students who do
not return may not be as supportive.

While, on average, taking a high-school physics course
appears to have little relationship to college physics perform-
ance, 79% of the variance in student grades still remains
unexplained. By accounting for other factors: level of physics
course, number of years of high-school physics, teacher
knowledge, teaching methods, emphasis on laboratory, con-
structivist orientation, or selection of text one can account for
up to 20% of additional variance. We originally collected this
data along with the reported demographic information and
are currently completing our study. Our initial analysis finds
that several decisions that high-school physics teachers make
are linked very strongly to a student’s performance in college
courses. Surprisingly, some types of high-school physics
courses have the opposite effect; they predict worse college
grades than taking no physics at all. Our hope is that our
efforts will help to identify those decisions, practices, and
resources that will aid those high-school physics teachers
who wish to provide the best possible preparation for their
college-bound students. We hope to report on these findings
in the near future. Any reader who would like more information should contact the authors.

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References

5. Indicators of Science and Mathematics Education 1995 (NSF 96-52), edited by Larry E. Suter (National Science Foundation, Virginia, 1996).
6. Michael Neuschatz, American Physical Society, College Park, MD, private communication, July 16, 1996. This may be a low estimate since colleges without physics departments, and physics courses outside of physics departments are not included.
11. Proximity to bodies of standing water was historically associated with high probability of contracting malaria. Yet, there must be both anophel mosquitoes and the presence of human carriers of the disease. Those living near swamps without either do not contract malaria.