

Advanced Placement Exam Scores as a Predictor of Performance in Introductory College Biology, Chemistry and Physics Courses

Survey data from 8,594 students in 55 randomly chosen colleges and universities finds that those having passed an AP science exam earn somewhat higher college science grades, but not enough to assume prior mastery. Moreover, half of this performance difference appears to be related to demographics and high school coursework and not to students' AP coursework.

Introduction

Students who take Advanced Placement (AP) examinations in high school seek the option of receiving credit for and bypassing introductory college level courses. These exams are constructed and graded by the College Entrance Examination Board (College Board) to “allow participating colleges and universities to award high school students college credit, advanced placement, or both” (College Board, 2004, p. 6). While the granting of credit or placement remains at the discretion of each individual college or university, the College Board is unequivocal in its interpretation of AP exam scores:

AP Exam grades of 5 are equivalent to the top A-level work in the corresponding college course. AP Exam grades of 4 are equivalent to a range of work representing mid-level A to mid-level B performance in college. Similarly, AP Exam

grades of 3 are equivalent to a range of work representing mid-level B to mid-level C performance in college (College Board, 2006, p. 1).¹

The purpose of this study is to appraise the College Board's claim of the equivalence of Advanced Placement courses as measured by AP exam scores with the comparable college course in three science disciplines: biology, chemistry, and physics. This is a complex issue because, to some degree, AP course-taking is a sorting process that draws primarily highly motivated, high achieving students. If this self-selection effect is ignored,

Colleges vary considerably in their policies and in their advice to their students concerning enrollment in introductory science courses.

the outcome of AP course-taking itself may be overestimated. Dougherty, Mellor and Jian (2006a) offered the following insight:

Much of those [AP] students later success in college may be due not to the AP classes themselves, but to the personal characteristics that led them to participate in the classes in the first place – better academic preparation, stronger motivation, better family advantages, and so on. These selection effects will affect any comparison of AP and non-AP students (p. 3).

Colleges vary considerably in their policies and in their advice to their students concerning enrollment in introductory science courses. As a result, there exists a sizable population of students taking introductory science courses who have done well in AP science courses while in high school,

1. In this research we refer to the numerical score earned on the Advanced Placement exam (1, 2, 3, 4, or 5) as the “AP exam score.” We refer to the teacher's assessment of the AP students' coursework as the “AP course grade.” In its literature, the College Board generally refers to the AP exam score as the “AP grade.”

yet do not “place out” in college. Since the AP exam is taken prior to college entry, one would expect that these students, whom the College Board has awarded passing exam scores, would earn substantially higher grades, on the average, upon re-taking an introductory college course in the same subject. The apparent advantage is clear. Students exhibiting higher levels of AP performance would most certainly be expected to have a stronger grasp of the relevant college content. They should do better than students who have not had the advantage of what is typically a second year of study in the subject while in high school. The intent of this paper is to characterize the performance of these students as both an independent approach to the validation of Advanced Placement exams in biology, chemistry, and physics and as an estimate of the contribution of these advanced high school courses.

Background

The AP Program of the College Board provides “motivated high school students with the opportunity to take college-level courses in a high school setting.”² High school AP courses corresponding to the 35 AP examinations administered by the College Board in both science and non-science disciplines are taught by 110,000 teachers in the US. These exams are central to the AP Program

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and offer a means of certifying each student’s mastery of course content at the college level. In the sciences, students sat for a total of 311,595 exams in environmental science, biology, chemistry, or physics in 2005.³ Among these science test-takers, 59% earned scores of 3 or higher (5-point scale). By comparison, 62% of mathematics test-takers earned scores of 3 or better. As a result, many of these students would have grounds to expect their prospective colleges to offer them course credit in these disciplines when they matriculate.⁴ This outcome would be consistent with the original purpose of Advanced Placement envisioned by representatives of the faculties of the three private academies (Andover, Exeter, and Lawrenceville) and three private universities (Harvard, Princeton, and Yale) responsible for formulating the program.⁵ To promote this policy, the College Board makes available research studies that support its contentions.⁶

With tests scores in hand, students are assured by the College Board that “Over 90 percent of the nation’s colleges and universities have an AP policy granting incoming students credit, placement, or both, for qualifying AP Exam grades.”⁷ However, the fine print is more complex. Having an “AP policy” does not mean that colleges and universities follow the College Board’s recommendation that an AP score of 3 should garner course credit or advanced placement. Many times, colleges only offer credit for scores of 4 or even 5. Some college policies do not grant either to incoming students.⁸

While the College Board puts much energy into the construction, monitoring, and scoring of AP exams in an attempt to attain a measure of college course equivalency, there is a considerable range of opinion concerning the value of AP courses in the sciences and mathematics. Many professors believe that all students can benefit from taking introductory science courses in college (National Research Council, 2002, p. 58). Others argue that college-level courses require the efforts of college-level faculty (Juillerat, Dubowsky, Ridenour, McIntosh & Caprio, 1997). Some colleges administer their own placement exams. Others allow credit only for students not majoring in that specific field or award credit only after a student has taken and passed a higher-

2. College Board AP Central website. <http://apcentral.collegeboard.com>.

3. <http://apcentral.collegeboard.com/members/article/1,3046,152-171-0-39036,00.html>

4. “ACE [American Council on Education] notes that the practice of granting provisional credit for a grade of 2 is becoming more frequent because comparability studies have shown that many of these students are potentially qualified for college-level work -- credit is made permanent if the student satisfies another criterion, such as successfully completing the next course in the discipline.” http://apcentral.collegeboard.com/apc/public/colleges/setting_policy/index.html

5. “[For] the student of marked mathematical and scientific ability and interest, who is probably heading for a college major in science and a career in science or engineering ... could take a one-and-a-half or two-year school course in chemistry, physics, or biology, designed to prepare him for admission to the sophomore college course in the field chosen for concentration in school [i.e. in college]. (Phillips Academy, 1952, p. 65.)

6. <http://apcentral.collegeboard.com/article/0,3045,152-167-0-11592,00.html>

However, research that can be considered somewhat critical of the claims of the College Board concerning the AP program does not appear to be included at their website (e.g. Geiser & Santelices, 2004; Lichten, 2000).

7. <http://apcentral.collegeboard.com/program/0,3060,150-0-0-0,00.html>

8. Lichten’s (2007) sampling of colleges and universities found that only 30% of colleges accept an AP exam score of 3 for advanced placement, while 89% accept a score of 4, and 95% accept a score of 5.

level course in the subject (National Research Council, 2002, p. 58). Some universities offer special transitional courses for those students who place out of introductory courses, but do not advance to the next level course (National Research Council, 2002, p. 59).⁹ Lichen (2000) argues that the quality of AP courses has diminished to the point that the College Board's recommendations are no longer accepted by a large number of colleges, particularly those considered highly selective (e.g. Harvard, Yale, MIT, University of Pennsylvania).¹⁰ An NRC committee recommends that colleges should be strongly discouraged "...from using college scores on AP and IB exams as the sole basis for granting automatic advanced placement out of specific courses for majors, or out of biology distribution requirements for non majors (Wood 2002, p. 125.)"

The population of students who have taken AP courses in high school and retake introductory courses has been largely neglected by researchers.¹¹ Surprisingly, researchers have rarely structured past studies to reveal the degree to which AP courses bestow an added benefit upon students who take them, "... the existing empirical evidence regarding the benefits of AP experience is questionable (Klopfenstein and Thomas, 2005, p. 5)." Klopfenstein and Thomas refer to the body of AP research, a majority of which lack or include insufficient controls. We should keep in mind that, in

addition to attracting potentially more highly motivated and gifted students, there are other potential covariates: AP courses are more prevalent in wealthier communities, are typically taught by more experienced teachers (Burdman, 2000) and predominantly enroll students who have already studied the subject for a year. Much of the existing AP research gives no recognition to these factors. Studies lacking controls suffer the potential weakness of overestimating the effects of AP courses, because they conflate the influence of numerous factors and fail to account for the relationship of AP courses net of the covariates. While many assume that students who do well in AP courses in high school owe their success to their AP studies, other factors may well be involved, such as coming from more advantaged homes and attending schools that emphasize college preparation (Willingham & Morris 1986). Moreover, the fast pace of AP courses, due in large measure to the focus on test preparation, may not serve students as well as courses that progress at a more moderate pace, focusing on topics in greater depth and detail. This supposition led a recent national study to posit that, "It is possible that AP students were at a disadvantage in some classes or at some colleges" (National Research Council, 2002, p. 194). While most assume that such an outcome is unlikely, we are willing to subject such hypotheses to scrutiny. For example, students reporting the

lowest score of 1 (out of 5) on the AP exam have not demonstrated content mastery. However, this outcome leads one to wonder whether this year for these students of study could have been better spent in a course with a different format. Also troubling are the low AP science exam passing rates among under-represented groups.¹²

Prior Research

Research on the value of AP courses in the sciences has primarily focused on accounting for differences in freshman grade point average or persistence to graduation, both rather indirect measures of the equivalence of AP courses and introductory college science courses. Others judge the performance of students who "place out of" one or two semesters of the introductory course in a scientific field and then enroll in a second or third semester science course equivalent to students who take the prerequisite course in college. Such studies have not controlled fully for the fact that AP students generally have stronger high school preparation in math and English, contributing to the ability to "skip ahead." Moreover, second and third semester science courses can cover content unrelated to the prerequisite course (e.g. second semester physics usually entails a study of electricity, magnetism, and light, topics distant from first semester kinematics and Newtonian mechanics). In most cases, studies examine the perfor-

9. None of the courses participating in this study have that profile.

10. USA Today, 3/20/2006, Advanced Placement: A detour for college fast track? Mary Beth Marklein

11. Studies comparing student performance in second-year college courses typically compare those who have "placed out" with high AP exam scores to those with students who take the introductory level college course with either a failing AP exam score or no AP experience (Dodd, Fitzpatrick, De Ayala, & Jennings, 2002). No mention is found in the literature of the experience of those students who chose to retake the introductory college course with a passing AP exam score.

12. Fewer than half of under-represented minorities are "passing" the AP exam with scores of 3 or higher, while scores of 1 (the lowest score possible) are awarded to more than half of African American and Chicano students. Put in another way, students not "passing" the exam constitute 70% of Chicano and African-American students, while more than 50% of Native Americans and Puerto Rican students score below 3. Based on this measure, AP courses do not appear to be an effective means of AP exam preparation for many students. For more information, please consult the AP National Report 2005, http://www.collegeboard.com/student/testing/ap/exgrd_sum/2005.html

The élan of having AP courses, especially in science and mathematics, is well known.

mance of students at a single college or university or within a single state, making generalization to the entire U.S. problematic. These studies also fall into two general categories: studies with adequate control variables and those without. The latter group typically compared grand means between samples of AP and non-AP students or correlated the performance of AP students with other performance-related variables. We found that these studies typically appear as reports that are not published in peer-reviewed journals. Often the source of funding for much of this work is unclear. On the other hand, the “with controls” studies more frequently appear in peer-reviewed journals, having been subjected to more scrutiny and review.

While we reviewed both forms of research, we summarized only the findings of the “with-controls” studies below, grouping the findings under four commonly analyzed outcome variables. The 1986 Willingham and Morris report was especially useful in constructing this list.

- **College Grade Point Average (GPA)**– The total number of AP courses taken in high school has little effect on predicting freshman college GPA, but AP exam scores are a strong predictor of sophomore grades (Geiser & Santelices, 2004). Using matched sets totaling 688 students at Indiana University, AP students were found to earn higher college GPA’s (Chamberlain, Pugh, &

Shellhammer, 1978). Willingham and Morris’ (1986) found that about half of the grade differential (those with a college grade average of B or above) of AP students over non-AP students was accounted for by matching pairs of 1878 students on their academic background. Klopfenstein & Thomas (2005) found that of 28,167 students, those taking AP courses in high school did not earn higher freshman grades in college.

- **College Science Course Grades.**

Ruch (1968) did not find a statistically significant difference between matched pairs of AP and non-AP students on college grade in the courses related to the AP course taken or overall freshman GPA. Dodd, Fitzpatrick, and Jennings (2002) studied the performance of three groups of 831 students in a second semester biology course at the University of Texas at Austin. They compare the mean grades of three student groupings:

1. Those who earned credit for the prerequisite course with a score of 3 or above on their AP exam (AP-CR).
2. Those who earned lower than a 3 in their AP course and took the prerequisite (AP-Class).
3. Those who did not take an AP class and enrolled in the prerequisite class (Non-AP).

AP-CR and Non-AP groups were matched using high school class rank and SAT and ACT scores. Over a four-year period, the Non-AP group earned higher mean grades than either the AP-Class or the AP-CR groups in the second semester course. This

difference was reported to be statistically significant for one year of the study. The AP-Class group earned slighted higher grades in the second semester course than the AP-CR group. Reported GPA’s in other college biology courses were also higher for Non-AP students.

- **Persistence to college graduation** – The combined number of AP and honors courses taken in high school was not a significant predictor for persistence through freshman to sophomore years in college (Geiser & Santelices, 2004); Klopfenstein & Thomas (2005) found students taking AP courses in high school have no higher probability of persisting to a second year of college. Low-income students who take AP courses in high school graduate college at a greater rate (Dougherty, Mellor & Shuling, 2006a)
- **Choice of Further Study** – Ruch (1968) used 21 matched-pairs of students and found that that AP students were more likely to continue with the same subject in college. Chamberlain, Pugh, & Shellhammer (1978) found academic progress, college GPA, and course-taking measures were superior for AP students over 344 matched sets of students (Cahow, Christensen, Gregg, Nathans, Strobel, & Williams, 1979). Willingham and Morris’ (1986) found that of 1878 students, AP students were no more likely to take more than one year’s coursework in biological or physical science, nor to major in those fields.

All of the studies above controlled for students’ high school performance (i.e. rank, HSGPA, or coursework

completed) except for Chamberlain *et al.* (1978) and Dougherty *et al.* (2006a). Geiser & Santelices (2004), Klopfenstein & Thomas (2005), and Dougherty *et al.* (2006a) included measures of students' socio-economic status. Ruch (1968), Dougherty *et al.* (2006a) and Klopfenstein & Thomas (2005) included high school quality ratings, while Willingham & Morris (1986) matched students by college attended.

From this short list of controlled studies, it is apparent that the measure of AP coursework value varies with the outcome variable considered and the control variables included. We did not find any studies that measured performance in introductory college science courses while controlling for relevant covariates such as performance in high school courses considered prerequisites for AP science courses. Given that performance in prior coursework and is widely regarded as the strongest predictor of subsequent performance, it is essential that this factor should be included in any analysis seeking to isolate the relationship to AP coursework itself, rather than merely considering an aggregated analysis that lacks both detail and is unable to estimate the relative contributions of various factors. The inclusion of such controls provides an opportunity for refinement of models that more accurately estimate the relationship of AP coursework relative to other factors. Regression models must be constructed using variables representing viable alternative hypotheses to the main relationship being studied

in order to be considered robust. For example, inclusion of SAT scores alone, entered as a control for high school-level learning, is insufficient to account for prior science knowledge learned in first-year high school science courses. It is incumbent on the scholar employing regression to explore alternative relationships that are potentially causal and to take great care in considering, measuring, and including factors that could account for additional variance. Put another way, it is the attention that scholars pay to controlling for alternative hypotheses that is often a measure of quality research.

But, why is research on the direct comparison of AP and non-AP students important? Conventional wisdom ascribes clear and overwhelming benefits to Advanced Placement classes in high schools. The élan of having AP courses, especially in science and mathematics, is well known. As a result, the College Board's AP program has grown dramatically over the last 20 years, with a sustained increase in the number of exams including all subject areas of 9.3% (with an 8.8% increase in number of students) annually. To offer some perspective, this growth is more than five times faster than the growth in the US high school population.¹³ The ratio of students to exams tracked closely until recently; their separation is indicative of an increase in the number of students taking multiple AP exams (1.29 in 1970 vs. 1.72 in 2005). In 2005, 1.2 million students took 2.1 million AP exams. According to the latest available data,

2.1 million entering freshmen enrolled in degree granting institutions in Fall 2003. One might assume that on the average nearly half of all entering college freshmen have taken at least one AP course in high school.¹⁴ In reality, many have taken more than one course. Our estimate is that in 2004, those taking AP science exams represented one of five college freshmen (Digest of Educational Statistics, 2004).¹⁵

The expansion of AP Programs is also currently propelled by economic and political support since several states currently extend financial incentives to high schools that offer AP courses¹⁶, while others require all high schools to participate (Hershey, 1990; Willingham & Morris, 1986).¹⁷ Many states have mandated through legislation the inclusion of AP enrollment in admissions decisions or the granting of college credit for high AP exam scores in public institutions of higher education (Lichten, 2000). The U.S. president has called for an addition of 70,000 Advanced Placement teachers in science and mathematics, a near doubling of current numbers.¹⁸ In addition, the U.S. Department of Education subsidizes AP programs for low-income students (Klopfenstein, 2004).¹⁹ This expenditure of public funds, in effect, subsidizes one particular educational program over others. Hence, it is desirable that Advanced Placement policies and programs be rigorously assessed so that scarce resources can be spent the most wisely.

A powerful motivating factor for students is the fact that one may enter college with course credits and in some

13. <http://apcentral.collegeboard.com/members/article/1,3046,152-171-0-47040,00.html>.

14. http://nces.ed.gov/programs/digest/d05/tables/df05_180.asp.

15. <http://apcentral.collegeboard.com/members/article/1,3046,152-171-0-39036,00.html>.

16. Florida, Louisiana, and Utah.

17. South Carolina.

18. George W. Bush, State of the Union Address, 1/31/2006.

19. Higher Education Act Amendments of 1998, Title VIII, Part B, P. L. 105-244.

cases with enough credits to bypass the freshman year, saving a year's tuition (MacVicar, 1988; Pushkin, 1995). Troubling to many professors is that students may use AP credit in many colleges to satisfy their requirements for science courses and never take another science course when in college (National Research Council, 2002, p. 59). For example, Lichten (2000) found that only 22% of students who had scored "3" on their AP calculus exam enrolled in an advanced calculus course in college, while 17% took a remedial calculus course. Though high school AP teachers may be very talented, they generally do not have the breadth of knowledge nor the most recent and relevant content knowledge possessed by college faculty (Lichten 2000). By accepting AP exam-related course credits, students may be foregoing the opportunity to learn about the most topical findings and issues from college instructors whose "other" job it is to do research.

The striking expansion of the AP program offers an opportunity to gauge the pedagogical influence of AP coursework. Merely presuming that AP courses are comparable with college courses ignores the opportunity we have to analyze the degree of this purported similarity as a means to improve college preparation through high school instruction.

Methods

The Sample

Factors Influencing College Science Success (Project FICSS) is a large-scale national study of introductory college students and their high school science experiences, which collected a total of nearly 18,000 surveys. The data includes a series of subsamples of college students in various college science courses. In this particular analysis, we

analyzed survey data gathered from students in 124 different first semester introductory college biology, chemistry, and physics courses in 55 colleges and universities. These institutions were from a stratified random sample reflecting a nationally representative distribution of institutional size and selectivity, from small liberal arts colleges to large state universities. All participating introductory science courses met in lecture-style classes with weekly recitations sessions and laboratories and had enrollments of 10 students or more.

Of 9354 collected surveys in this subsample, 1029 respondents reported having taken an AP course in the subject in high school in which they were currently enrolled in college. Of the students who took AP courses, 316 earned scores of 3 or higher on the AP exam, roughly 3% of the entire sample. While this can be considered a small number compared to the 170,000 students who earned scores of 3 or higher on AP exams in these subjects in 2005, the data used in this

... many students feel that while AP is a good preparation for college science, many also feel they benefited from taking the actual college science course.

analysis represents a national sample of students who have both taken part in Advanced Placement courses and exams in high school and also take introductory level college science courses. The theory and practice of inferential statistics has established that valid inferences (within appropriate confidence limits) can be drawn from relatively small number

of participants, provided they are from a well-selected random sample.

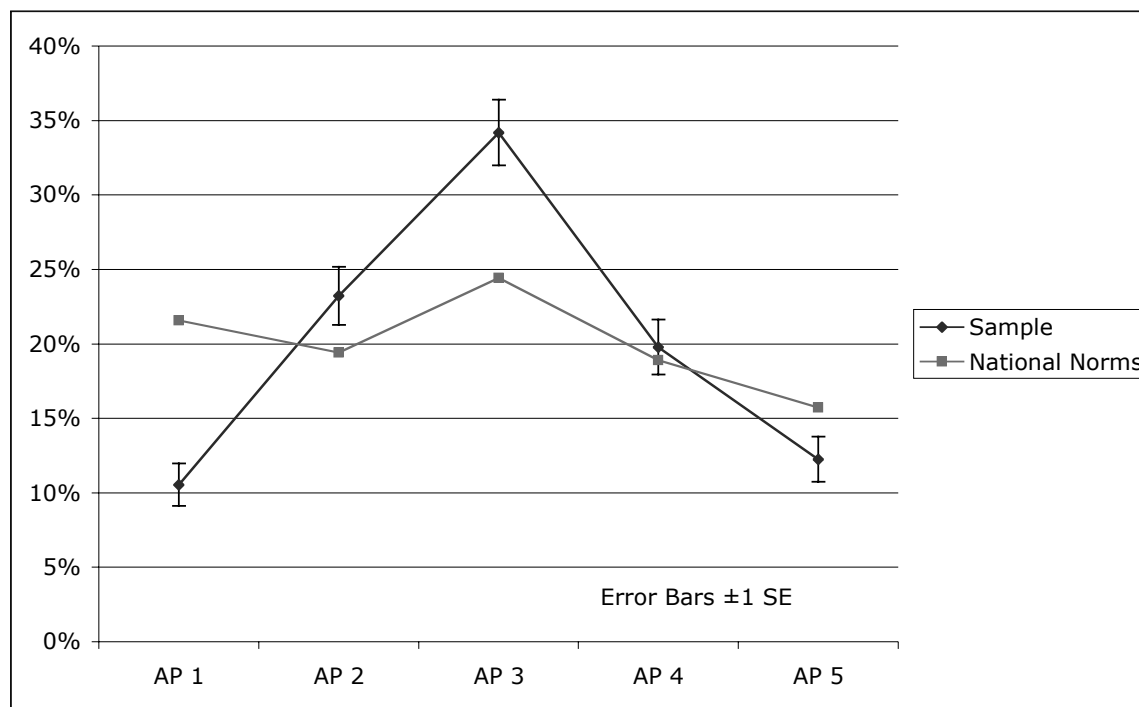
Choosing to focus only on undergraduates, we omitted cases of 103 graduates and 400 non-traditional students. We also omitted 397 students who spent their high school years outside of the United States. Allowing for some students in the intersection of these various groups, our final sample included 8594 undergraduates.

Of this total, 31% of the sample was enrolled in biology, 42% in chemistry, and 27% in physics. Females made up 60% of the biology students, 55% of the chemistry, and 42% of the physics students. Parental education was related to the highest level of mathematics taken by students, with representation of students taking calculus in high school ranging from 33% of student with parents having a high school diploma or less to 49% of students with a parent holding a graduate degree. The sample identified themselves as 77% White, 7% Asian/Pacific Islander, 6% black, 5% Hispanic, 3% multi-racial, and 2% other or unreported.

This study, by its very nature, may only examine students who take introductory-level college science courses. Students enrolled in colleges that offer the option of bypassing introductory-level science courses with sufficient AP exam scores and who also make the decision to take advantage of this option to place out are not included. Yet, since prior research studies have generally ignored this interesting population, studying these students can make a valuable contribution to understanding the value of Advanced Placement programs.

Students who did poorly on AP exams in a given science discipline may choose not to take the college course. By comparing the national statistics for AP exam scores with the

Figure 1: Distribution of AP Exam Scores in Sample vs. National Norms



distribution in our sample, one can see differences (Figure 1).²⁰ The five AP score categories each average about one-fifth of the students who take the exam.²¹ It appears that students at the low end (AP exam scores of 1 and 2) and at the high end (AP exam scores of 4 and 5) are under-represented in the sample. Presumably a larger fraction of those who scored below 3 chose not to enroll in a college course. Many at the higher end arguably took advantage of placement to enter a higher-level course or received credit for the introductory course. The mean AP exam score for the national data is slightly lower (2.81) than the sample used in this analysis (2.99) reflecting

a relative dearth of students earning low AP exam scores.

We were also careful to check for any anomalies in the makeup of students who earned scores of 3, 4, or 5 on their AP exams. Table 1 displays a comparison across seven measures of academic performance among nine high school science preparation categories ranging from Computed grades represent the mean grade for a particular group (on a 100-point scale where A=95, B=85, etc.). “Not Taken” for students reporting that they had not taken a high school course in the discipline of their introductory college science course to “AP 5” for students reporting they had taken the Advanced

Placement exam in the discipline of their introductory college science course and received a score of 5.²² In general, AP students outperformed honors students, who in turn outperformed regular students, who in turn outperformed students with no high school coursework in the corresponding college science discipline. Within the AP group, we see a clear pattern of higher performance corresponding to higher AP exam scores. High scoring AP 4 and AP 5 students consistently reported higher SAT scores, mathematics grades, in-discipline science grades for regular or honors courses, and grades in other science courses. Higher scoring students in our sample

20. The national statistics for AP biology, chemistry, and physics have been averaged.

21. One should note that the distribution of scores for the AP exam is not Gaussian as is reported for most national standardized exams such as the SAT or ACT. While those at the center of the distribution can be thought of as earning close to the mean score, those at the 4 level or above (35%) or at the 5 level (16%) occur with much greater frequency than students at one standard deviation above (16%) or two standard deviations above (2%).

22. Regular signifies that the highest level of course taken in high school was neither AP nor honors level. Honors signifies an honors course. AP courses are broken down by AP exam scores of 1 through 5 or the category of students not taking an AP examination. Means are reported for the SAT math or SAT verbal scores (or the equivalent from the ACT), the fraction completing a calculus course in high school, the last grade in mathematics, the mean grade in the relevant science preparatory course (if taken), the mean grade in the AP course (if taken), and the average of science grades in fields other than the college science course of interest.

also reported higher grades in their AP courses, on average. Students in our sample who chose not to take the AP exam, even after taking the AP course, reported academic performance measures similar to the students in the AP 3 category.

In our analysis, we were particularly concerned with the academic performance in college of students who reported receiving AP Exam scores of 3, 4, or 5. We wondered if the students in our sample were particularly weak in these science disciplines despite their high AP exam scores. Might a weakness in their academic background have led them to pursue additional course work at the introductory college level? We imagined that students with high AP exams, but relatively weak academic backgrounds may not be fully fluent in English, or may have weaker math backgrounds, or may have earned lower overall high school grades. To address these possibilities, we analyzed these various background measures and did not find that, compared with other students, high AP exam scorers exhibited any weaknesses in language proficiency (SAT Verbal score), mathematics proficiency (SAT Math score, high calculus course taking patterns, high school mathematics course grades), or overall high school grades (grades in

various high school science courses including AP, regular, or honors). On the contrary, we found in our sample that students who reported an AP exam score of 5 also averaged 1300 on their SAT's, with three-quarters having taken calculus in high school, and also reported earning an "A" on average in their high school science and mathematics courses.

Who are the group of students who have taken an AP course in high school and have earned an AP exam score greater than 3? Why are they taking an introductory course in college? Were they advised or required to take this course by their college? To gain a better understanding of possible motivations, we contacted 44 students who both scored well on AP exams and took introductory college science courses in these disciplines. These students had volunteered their contact information in response to a question asking if they would agree to future contacts in light of survey related queries. Among the responses, fifteen students provided detailed replies. While these responses should not be considered representative, they do offer some insight into the diversity of students' experiences and opinions. Five made the personal decision to take the introductory course even though they could have placed out, citing advice from more advanced

students in the field or their academic advisors. Five took the course because of department requirements in their disciplines. Three reported AP exam scores of 4, while their college required a score of 5 for credit. Two reported low scores on departmental placement exams required by their colleges to earn course credit. All but one felt that their AP course prepared them well for introductory college science. However, eleven reported that taking the introductory college course as a very worthwhile experience that paid off for them later in their college science course work. Four noted, in retrospect, after taking advanced courses, that they should have moved directly to higher-level course work.

As one of those students noted:

- *I very much should have been [granted] credit. The class was pretty much a waste of my time.*

In contrast, others offered more positive reports of their college science course experiences:

- *It was worthwhile and I am glad I chose to take the intro level course. I recommend it to freshman coming in who face a similar situation. Taking the introductory course refreshes my memory on the subject, provides deeper insight into the subject that just*

Table 1: Comparison of High School Performance Measures by Group

Highest HS Course or AP Score	Sat Math	SAT Verbal	HS Calculus	Last Math Grade	Other Science Grades	Grade in Honors or Regular	AP Grade
not taken	475	454	27%	86.0	88.9		
regular	529	510	32%	87.7	89.4	88.8	
honors	596	564	60%	89.4	90.8	90.4	
AP, no exam	610	574	70%	89.6	91.1	92.4	87.6
AP 1	543	508	47%	85.2	88.4	90.0	85.0
AP 2	592	541	54%	90.1	90.5	91.5	88.1
AP 3	595	568	61%	90.1	90.9	91.8	88.9
AP 4	631	628	64%	91.0	92.1	93.9	92.2
AP 5	666	654	75%	92.5	93.0	94.0	94.1

Figure 2: Survey Questions Relating to High School Course Taking in Science and Mathematics

1 For each science course you took in each of the science topics listed below, please indicate the level of the course, the year in school you took the course, and the grade you earned in each course. Please provide information for only one additional science course if this applies to you.

SCIENCE TOPIC	COURSE LEVEL		YEAR IN SCHOOL	FINAL GRADE
	Regular/General	Honors		
Physical Science	<input type="radio"/>	<input type="radio"/>	<input type="radio"/> 9 <input type="radio"/> 10 <input type="radio"/> 11 <input type="radio"/> 12	<input type="radio"/> A <input type="radio"/> B <input type="radio"/> C <input type="radio"/> D <input type="radio"/> F
Biology	<input type="radio"/>	<input type="radio"/>	<input type="radio"/> 9 <input type="radio"/> 10 <input type="radio"/> 11 <input type="radio"/> 12	<input type="radio"/> A <input type="radio"/> B <input type="radio"/> C <input type="radio"/> D <input type="radio"/> F
Chemistry	<input type="radio"/>	<input type="radio"/>	<input type="radio"/> 9 <input type="radio"/> 10 <input type="radio"/> 11 <input type="radio"/> 12	<input type="radio"/> A <input type="radio"/> B <input type="radio"/> C <input type="radio"/> D <input type="radio"/> F
Physics	<input type="radio"/>	<input type="radio"/>	<input type="radio"/> 9 <input type="radio"/> 10 <input type="radio"/> 11 <input type="radio"/> 12	<input type="radio"/> A <input type="radio"/> B <input type="radio"/> C <input type="radio"/> D <input type="radio"/> F
Other: _____	<input type="radio"/>	<input type="radio"/>	<input type="radio"/> 9 <input type="radio"/> 10 <input type="radio"/> 11 <input type="radio"/> 12	<input type="radio"/> A <input type="radio"/> B <input type="radio"/> C <input type="radio"/> D <input type="radio"/> F
AP Biology: AP test score:	<input type="radio"/> 1 <input type="radio"/> 2 <input type="radio"/> 3 <input type="radio"/> 4 <input type="radio"/> 5 <input type="radio"/> Not taken		<input type="radio"/> 9 <input type="radio"/> 10 <input type="radio"/> 11 <input type="radio"/> 12	<input type="radio"/> A <input type="radio"/> B <input type="radio"/> C <input type="radio"/> D <input type="radio"/> F
AP Chemistry: AP test score:	<input type="radio"/> 1 <input type="radio"/> 2 <input type="radio"/> 3 <input type="radio"/> 4 <input type="radio"/> 5 <input type="radio"/> Not taken		<input type="radio"/> 9 <input type="radio"/> 10 <input type="radio"/> 11 <input type="radio"/> 12	<input type="radio"/> A <input type="radio"/> B <input type="radio"/> C <input type="radio"/> D <input type="radio"/> F
AP Physics: AP(AB) test score:	<input type="radio"/> 1 <input type="radio"/> 2 <input type="radio"/> 3 <input type="radio"/> 4 <input type="radio"/> 5 <input type="radio"/> Not taken		<input type="radio"/> 9 <input type="radio"/> 10 <input type="radio"/> 11 <input type="radio"/> 12	<input type="radio"/> A <input type="radio"/> B <input type="radio"/> C <input type="radio"/> D <input type="radio"/> F
	AP(BC) test score: <input type="radio"/> 1 <input type="radio"/> 2 <input type="radio"/> 3 <input type="radio"/> 4 <input type="radio"/> 5 <input type="radio"/> Not taken			

wasn't there in high school, and prepares me for higher level courses in the subject.

- *It was definitely a worthwhile experience to retake the classes, as it gives you a second chance to absorb the material—which can never hurt.*
- *I was at least familiar with many of the topics covered in my college class. Many concepts were covered with greater detail in college. I felt well prepared for the college class, but I am glad I took the class instead of testing out.*

The student comments indicate that both motivations and experiences associated with introductory college science courses differ widely.

The Survey

The survey instrument was constructed to collect data concerning academic experiences and performance measures closely associated with high school science course work that might predict performance in introductory college science classes. In the form of a 4-sheet booklet, students were asked

to complete these surveys while in their college classes. Using the names and ID numbers provided by students on the cover, college instructors entered students' course grades. After this process was completed, the perforated cover with student identification was torn away and discarded, leaving the surveys anonymous, except for any contact information students may have volunteered in response to a "further contact" request. Students also reported on a variety of demographic variables (parents' education, profession, etc). Home ZIP codes allowed us to match the surveys with existing data on median income, home value, and average educational background of each home locale. The survey questions themselves were carefully designed to fit on the front and back of the remaining three sheets. See Figure 2.

Two major concerns loom for any large-scale self-report study, accuracy and reliability. These concerns stem from a report by Bradburn, Rips, and Shevell (1987) that appeared in the journal *Science*. The study concluded that self-report data were inaccurate

and unreliable. However, in research that has followed in the intervening years, which includes further research by Bradburn himself, these conclusions have been qualified and mollified to portray a complex and more responsible conclusion: that the accuracy and reliability of self-report likely depend on several factors including context, relevance, and survey clarity (Pace, Barahona & Kaplan, 1985; Bradburn, 2000; Niemi & Smith, 2003). In particular, self-reports of course taking, grades earned, and standardized test scores made by college students tend to be highly accurate (Baird, 1976; Anaya, 1999). Enrollment reports are especially accurate for courses with unambiguous names and for high-achieving students (Sawyer, Laing & Houston, 1989). In a recent review of existing research on self-report, Kuncel, Credé, & Thomas (2005) conclude that self-report may be characterized as reasonably accurate in samples where the surveys address issues relevant to the respondents. Our study surveyed introductory college science students in their fall semester college science classes where reflec-

tion on their prior experience would be commonplace. In addition, the students' own instructors administered the surveys.

We entered this project with previous survey research experience in which we surveyed over 2000 college physics students in over 20 different college and universities (Sadler & Tai, 2001). The design of the current survey included the use of student focus groups to comment on question formats, two pilot surveys that included 304 college science students, a review by an advisory panel of college professors and high school teachers, and a separate reliability study where 113 college chemistry students took the survey twice, two weeks apart and where their responses were compared. Much can be done to enhance accuracy and recall: careful design, contextual cues, and participant relevance all play important roles.

In large-scale surveys, missing responses are not uncommon. In dealing with missing responses, list-wise deletion is the simplest and most commonly applied option. However, list-wise deletion assumes that the data are missing at random. Should a large percentage of the sample exhibit missing responses, this approach may not be the most appropriate option. We analyzed the percentage of miss-

ing responses and found that, for the variables of concern, only about 1-2% were missing for each. Given this characteristic, we chose to use list-wise deletion. The two exceptions were that no standardized test score (SAT or ACT) was entered for 347 cases (quantitative) and 386 cases (qualitative). A mean value for such scores was substituted in these cases since we did not want to eliminate students from the dataset who had not taken these exams.

Choice of controls

Our initial analysis compares the mean college grades for students with different levels of high school coursework in biology, chemistry and physics. This particular analysis only shows the predictive value of AP exam scores on college course grades, quantifying the magnitude of the difference between students who take AP or not, and those who score at different levels on the AP exam. This first step describes the differences that need to be explained by competing hypotheses (Dougherty, Mellor & Jian 2006a).

However, attempting to account for the potential of taking an AP course requires controls for demographic and academic preparation differences among students as well. Far from being *tabularasa*, students' skill and knowledge prior to, or unrelated to, taking an

AP course should be included. Table 2 shows the Pearson correlations between academic preparation variables and college course grade.

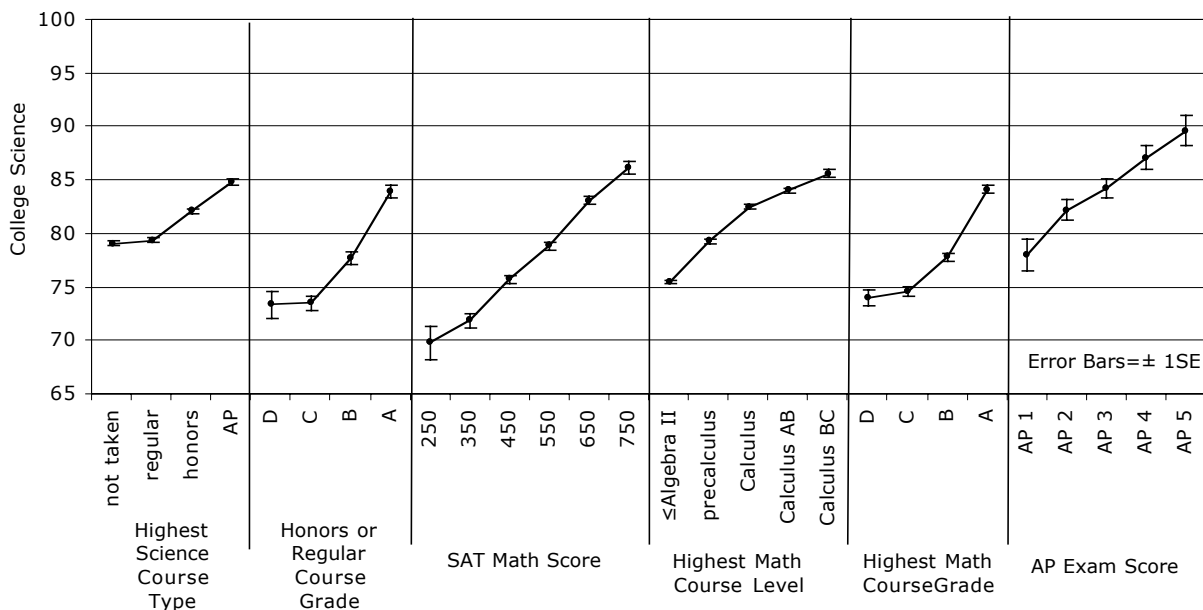
Among the nine academic performance measures, AP Score exhibits the highest correlation with College Grade in introductory science courses, though other measures with similar correlations include: SAT Math, "other" science GPA, and last high school math grade. A central issue faced by those investigating the association between AP exam performance and college performance is that many other measures of academic performance are also positively associated with college grades.

Figure 3 offers a graphical representation using the results produced from our sample. College science grades vary with AP exam score, but they also vary with the other five measures of academic preparation. As expected, more rigorous levels of high school science and mathematics courses match with higher college science grades. Each graph shows a clear monotonically increasing association between college grades and the six high school measures of academic achievement. It should be noted that the average grade attained by students who earn an AP score of 3 is equaled by students: earning a grade of "A" in

Table 2: Correlation Coefficients of Academic Preparation Covariates

	College Grade	SAT Math	SAT Verbal	Last Math Grade	Last Eng Grade	Science GPA	Regular or Honors Grade	Honors	Calculus	AP Score
College Grade	1.000									
SAT Math	0.315	1.000								
SAT Verbal	0.200	0.330	1.000							
Last Math Grade	0.317	0.288	0.108	1.000						
Last Eng Grade	0.219	0.134	0.200	0.343	1.000					
Science GPA	0.306	0.254	0.190	0.387	0.378	1.000				
Regular or Honors Grade	0.269	0.238	0.166	0.306	0.265	0.464	1.000			
Honors	0.128	0.199	0.140	0.107	0.098	0.129	0.063	1.000		
Calculus	0.244	0.415	0.203	0.192	0.159	0.247	0.196	0.281	1.000	
AP Score	0.328	0.311	0.404	0.216	0.189	0.277	0.207	0.004	0.157	1.000

Figure 3: Course Grade and Values of Key Covariates.



an honors or regular science course, scoring a 750 on their quantitative SAT, who take an AP course in calculus, or whose last high school mathematics course grade was an “A.”

Results

Descriptive statistics

Table 3 displays a cross tabulation between college science grades and the various academic performance levels displayed in Table 1. Approximately 13% of students in introductory courses did not take a corresponding course in high school. Roughly half of the students in our sample reported taking only the regular level high school course in the discipline corresponding to college science course, with a quarter enrolling at the honors level in high school and 11% enrolling in AP courses of the corresponding science. Of the students who reported enrolling in AP courses, 433 took the AP exam and reported their scores.

Inferential Analysis

The inferential analysis offers a series of five multiple linear regression models. Model A includes only the AP status of student: if they took AP, if they did not take the exam, or exam scores if they did take the exam. It explains only 2% of the variance in college grade. This number is to be expected since the AP status is only one factor in the background of students. Model B includes a dummy variable for each professor (each separate college course) and accounts for differences in grading severity between courses. This shows the predicted grades as if all the students enrolled in the same university course. This model shows a small upward change in the predicted mean grade earned by each AP grouping. Model C adds in students SAT scores, or ACT scores converted using a concordance table (Dorans, Pommerich & Lyu, 1999) for both mathematics and composite scores. Model D includes variables that account for general high school performance in science, mathematics,

and English, typical of many studies accounting for high school grade point average (HSGPA) or its correlate, high school rank-in-class. Model E adds the kind of course and performance in any preparatory course prior to taking the AP course in the subject. This model seeks to control for the influence of different levels of preparation in biology, chemistry or physics. Model E can be interpreted as presenting the difference in college performance that is related to taking an AP course or to a certain performance on the AP test between hypothetically identical students in all other variables, i.e. between students who had the same preparation and background in prior years. It generates an estimate of the incremental effect of taking an AP course or having a certain performance on the AP test on the college grade in the same subject. Included for each model are the standardized beta (β) coefficients that allow a comparison between the magnitude of the relative contribution of each variable to the

Table 3: Distribution of College Grades by Most Rigorous High School Course in the Subject

College Science Grade	Prerequisite HS Course			Advanced Placement Course							total
	not taken	regular	honors	no exam	took exam	AP1	AP2	AP3	AP4	AP5	
55 F	106	356	117	12	12	4	3	4	0	1	603
61 D-	4	36	11	0	3	1	1	1	0	0	54
65 D	102	381	127	22	11	3	4	2	2	0	643
68 D+	12	83	21	0	5	0	3	1	0	1	121
71 C-	48	163	57	5	15	2	5	5	3	0	288
75 C	226	957	382	78	56	9	17	23	6	1	1699
78 C+	46	245	61	12	22	3	8	5	5	1	386
81 B-	56	225	83	22	28	7	8	5	7	1	414
85 B	243	934	518	134	79	6	17	38	12	6	1908
88 B+	44	226	102	27	56	5	16	14	10	11	455
91 A-	36	202	90	22	39	1	6	15	10	7	389
95 A	179	659	447	165	101	4	17	31	27	22	1551
98 A+	1	31	40	5	6	0	1	1	2	2	83
total	1103	4498	2056	504	433	45	106	145	84	53	8594
Mean	78.79	79.18	81.98	85.21	84.35	78.11	82.11	84.30	87.15	89.77	80.42
SE	0.36	0.17	0.25	0.43	0.47	1.63	0.96	0.78	0.88	1.05	0.12

explained variance. Note that the final regression model accounts for 35% of the overall variance. The lack of high correlation coefficients in Table 2 as well as other tests are evidence of a lack of colinearity in the models.

A graphical comparison of Model A and Model E is shown in Figure 4. (Error bars represent one standard error from the mean for each category.) The two models show the comparison of mean college science grades by simple calculation from raw grades in Model A and by controlling for the collection of important covariates in Model E. The course mean is represented by a horizontal dashed line. The magnitudes of coefficients for AP experience are clearly muted when important background factors not associated with AP are accounted for in subsequent models. The average slope of the data relating AP score with course grade is considerably reduced as shown in the third panel of Figure 4. Accounting for covariates leads to

a reduction in the magnitude of all AP-related coefficients.

Model E, deemed the “full model,” is particularly interesting, given that it accounts for several factors not easily disaggregated from students’ and teachers’ experiences. This model includes four significant demographic variables that together may be thought of as measures of socio-economic status (SES). Adjustments for such variables can never insure that SES is controlled for fully, since it cannot be measured without error:²³

- Race – Accounting for the self identified race or ethnicity of students: White, Black, Hispanic, Asian, multi-ethnic, or other.
- Hipared – the highest level of education of either parent: less or equal to a high school diploma, some college, 4-year degree, graduate or professional degree.
- Hstype’ – The kind of high school last attended: private, public or other.

- Mean Ed Level – The average educational level of those in the student’s home ZIP code, based on the categories use for Hipared.

Discussion

The initial model which does not control for student backgrounds and academic performance prior to, and independent of, any AP course experiences, shows large differences between students who enroll in AP and others, earning college course grades about four points higher than the course average. There is little difference between those reporting taking the AP exam and those who choose not to in AP courses. However, when demographics and prior academic achievement are accounted for, the apparent advantage held by students with AP experiences in high schools are roughly cut in half. This reduction is similar to findings by Dougherty *et al.* (2006a) in which the introduction of controls in their regression analysis

23. This point suggested by an anonymous reviewer of this paper.

Table 4: Regression Models Explaining Variance in College Science Grade

	DoF	Model A	SE	Model B	SE	Model C	SE	Beta	Model D	SE	Beta	Model E	SE	Beta
Constant	1	83.79 ***		84.76 ***	0.45	59.07 ***	1.26		37.73 ***	1.61		42.84 ***	1.68	
Prof ID	123			***		***			***			***		
Race	5					***			***			***		
hipared	3					***			***			***		
Hstype'	2					**			***			***		
Mean Ed Level'	1					-			***			0.61 ***	0.19	0.03
SATM_CAL'	4					0.01 ***	0.00	0.09	0.01 ***	0.00	0.09	0.02 ***	0.00	0.13
SATV_CAL'	1					0.03 ***	0.00	0.27	0.01 ***	0.00	0.06	0.01 ***	0.00	0.06
himath	4								***		0.13	***		0.11
≤Algebra II									-2.69	0.28		-2.31	0.28	
precalculus									-1.33	0.19		-1.16	0.19	
Calculus									0.36	0.25		0.27	0.25	
Calculus AB									1.38	0.23		1.17	0.23	
Calculus BC									2.28	0.37		2.03	0.37	
Math Grade	1								2.51 ***	0.15	0.17	2.27 ***	0.15	0.16
English Grade	4								0.93 ***	0.19	0.05	0.75 ***	0.19	0.04
Science Grades	1								2.99 ***	0.23	0.14	2.13 ***	0.24	0.10
Prep Course	4											***		0.08
not taken												0.19	0.29	
not reported												-0.41	0.39	
C or lower												-1.63	0.33	
B												-0.28	0.22	
A												2.12	0.21	
Honors	1											0.97 ***	0.26	0.04
AP Status	6		***		***		***	0.19		***	0.14	***		0.15
no AP		-3.91	0.45	-4.66	0.44	-3.57	0.41		-2.69	0.39		-2.26	0.40	
No AP Exam		1.42	0.61	0.14	0.60	0.07	0.56		0.11	0.53		0.16	0.53	
AP 1		-5.68	1.49	-5.22	1.41	-3.32	1.33		-2.19	1.26		-2.47	1.25	
AP 2		-1.68	1.02	-1.34	0.97	-0.80	0.91		-0.94	0.86		-1.02	0.86	
AP 3		0.51	0.90	0.78	0.86	0.36	0.81		0.18	0.76		0.16	0.76	
AP 4		3.36	1.13	4.22	1.07	2.93	1.01		2.22	0.95		2.12	0.94	
AP 5		5.98	1.38	6.08	1.32	4.32	1.25		3.31	1.18		3.30	1.18	
Level of AS		Raw Data										Full Model		
no AP		79.88	7657	80.11	7657	79.05	7657		80.18	7575		79.46	7575	
No AP Exam		85.21	504	84.90	504	82.69	504		82.98	502		81.88	502	
AP 1		78.11	45	79.55	45	79.30	45		80.68	45		79.25	45	
AP 2		82.11	106	83.42	106	81.82	106		81.93	105		80.70	105	
AP 3		84.30	145	85.54	145	82.98	145		83.05	145		81.88	145	
AP 4		87.15	84	88.98	84	85.55	84		85.09	84		83.84	84	
AP 5		89.77	53	90.84	53	86.94	53		86.19	52		85.02	52	
Total Cases		8594		8594		8594			8594			8594		
Cases Missin		0		0		0			86			86		
Cases Used		8594		8594		8594			8508			8508		
r^2=		0.022		0.153		0.252			0.336			0.347		

resulted in reductions in the modeled outcome variable, college graduation rate, from 39% to 26% for students passing an AP exam. Hence, in that study, a third of the apparent effect of passing an AP exam was explained by the two covariates used: eighth-grade mathematics achievement and high school characteristics. Our findings are similar to those of Willingham & Morris (1986) who also found that half of the “AP advantage” was accounted for by matching students by background.

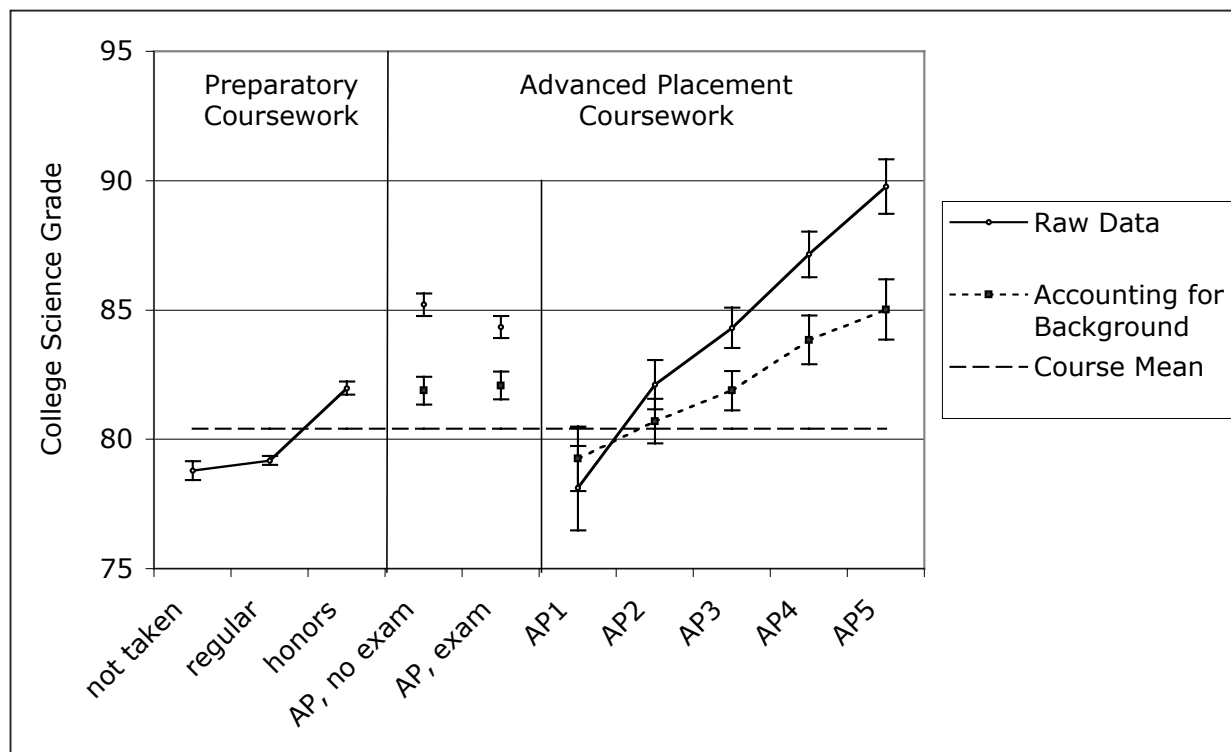
Analyzing college grade by different levels of AP exam score is also

illuminating (Figure 4). We found that students who are awarded an AP exam score of 1 earned college science grades no better than did those students who entered the college course after having taken a regular course in the subject. Similarly, students who have an AP exam score of 2 do no better than those who have completed an honors course. Since students usually complete either a regular or honors course prior to enrolling in an AP course, it appears as if students reporting low AP exam scores may have gained no benefit from their AP course. This finding contrasts with the belief espoused

by many that it is always better to take a more rigorous course and earn a low grade than an easier course and earn a high grade (Adelman, 1999).

Based on the results from the Full Model, those students who enroll in AP and have not taken the AP exam perform in college science about as well as AP3 students: about 1.5 points higher than the student average. AP4 students are predicted to earn college science grades 3.4 points above average. AP5 students are predicted to earn grades 4.6 points higher than average. Though these predicted scores appear to be fairly impressive, we should con-

Figure 4: Comparison of Model A (“Raw Data”) and Model E (“Full Model”)



sider that the student average sits just above 80 points, amounting to about a grade of B-. An additional 4.6 points would only elevate the course grade to roughly 85 points, suggesting that the average AP 5 student in introductory college science would be predicted to earn a letter grade of B if one accounts for those background variables that are different from most students in their science course.

Next we considered the relative importance of variables in the explained variance of the full model based on the standardized β (in units of the fraction of a standard deviation of college grade earned for one standard deviation change in the independent variable). As one might expect, AP exam score has a substantial role ($\beta = 0.15$). Yet, four other variables have similar ratings: high school math grade ($\beta = 0.16$), SAT Math ($\beta = 0.13$), highest math course taken in HS ($\beta = 0.11$),

and average science grade (in other subjects ($\beta = 0.10$)). Taken as a group, these are arguably stronger predictors of college grade than performance in high school courses preparatory to an AP course ($\beta = 0.08$). This may reflect the importance of mathematical knowledge and reasoning ability for college students in the sciences (Burton & Ramist, 2001).

Poor performance in AP courses is often attributed to a concern over the “lack of academic readiness” for advanced placement courses, particularly a deficit in the “possession of prior relevant knowledge (Dougherty *et al.*, 2006b, p. 6).” While one may assume that such knowledge could be acquired from a preparatory course (e.g. regular or honors chemistry for an AP chemistry course), the relatively low standardized coefficients related to these courses (0.04 for honors level and 0.08 for the grade in this course)

tend to invalidate this claim. More important to success in college science appear to be general academic skills, particularly in mathematics. AP exam score had a correlation of 0.404 with SAT verbal scores (Table 2). This can be interpreted as evidence that high verbal functions (both in reading and writing) are necessary to get the most from an AP course (particularly reading the textbook) and to perform well on the AP exam.

There are many possible explanations for why AP exam high-scorers do not consistently attain levels of performance commensurate with stated College Board expectations. We discuss some of these below:

- **Non-equivalency of the AP exams and college science attainment measures.** AP exams may not fully reflect content of the college courses in this study, even though the College Board’s

efforts are designed to accurately reflect the college curriculum. Certainly there is content at the college level that is uniquely presented by college professors that cannot show up in a standardized AP test. Also, more goes into a college course grade than a single final exam. Students often take additional tests (e.g. mid-terms), are graded on their laboratory work and problem sets, and may be required to pursue a project or paper. No matter how close the AP exam is to the college-level exam, there may be missing elements that do not make the AP test a valid substitute for a college grade in science, however similar it may be to the final exam.

- **Over-generosity in AP Exam Scoring.** *“In general, an AP grade of 3 or higher indicates sufficient mastery of course content to grant a student exemption from a college course, credit, or both (College Board, 2004, p. 6.)”* The College Board is clear in its guidelines, adjusting the cut-points (how exam scores are assigned) of each of its AP examinations so that *“... the lowest AP 5 is equivalent to the average “A” in college, the lowest AP 4 is equivalent to the average “B,” and the lowest AP 3 is equivalent to the average “C” (College Board, 2004, p. 11).”* The so-called “composite score boundaries” set the cut-offs for AP exam “grades” of 1, 2, 3, 4, or 5 from the raw scores or “formula scores.” The setting of these boundaries is explained on the AP

website.²⁴ An example is given for the Physics C (Electricity and Magnetism Exam). The cut-off score over which students earn a “5” is 19.7 out of 35 problems correct or 56%. The cut-off score over which students earn a “4” is 40% and over which they earn a “3” is 31%.²⁵ While assigning final “grades” is a function of item difficulty, such a low percentage of items correct translating into a top score is unusual for a test. As a criterion referenced exam, the criteria may be set too low (Lichten, 2000).

- **Lack of Sufficient Content Coverage in AP Exams.** A fundamental limitation of all standardized exams is the amount of content each exam may include. Although exams may be “comprehensive” in some ways, a single Advanced Placement exam has no hope of including the degree of comprehensive content coverage typically included in college coursework. As a result, AP exams are at a fundamental disadvantage, depending largely on an assessment of student content knowledge based on a sampling of student performance. This approach is based on the same premise as this large-scale study; however, the difference lies in its application. While we make no claims as to the performance of individuals based on our analysis, but rather limit our conclusions to generalizations for large groups, AP exams do make the claim of providing a highly accurate appraisal of an individual

student’s knowledge and ability. The accuracy of these claims must be clear and unequivocal, since decisions for an individual are made on the weight of a single AP exam score. A decision to bypass an introductory course does have potential repercussions for individual students.

- **Weak Methodology in AP Score Validation.** For the process of validation carried out by the College Board, items from the relevant AP exam are administered to college science students at the end of their course. Any laxity of effort on the part of these students to do well would invalidate the equating of AP scores to college grades (Lutkus, Weiss, Campbell, Mazzeo & Lazer 1999). The College Board is silent in its technical manual as to what motivation these students have to do their best on these exams. Also, extensive preparation of AP students with practice exams familiarizes them with the format and probable content. Participating college students enjoy no such “prepping” for the questions that they answer drawn from AP exams and may be unaccustomed to their formulation, earning them lower scores. There is a lack of parity since the College Board does not administer actual college science final exams to AP students while in high school to see if they score at levels reflective of high college grades.
- **Sample Size of the Current Study.** While 8594 students were included in this study, only 937

24. “An AP grade may also indicate that the student should receive credit for a college course that he or she has not taken. To check the validity of such decisions, studies are conducted in which the AP Exam is administered to students taking the college courses in question. The college students’ grades on the AP Exam are then compared with their grades in the college course.” (<http://apcentral.collegeboard.com/article/0,3045,152-167-0-2052,00.html#key>)

25. <http://apcentral.collegeboard.com/members/article/1,3046,154-181-0-11583,00.html>

reported taking the relevant AP course in high school. Of these students 433 reported taking the exam with 282 reporting AP exam scores of 3 or higher. While this study is smaller than several concerning Advanced Placement, it is the largest investigation of its kind that controls for relevant background factors such as prior mathematics and science course-taking and performance. This study offers a snapshot of the actual performance of students in introductory college science in U.S. colleges and universities. While studies with larger samples of AP students abound, most control for few or no background variables. These results offer *little to no information* about the *disaggregated* relationship of Advanced Placement experiences and student performance in college. After controlling for several covariates, our study found that AP course participation and performance on AP tests were indeed related to performance in college science courses, but that the magnitude of the effect was about half that found without controls. Moreover, we do not know if AP experiences help students or if better students help AP outcomes. Given the clear disparities of educational resources in American education, the latter may not be further from the truth than the former.

- **Missing students who “place out” in the current study.** This study, by its very design, does not include any students who have earned high enough AP exam scores to receive credit for an introductory college science course

and, hence, do not take it. Many, perhaps most, of the students in colleges that we study who earn a 3, 4, or 5 are simply not in our sample. There is no direct way to know how these students would fare in an introductory course, one can only analyze the grades of those who are actually enrolled in an introductory course, as we have. However, we have established that these high scoring AP students have no apparent deficiencies in other areas. Through our follow-up survey we have also found that most thought retaking the introductory course was beneficial. These students strive for high grades and work as hard or harder than their classmates.

- **AP students were bored retaking introductory courses.** One explanation may be boredom among AP exam takers since the college course may merely be a review of concepts covered in high school. With this issue in mind, we queried students in our survey who offered “further contact” information and who reported high AP exam scores. Our follow-up inquiries found that a majority of the students contacted reported the “re-taking” of the college science course to be beneficial. In addition, we did not find significant differences (at $p \leq 0.05$ for χ^2 test) in level of effort reported in college science between AP students who passed or failed the AP exam in high school.

Conclusions

This study seeks to disentangle two issues: the validity of Advanced

Placement exams as predictors of college science performance and the “value-added” of taking AP science courses in high school. AP courses act as both a filter for the most motivated and brightest high school students, while offering an opportunity to learn science in a rigorous, fast-paced environment modeling an introductory college course. We have chosen to examine the performance of college students taking introductory college biology, chemistry, and physics. These students have varied academic backgrounds that allow for the use of multiple regression to model the degree to which specific variables explain differences in college performance.

We find that the students in our sample who reported AP exam scores of 3 or higher earned college grades that were higher than the student average. However, many AP 5 students performed at levels below the College Board’s claims of excellence even after taking a semester of the college science. While 73% of AP 4 students earned college science grades above the College Board’s stated “*mid-level B performance in college*,” about half of the AP 5 students missed the A level performance cited by the College Board. We should be clear on one very important point, all the students in our survey experienced a semester of actual introductory college science course work. Thus, given that high school AP courses are intended to stand in place of college courses, it can be argued that AP students have taken the introductory college course twice, and despite this clear advantage, their performance is by no means indicative of the benefit many would have us believe Advanced Placement courses would impart to high school students who take them. As a measure

of introductory college science content knowledge mastery, the performance of a considerable fraction of AP takers does not appear to adequately reflect the professed notions of the College Board. In fact, in our qualitative probe, many students feel that while AP is a good preparation for college science, many also feel they benefited from taking the actual college science course.

Based on our analysis, it appears that about half of the advantage attributed to AP experience can be accounted for by variables representing the academic abilities and experiences possessed by AP students prior to, or independent of, their AP course experiences. Students' backgrounds, particularly their mathematical and verbal skills, appear to contribute mightily to their performance in college science courses. While the AP examination program is an elaborate system, with its professional development program rivaling its assessment program in size and productivity, the Advanced Placement exams themselves appear to fall short of the predictive validity claimed by the College Board. Based on the findings from our study, AP exams scores of 3 do not appear to warrant the granting of college credit over those students who take an AP course in high school, but do not take the exam. In addition, we found that an AP exam score of 1 or 2 offered little evidence of any benefit derived from the AP course work experienced by the students in high school. In addition, students passing an AP exam might well consider retaking introductory courses in college to more completely master the content, as many colleges and universities already require.

... our study has found indications that the AP program, while certainly of value to many students, may lack some of the evidence necessary to support its claim of academic rigor equal to that of introductory college and university courses in science.

Our findings suggest that the educators, teachers, parents, and students would be better served by:

- An acknowledgment from the College Board that evidence exists indicating the non-equivalence of AP courses and college courses in biology, chemistry, and physics.
- A more balanced mix of both supportive and critical research at the Advanced Placement website.²⁶
- The College Board clearly stating their role in funding research studies cited as evidence for AP course effectiveness.
- AP exam scoring made more stringent so that the highest exam score truly represents achievement at the highest level of college work.
- The College Board acknowledging that the later performance of students who pass the AP exams appears to be explained as much by their prior background as their AP course enrollment.

For high schools seeking to evaluate their AP science courses, a preponderance of AP exam scores of 1 or 2 may be interpreted to mean that the AP

course in their school offered little or no benefit to students beyond regular or honors level science courses. Schools in which the majority of students score in this range should examine whether exposure to AP-level rigor holds any benefits apart from the "academic padding" coined by Lichten that aids them in the college admission process.

Advanced Placement has become one of the most highly respected "brand-names" in secondary/post-secondary education. However, our study has found indications that the AP program, while certainly of value to many students, may lack some of the evidence necessary to support its claim of academic rigor equal to that of introductory college and university courses in science. While this current study certainly suffers from limitations, as do all research studies, what is clear from our findings is that the claims of the College Board regarding the interpretation and validity of AP exam scores are problematic. Our findings indicate the need for further investigations of greater size, scope, and intensity, especially given the potential being ascribed to the Advanced Placement program as part of the cure for what ails American science education.

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