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The Role of Advanced High School Coursework in Increasing STEM Career Interest

Abstract

Several avenues are open to students who wish to study advanced science or mathematics in high school, which include Advanced Placement courses and teacher-designed courses unaffiliated with organized programs. We employ a retrospective cohort study of 4,691 nationally representative college students at 34 randomly selected, colleges and universities to examine the relationship between taking advanced high school courses and students' interest in pursuing a STEM career, while controlling for prior interests and experiences. We are able to distinguish between those students choosing to take an additional year in a science or math subject from those taking Advanced Placement (AP), which is most commonly taken as a second year course, but is increasingly taken as a first year course. We find that the number of years of a science or math subject taken in high school is associated with significant increases in STEM career interest, with results differing by subject. Taking AP courses in science or calculus appear to have no significant impact on STEM career interest over that of other advanced, non-AP courses. Taking calculus, a second year of chemistry, or one or two years of physics all predict large increases in STEM career interest. Additional years in biology and other subjects show no such relationship.

Introduction

Maintaining a robust STEM (Science, Technology, Engineering, Mathematics) workforce is a matter with profound economic implications for the U.S. economy (Obama, 2009; National Research Council, 2005). Interest in a STEM career is often characterized as a pathway in which certain experiences serve to increase student interest in continuing on the STEM path (or joining the path), whereas other experiences reduce it (Blickenstaff, 2005; Kerr & Robinson Kurpius, 2004; Mitchell & Hoff, 2006; Riegle-Crumb, Moore & Ramos-Wada, 2011). While some students are exposed to STEM opportunities outside of school through their parents or other adults, or by engaging in informal science experiences, such as science museum visits or clubs (Dabney et al., 2012), their major exposure comes from school coursework (Jones, Howe & Rua, 2000; Hazari, Sadler & Tai, 2008).

Advanced coursework in high school is an increasingly popular option for high school students. With reduced funding of dedicated programs for gifted students (Ward, 2005), many school systems opt for increasing students' opportunity to take advanced coursework. Three major outcomes are posited for students' taking advanced STEM coursework in high school:

- gaining a head start on their college education with the possibility of reducing time to degree (National Research Council, 2002)[1],
- making the learning in college STEM courses easier, owing to a stronger foundation (Federman, 2007; Sells, 1980, Sadler & Tai, 2007), or easing the transition to college work from high school (Schwartz, Hazari & Sadler, 2008),
- and increasing students' STEM interest and their persistence to a STEM career (Tyson, Lee, Borman & Hanson, 2007).[2,3]

The rationale for this study is that while the first two major outcomes listed above have been studied extensively and reported on in the research literature, the impact of advanced coursework in high school on STEM interest and persistence has received less attention from researchers.

The public primarily associates advanced high school coursework with the Advanced Placement program, which has expanded dramatically at a rate of 9.3% per year over the last two decades (Sadler, 2010). The popular US News & World Report's yearly ranking of the best U.S. high schools uses AP exam data. A succession of efforts to expand advanced science and mathematics offerings in high school call for training an additional 70,000 AP science and math

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[1] However, elite colleges have increased the AP exam scores required for course credit (Byrd, 2007), and AP courses have not been found to shorten the time to college graduation (Klopfenstein, 2010).

[2] Often downplayed as motivator is the fact that college admissions, especially at elite colleges and universities, are directly influenced by the number of advanced courses taken by applicants (Hawkins & Clinedinst, 2006) and indirectly by the fact that students receive "bonus points" when their high school rank-in-class is calculated by their high school (Cognard, 1996; Dillon, 1986; Jones, 1975; National Research Council, 2002).

[3] Particularly among African American students "… high school course taking patterns can have a significant impact on career choices..." (Russell & Atwater, 2005, p. 692).

teachers (National Research Council, 2005), federal and state subsidization of AP examination fees (Klopfenstein, 2004), and for offering cash incentives for students who pass AP exams and bonuses for teachers of students who do well on AP exams (Jackson, 2008). Yet, Advanced Placement courses are but one of many approaches to accelerate students' learning (Gallagher, 2009; Rogers, 2004). Several other competing and preexisting options are available: the International Baccalaureate program, dual credit (in which students take courses at community colleges that also count for high school credit), and advanced high school courses unaffiliated with outside institutions. Many educators complain that the expansion in AP courses has supplanted "home grown" advanced courses in areas in which high school teachers have strong expertise (e.g., astronomy, marine biology, anatomy, geology) or courses that are described as being equal to, if not more rigorous than AP, but emphasize the laboratory and/or student research projects instead of coverage of a traditional college lecture course (Herr, 1991a; Herr 1991b; Gallagher, 2009; Oxtoby, 2007; Schneider, 2009).

The high school years are a time when students carefully examine their career options (Ing, 2013), and a large fraction of students (24% of males, 15% of females) shift in their interest into or away from STEM (Sadler, Sonnert, Hazari & Tai, 2012). With substantial efforts under way to raise U.S. students' interest in STEM careers, we examine one potential avenue toward that goal, conducting an empirical study of how taking advanced high school coursework in STEM fields affects students' STEM career intentions.

Literature review

Studying the influence of advanced coursework on high school students' career interest is problematic because the decision to take an advanced course is voluntary; hence, participants are "self-selected." In this way, advanced science or mathematics courses in high school generally attract highly motivated, high achieving students who already have an interest in pursuing a STEM career. Such students might have a high probability of earning a STEM degree in college whether or not they take an advanced course in high school. Ignoring this self-selection effect leads to over-estimating the impact of advanced STEM course-taking in high school (Dougherty, Mellor & Jian, 2006; Federman, 2007). For this reason, it is inadvisable to simply compare the STEM career interest rates of groups of students and attribute any differences found to the impact of a single variable. Alternatively, conducting randomized control trials in which students are randomly assigned to advanced high school STEM courses or to a "control group" who are prohibited from taking such courses is impractical or even unethical. Instead, research methods have been developed, particularly by epidemiologists, to account for preexisting differences between subjects in different groups of interest. Such methods can help to isolate the effects of advanced STEM coursework from other confounding factors. Although these methods to reduce selection bias cannot definitively prove causality, they can offer strong evidence for or against the effect of educational experiences. Whenever the predictive power of a variable of interest disappears in the presence of variables that account for preexisting conditions, a reasonable interpretation is that there is no causal relationship.[4] Key to the quality of studies using such statistical methods is the degree to which they account for a large number of "alternative hypotheses." We consider the most important control variable to be student interest in a STEM career prior to enrolling in advanced STEM coursework. In this literature review, we examine existing work on the influence of advanced STEM coursework on STEM career interest in this light.

Robinson (2003) studied 315 students enrolled in AP courses in eight high schools located in a single, diverse school district. He found that the majority of the students enrolled in AP calculus, biology, chemistry, and physics courses later followed STEM-related career tracks in college. No statistical tests or controls for student background or STEM interest prior to taking advanced courses were employed in this study. Lack of controls did not keep the author from concluding, "Furthermore, based on the data from this study, it is recommended that high schools, counselors and teachers, encourage more minority students to take the challenging courses, for example, AP, that will prepare them for college and/or better jobs after high school" (Robinson, 2003, p. 272 -273).

Tyson, Lee, Borman, and Hanson (2007) analyzed data from 16,587 students earning college degrees within 6 years of graduating from high school. Drawing from longitudinal data of these students' high school course-taking in Florida from 1996–1997, they found that race and gender, but not SES, predicted who graduated college with a STEM degree. Asian and Hispanic students were found to persist at significantly higher rates than other students, while females persisted at lower rates. Students who had taken high school physics or calculus had greater odds of earning a STEM degree. The authors did not attempt to control for prior student interest in STEM careers before selecting their high school courses, yet they conclude "… that it is critically important that schools find ways to offer opportunities for all students to enroll in the highest level courses in mathematics and science, for if they do, students taking these courses are more likely to persist in the STEM pathway regardless of race or ethnicity" (Tyson et al., 2007, p. 269).

Keng and Dodd (2008) compared AP calculus (AB and BC), biology, and chemistry students with others in four entering classes at the University of Texas at Austin, concerning the number of college course credits earned in the same subject. A small to moderate effect size was found for students who earned AP credits, compared with other students. Students were matched on a

[4] However, one cannot ignore the possibility that an effect exists but is too small to be identified with the given sample size, or that the relationship is being obscured by not accounting for an important variable.

single variable, their SAT/ACT scores. No matching was carried out on other potentially confounding variables (e.g., gender, prior interest in a STEM career, number of years of high school coursework in a STEM subject).

Maltese and Tai (2011) used data from 4,700 U.S. students who participated in the National Education Longitudinal Study of 1988 (NELS:88) to model the planned college major (and later completion of degree) while controlling for students' early interest in a STEM career, as well as attitude towards and knowledge of science and mathematics. This study did not identify high school STEM courses as advanced, but did find that students' taking biology in 11th grade and chemistry in 12th grade were significant predictors of a STEM career intention at the start of college. Since biology and chemistry are typically taken earlier in high school, the courses under consideration may have been second-year, advanced courses in these two fields. In addition, high school trigonometry (i.e., pre-calculus) and calculus all had positive associations with earning a degree in STEM when controlling for student background variables. The total number of high school science courses was also a positive predictor (correlated with physics and chemistry) even after controlling for prior interest in science.

Rigorous high school coursework (e.g., 4 years of mathematics, 3 years of science, and at least one AP class or test taken) is found to be associated with high rates of persistence to a college degree, generally (Adelman, 1999; Long, Conger & Iatarola, 2012; Warburton, Bugarin & Nunez, 2001; Burkam & Lee, 2003; Schneider, 2003; Horn & Kojaku, 2001; Schneider, Swanson & Riegle-Crumb, 1998), and with persistence to a science or engineering degree, specifically (Adelman, 1998; Kokkelenberg & Sinha, 2010). Federman (2007) focused on the influence of selection bias in any attempt to establish causal patterns between high school coursework and later college major, noting that little attention has been paid to this issue in the sociology and education literature: "Students who are considering majoring in a technical field will choose to take additional math and science courses in high school. Thus, it is the interest in a potential technical major that is causing the increased course taking" (p. 15). After controlling for interest and scores on mathematics and science tests prior to high school for 3,166 NELS:88 subjects, as well as parental education, race/ethnicity, and community SES measures, Federman (2007) did find that the number of high school mathematics and science courses had an impact on students' choice of a STEM major. AP involvement was found to predict educational success for intellectually talented youth, as well (Bleske-Rechek, Lubinski & Benbow, 2004).

In terms of racial minorities, black students are found to persist in STEM fields at lower rates than non-blacks (Leslie, McClure & Oaxaca, 1998; Ost, 2010). Russell and Atwater (2005) traced the academic journey of 11 African American students in their final year of a college biology major. Using a qualitative methodology, they found that several factors appear to have had an impact on the students' choice of a science major. These include home environment (parental encouragement, acceptance, and expectations) and high-level STEM courses in high school in which they had teachers who had high expectations and offered encouragement. This study suggests that advanced high school STEM courses may show an impact on student persistence simply because they are taught by highly supportive teachers. In addition, students in these courses may have parents who are more directive and encouraging. These two factors, which are not related to advanced high school coursework itself, may strongly influence students to pursue a STEM career.

Another alternative hypothesis is the impact of exposure to role models, particularly adults with whom students can identify because they are the same gender, race, or family, has been investigated. Hoffman and Oreopoulos (2007) and, later, Price (2010) found that a female instructor in a mathematics or science course is associated with a surprising decrease in the number of same subject courses taken by female students in later years. Carrel, Page, and West (2009) showed that, on average, female students do not differ in graduating in a STEM field, based on having had female (versus male) teachers. On the other hand, Sonnert, Fox and Adkins (2007) found that a greater representation of females among college STEM faculty is associated with a greater percentage of female majors. Parents can be thought of as the most primary of role models, and students who had a parent with a bachelor's degree are more likely to stay on track to earning a degree (Warburton, Bugarin & Nunez, 2001); those who had a parent with a STEM degree had a higher probability of earning one themselves (Leslie, McClure & Oaxaca, 1998). Compared with the positive influence of parental education on the choice of a STEM career, the gender of the parent was found to be less important (Sonnert, 2009).

Ost (2010) found that student performance measures (both grades earned and SAT scores) influence persistence in STEM fields at the university level, with females being more susceptible to leaving STEM when earning lower grades in their STEM courses. High grades in non-STEM courses were associated with students being "pulled away" (p. 923) from a STEM career interest. Rask and Tiefenthaler (2008) explained the stronger impact of grades on female students as the possible effect of stereotype susceptibility that tends to occur whenever a particular group is in the minority.

Returning to the issue of Advanced Placement courses and exams, Shaw and Barbuti (2010) found that students taking three or more AP exams in STEM fields are likelier than those with fewer such exams to choose STEM majors in college. In spite of the absence of any control variables (e.g., parental education, prior interest in STEM fields, SAT score), they conclude, "Therefore, AP STEM exams may be a useful high school tool in increasing STEM major persistence" (p. 29). The "concern voiced by colleges … that those taking AP courses will not continue to take courses in areas closely related to the discipline characterized by that exam" (p. 4) was addressed by Morgan and Klaric (2007) of the College Board. Using the records of 72,457 students from the freshman class of 1994 at 27 institutions, they compared students who had taken an AP exam with those who did not and found that AP exam takers enrolled in more college courses in a closely related subject area. They also found that AP exam takers in math or science were more likely to major in a STEM field. However, because of the absence of any controls, it is impossible to know if other variables (e.g., SAT/ACT scores, class rank, earlier interest in a STEM career) could account for this difference. The authors concluded, "Given the data, there are few signs of AP Exams serving to discourage continued college course work" (p. 5). Tai, Liu, Almarode, and Fan (2010) found that those students who take AP exams in calculus have significantly greater odds of earning a college degree in physical science or engineering. They also found that taking an AP science exam (in biology, chemistry, or physics) is associated with greater odds of earning a life science degree, but not a physical science or engineering degree.

From this review of the relevant literature, we find that most existing studies lack appropriate control variables and hence carry less weight in providing evidence-based arguments. However, they do proffer several associations that could be used as controls in a more rigorous study: gender, race/ethnicity, SES, encouragement by teachers, role models, or taking specific high school courses. Advancing beyond prior work in this area, our study examines the relationship between high school science course-taking and STEM career interest while controlling for the effect of several alternative hypotheses posited to be related to students' STEM career interests.

Methodology

We employ a retrospective cohort method comparing past experiences of two different groups of college students—those who plan to pursue a STEM career and those who do not. Although, as pointed out previously, randomized control trials are generally considered the "gold standard" in establishing causal effects, they require much longer time periods than retrospective studies and, in the case of advanced high school coursework, random assignment of students is near impossible. Alternatively, longitudinal education studies are commonly prospective in that they follow a group of similar individuals forward in time to find how certain differences in exposure result in different outcomes. Such prospective studies (e.g., NELS:88) typically take much longer (and are more expensive) than retrospective studies and, hence, cannot include variables generated from recent research in the field. They also generally require a much larger sample, since the outcome (in this case, interest in a STEM career) is exhibited only by a minority of the population. Research can suffer from issues of sample degradation due to high attrition rates. Instead, we ask students early in their college experience to report retrospectively about their earlier experiences (e.g., high school course-taking) and seek to identify which variables are associated with an interest in STEM. Our hope is to be able to generalize to a large population of students—U.S. college students in mandatory college English courses. Having the full range of high school course-taking experiences in our sample for both STEM avoiders and STEM persisters is necessary for establishing the relationship of advanced high school coursework with STEM career choice.

Sample

This project sought to recruit a nationally representative sample of two- and four-year college and university students beginning their studies and enrolled in a mandatory introductory English class at their institution. The rationale for this particular sample is that these students represent the broadest range of potential majors (most having just entered college and having not yet declared a major), including those intent on pursuing STEM majors and those who wish to avoid STEM at all costs. Seeking to build a nationally representative sample, the 3,779 post-secondary institutions comprising the 2005 Integrated Postsecondary Education Data System (IPEDS) database with an undergraduate enrollment of greater than 100 students were considered (44% of these were two-year institutions and 56% were four-year institutions). Those that did not offer undergraduate science majors were excluded. Within these groups, institutions were further categorized into similar size bins based on enrollment. Our sampling frame contained 1,732 small 4-year colleges, 297 medium 4-year colleges, 134 large 4-year colleges, 1,227 small 2-year colleges, 298 medium 2-year colleges, and 91 large 2-year colleges.

Each of these six lists of institutions was randomized. Recruiting proceeded down these six lists by identifying and contacting professors teaching required English courses. To prevent the possibility of students from any single institution constituting a substantial fraction of the sample, we imposed a cap of 500 students per institution, which was triggered a few times. In all, 160 professors were contacted. Of these, 43 professors (26.9%) initially agreed to participate; usable student questionnaires were received from 34 professors (i.e., from 79.1% of those who agreed to participate, or from 21.3% of all contacted professors). In terms of the institutions' (33-level) Carnegie classification reported by IPEDS, there were no statistically significant differences between the participants and non-participants (neither when we compared those who initially agreed to participate with those who initially declined, nor when we compared those who actually returned filled-out surveys with those who initially declined or initially agreed but did not follow through). Our recruiting goal was 4,000 students representatively distributed by the size and type of institution. The full dataset of returned surveys includes 6,860 students, but for this analysis students who were not born in the U.S. (and hence may not have been exposed to the courses and sequences typical in American schools) are excluded, as are students who were home schooled, not in their first two years of college, or who did not express any career preference. This resulted in a sample for analysis of 4,691 subjects at 34 institutions.

Of the students in our sample, 56.4% attended 4-year, and 43.6% attended 2-year institutions. In all, fourteen 2-year schools (6 small, 3 medium, 5 large) and twenty 4-year schools participated (12 small, 3 medium, 5 large). This proportion was extremely close to the corresponding proportion in the population, as described above (56% vs. 44%). Regarding our second stratification criterion, we had aimed at recruiting a sample that contained, among both the 4-year and 2-year students, a third of students who attended large institutions, a third of students at medium institutions, and a third who were at small institutions. In the final sample, among the 4-year students, 41.8% attended large, 26.0% attended medium, and 32.2% attended small institutions; among 2-year students, 39.6% attended large, 24.6% attended medium, and 35.8% attended small institutions. Whereas the target percentages of 33.3% for each group were not precisely attained, the actual percentages were deemed close enough to be an adequate representation of the population.

Instrument

The 7-page, 50-item survey instrument was constructed to gather information on the full range of student experiences in high school that might impact a student's choice to pursue a STEM career. Three sources guided the creation of hypotheses that were to be formalized in survey items:

1. An extensive review of the educational research literature for factors that might influence persistence in STEM fields
2. Open-ended, free-response questionnaires from 259 high school science teachers and from 153 scientists/engineers on what factors influence persistence in STEM
3. Extraction of items that turned out to be significant from a previous national study, Factors Influencing College Science in Success (Tai, Sadler & Mintzes, 2006). These factors include: high school science and math course-taking history, standardized test performance, gender, and parental education.

We were greatly influenced by the methodological practices of epidemiology in which great care is employed when substituting recall for longitudinal data collection. We closely followed recommendations that improve accuracy and reliability in large-scale studies that depend on self-reported data (Pace, Barahona & Kaplan, 1985; Bradburn, 2000; Niemi & Smith, 2003). Self-reports from college students of course-taking, grades earned, and standardized test scores 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). Kuncel, Credé, and Thomas (2005) found that self-report may be characterized as reasonably accurate in samples where the surveys address issues relevant to the respondents. In surveying college students, most in their first semester of college, reflection on their prior preparation and career aspirations would be commonplace. In addition, the students' own professors (who were individually recruited by the project) administered the surveys in class at the start of the term, raising student compliance and perceived importance of the survey.

We conducted a test-retest study of 96 students who took the survey and then completed it again after a two-week interval. Combining tests of both dichotomous and continuous variables (correlation and Cohen's Kappa), the reliability of the survey was 0.70. Coupled with the large sample size, the likelihood of a reversal in the direction of effect of a variable is less than 0.04% (Thorndike, 1997). In the case of identification of career interest, test-retest agreement was 87.2% between the two administrations. Validity was established through focus groups with researchers and teachers. A pilot survey was taken by 49 students to adjust scales and clarify wording. The items used in the analysis for this paper required little judgment or interpretation by students. A simple reporting of the courses taken in high school (i.e., year, course name, grade, AP exam score, etc.) in the few years before entering college was all that was required.

Variables

Subjects were asked to choose, from a list of professions, their career goals at several points in time. We grouped choices into five broad career categories, the first two of which were considered to constitute the STEM area:[5]

- Engineering (including computer science),
- Science (physical, life and earth sciences, mathematics, science and mathematics teaching),
- Medicine (physicians, veterinarians, all requiring advanced degrees)
- Health (nursing, medical technicians)
- Non-STEM-related fields (law, business, arts, social science, other teaching, etc.)

The desired profession the student indicated for the end of high school stage (that is whether the student chose science or engineering as his/her career aspiration just before the start of college) was used as the dependent variable in our

[5] This analysis uses the STEM categorization of the American Association of University Women (AAUW) which includes: the physical and biological sciences, mathematics and statistics, computer science, engineering majors, and teaching science or mathematics. Medicine and health careers are not considered STEM careers although students do typically major in a STEM field in college. Career aspiration rather than college major intention is the focus of our analysis because many students do major in STEM, but have no intention on entering the STEM workforce (e.g., students heading for medicine or business). Moreover, high school students may be much more aware of the career or profession they desire than of what their particular college major will be.

Table 1: Breakdown of Study Sample by Who Took an AP course and Who Took an AP Exam in the Subject

AP Course Taken	AP Exam Taken	Calculus	Biology	Chemistry	Physics
No	No	3938	4266	4347	4349
	Yes	11	33	31	19
	% who took AP exam	1.9%	12.7%	15.8%	9.9%
Yes	No	168	166	148	150
	Yes	574	226	165	173
	% who took AP exam	77.4%	57.7%	52.7%	53.6%

Note: A large fraction of students enrolled in AP courses do not take the exam and a small fraction of students not enrolled in AP courses do sit for the exams.

logistic models. In total, 28% of students expressed an interest in a STEM career at the end of high school. Also, the same five broad career choices were obtained for *middle school career interest* and *for beginning high school career interest.*

Of primary concern are the number of years that students enrolled in high school biology, chemistry, physics, other science, or calculus, and the level of the course (e.g., regular, Advanced Placement, International Baccalaureate, honors, etc.). Common in studies of Advanced Placement is the inclusion of only students who have taken a standardized and proctored AP examination as representative of taking an AP course in high school. Since we collected information on both students' course-taking (including the year in which the course was taken, their grade earned, etc.) as well as their AP exam score (if taken), we can examine the degree to which AP course-takers also took the AP exam (Table 1).

It is clear from Table 1 that some students who do not take an AP course do take the AP exam. These are students who may prepare for the exam by independent study, or by taking another course (e.g., honors, dual credit, IB, other advanced course). To include them in any analysis of those who were exposed to an AP course would be inaccurate. Secondly, not everyone taking an AP course goes on to take the AP exam. From Figure 1, we see that those students who enrolled in an AP course and chose to take the AP exam were from the upper strata of AP course grades. Many students who were taking an AP course, but were earning low grades, chose not to take the AP exam. This increases the purported effect of taking an AP course by acting as a filter for only the better performing students. Many AP teachers are evaluated based on how their students perform on the AP exam; this may lead to an encouragement for low performers to opt out of the standardized AP exam (National Research Council, 2002). Since AP exam-taking is not a completely accurate measure of whether students have taken an AP course, we choose to use students' own reporting of the kind of courses they took (cross-checked by their course grade and year) as the most reliable and accurate measure of AP course-taking.

Of concern is whether students who take a second year of a subject may be doing so because they failed the first year and had to repeat to gain credit. However, only 0.4% in our sample failed their first year courses and went on to take a second year in the subject. These were recoded as taking only their first year course (even though they took it twice).

In addition to gender (coded as female=0; male=1), demographic information was collected on the level of each parents' education (i.e., less than high school, high school, some college, 4-year degree, graduate degree), community affluence derived from home ZIP code and U.S. Census data, and race/ethnicity (i.e., white, black, Asian, American Indian, Pacific Islander, Hispanic, other). Multiple selections were allowed for race/ethnicity.

To serve as a rough proxy for potentially important pre-high school STEM proclivities, we included the average middle school mathematics grade in our models (A+ = 4.33, A = 4, A- = 3.67, etc.). We also employed several other measures of students' academic success and ability. For English proficiency we

Figure 1

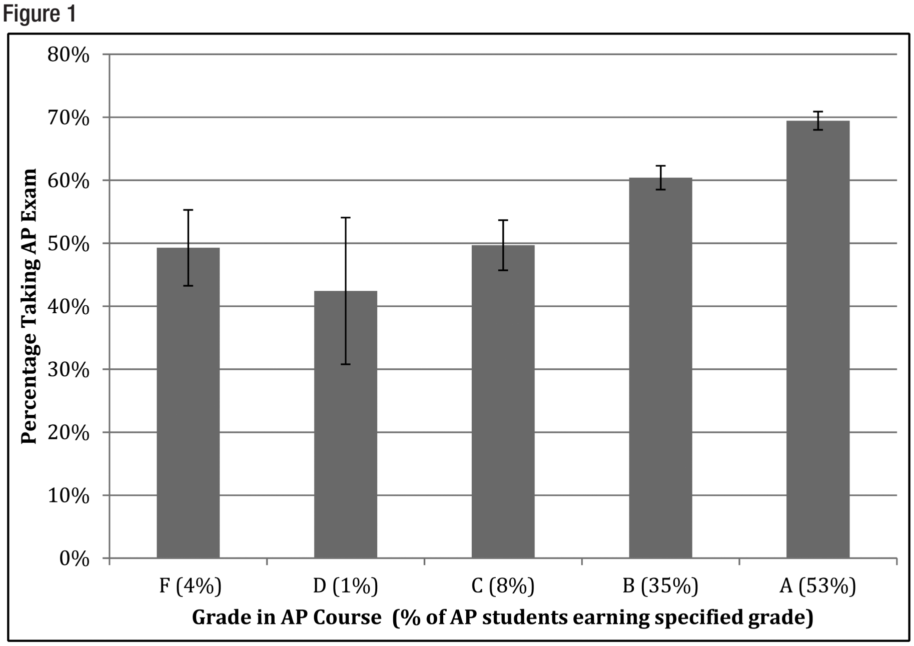

Figure 1: Percentage of students taking an AP Exam by grade earned in their AP course. These aggregated statistics sum across AP biology, chemistry, physics, and calculus. Students who earned a high grade in an AP course took the AP exam at a greater rate than those who did poorly. Note that 53% students earn a grade of A in their AP course. Error bars are ±1SE.

Table 2: Breakdown of Sample for AP and non-AP Coursetaking by Year Taken

	AP as a 1st year course	Non-AP as a 1st year course	AP as a 2nd year course	Non-AP as a 2nd year course
Calculus	12.1%	8.2%	4.3%	0.0%
Biology	2.6%	94.8%	6.3%	21.4%
Chemistry	2.5%	81.2%	4.7%	11.3%
Physics	4.0%	47.4%	3.6%	7.0%
Other	2.1%	24.3%		

used the SAT Verbal score; for mathematics proficiency we used the SAT Math score. ACT scores were converted to equivalent SAT scores using a concordance (Schneider & Dorans, 1999).

Descriptive Statistics

Interest in a STEM career was exhibited by 24.0% of our sample of 4,691when they were in middle school (16.5% of females and 32.2% of males). The interest level rose modestly to 27.2% by the start of high school (17.5% of females and 37.9% of males) and to 28.3% of students by the end of high school, although female students suffered a slight decline (16.8% of females and 41.0% of males).

A bit more than half of our sample was female (52.6%) reflecting a general trend in college enrollment. Students in our sample earned an average middle school mathematics grade of 89% (B+), with their SAT math scores averaging 532 (SD=110) and SAT verbal scores averaging 536 (SD=88). Students identified themselves as 79% white, 6% other or multiple, 8% black, 5% Asian/Pacific Islander, and 2% Native American. Within this demographic distribution, 11% identified as Hispanic. The parents of students represent the full range of levels of education with 39% of fathers and 42% of mothers having a 4-year college degree. Thirty-two percent of the students surveyed reported at least one parent having a job involving science.

Overall, 25% of students availed themselves of at least one Advanced Placement course in calculus or science in high school (of these, 7% took two, 2% took three, and 1% took four). In our sample, 40% took a second year of biology, chemistry, physics, or calculus. The breakdown of Advanced Placement and second year courses is listed in Table 2 and illustrated in Figure 2. Compression of the high school curriculum is evident when students take an AP course as the first year's study in a subject (National Research Council, 2002). This is particularly prevalent in physics: in our sample, 53% of students who took AP physics did so as a first year course. In both biology and chemistry, Advanced Placement was typically taken as a second year course (29% of AP biology students and 35% of AP chemistry students took it as a first year course). Non-AP second year courses are offered by many high schools in biology (advanced biology, microbiology, botany, ornithology, anatomy, marine biology, molecular and cellular biology, ecology), chemistry (advanced chemistry, organic chemistry), and physics (advanced physics, electronics, robotics, engineering, modern physics). AP calculus was more popular than non-AP calculus in the first year of study. Many students who took non-AP calculus in the eleventh grade went on to take AP calculus in twelfth grade. Other science courses (e.g., earth science, geology, astronomy, meteorology, environmental science, psychology, computer science, forensic science) were taken by 26% of students, for which AP exams were offered in computer science, psychology, and environmental science. Therefore, it is of critical importance for any study that desires to measure the impact of advanced STEM coursework in high school to separately account for the taking of AP courses and the number of years taking a science or math subject. Because the majority of second year STEM coursework in high school is taken in the form of an AP course, studies that do not separate AP from years taken run the risk of attributing to AP coursework the effect of a second year course. As we will show, taking a second year of a STEM course can matter far more than taking an AP course in a subject.

Figure 2

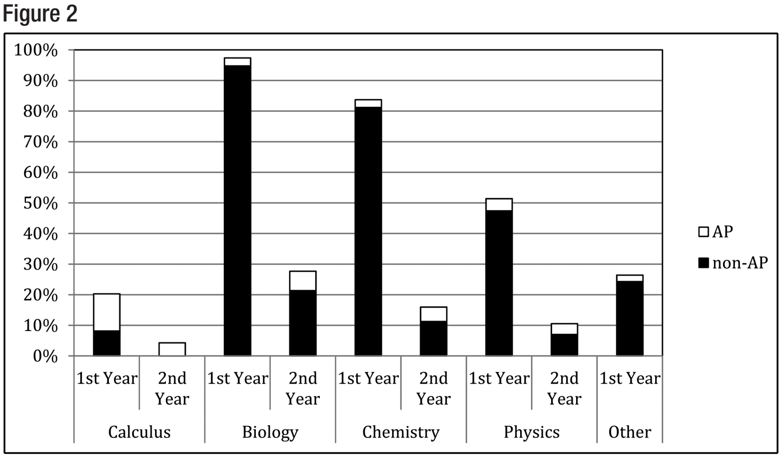

Figure 2: High school calculus and science enrollment. Note that while all second year calculus courses are reported as AP courses, non-AP courses dominate as second year courses in other subjects (e.g., IB, anatomy, ecology, organic chemistry, electronics, astronomy).

Analysis and Discussion

The most appropriate means for analyzing the issue of STEM career interest at the end of high school, a binary variable, is to construct logistic regression models that simultaneously test multiple independent variables for significance. We produced a series of nested logistic regression models and examined the behavior of the coefficients, first for their statistical significance and second for their magnitude (and derived odds ratio and calculated probability for a "typical" student). Table 3 shows the variables that are included in each of the five models, with the level of significance of each. We also include a measure of goodness of fit appropriate for logistic models, the McFadden R-squared adjusted for the number of degrees of freedom in each model (McFadden, 1973). We expect to maximize this measure as we are trying to explain the most variance possible in the dependent variable. The best model is the one that explains the most variance with the fewest variables.

Because our models employ a number of background variables to act as controls and as predictor variables, we chose to use multiple imputation rather than listwise-deletion which would reduce the sample by 21% (mainly due to missing SAT or ACT scores). This approach creates ten datasets which contain the same values for non-missing variables and imputed values for those that are missing. The distribution of the replacement values represents the uncertainty about the missing value. The same regression procedure is carried out on each dataset, producing slightly different parameter estimates which are then combined for a final estimate with appropriate standard errors (Allison, 2002).

We start in Model 1 with the "empty model" containing only a constant. Model 2 adds background variables that are known to impact student career interest in STEM: *Middle School Interest in a STEM Career, Beginning High School Interest in a STEM Career, Gender, SAT/ACT Math,* and *SAT/ACT Verbal*. These five factors of Model 2 form a "baseline" in which all five variables turn out to be significant. We also carried out a more expansive analysis with a number of other variables, but found that demographics related to race/ethnicity, parental education (as a proxy for socio-economic status), and a composite indicator of community socio-economic makeup, combining per capita income levels and educational levels in the students' home ZIP codes, were not significant predictors of STEM career interest at the end of high school, nor was having a parent with a science-related career ($p \leq 0.01$). Because this may appear surprising, we hasten to add that many of these variables that were not included did predict *beginning high school STEM interest*. It appears these variables bear on student interest in a STEM career before, but not during, high school. Their effect is best thought of as being subsumed in the baseline model.

In Model 3, we add five variables for taking an AP science or calculus course in high school. *AP Calculus*, *AP Chemistry*, and *AP Physics* are significant, while *AP Biology* and *AP Other Science* are not. We enter all AP variables and all *number of years* variables (dummy variables which allow comparison to zero years in a subject) together into Model 4 and compare this model's fit with that of Model 3. In this way, we can determine if the *number of years* variable set has an additional impact above and beyond that of the AP variable set. Inspecting the significance of the variables in Model 4 shows two interesting

Table 3: Logistic Models with Odds-Ratios and Statistical Significance of Variables

Variable		Model 1 Empty	Model 2 Baseline	Model 3 AP only	Model 4 All	Model 5 Years only	Model 6 Final
Constant		0.39(0.01)***	0.04(0.01)***	0.06(0.02)***	0.09(0.04)***	0.08(0.04)***	0.08(0.02)***
Gender	Male		2.29(0.18)***	2.27(0.18)***	2.25(0.18)***	2.25(0.18)***	2.27(0.18)***
Interest in STEM Career	Middle School		1.46(0.14)***	1.46(0.14)***	1.44(0.14)***	1.43(0.14)***	1.43(0.14)***
	Beginning HS		4.78(0.42)***	4.79(0.43)***	4.58(0.41)***	4.56(0.41)***	4.55(0.41)***
SAT / ACT Score /100pts	Math		1.44(0.00)***	1.38(0.00)***	1.24(0.00)***	1.24(0.00)***	1.23(0.00)***
	Verbal		0.85(0.04)***	0.84(0.04)***	0.84(0.04)***	0.84(0.04)***	0.84(0.04)***
Calculus	1 year				1.72(0.24)***	1.75(0.19)***	1.72(0.18)***
	2 years				1.74(0.47)*	1.82(0.39)**	1.77(0.37)**
Biology	1 year				0.99(0.28)	1.00(0.28)	
	2 years				0.76(0.27)	0.85(0.27)	
Chemistry	1 year				0.91(0.11)	0.91(0.11)	
	2 years				1.51(0.42)	1.67(0.34)**	1.79(0.30)**
Physics	1 year				1.32(0.12)***	1.35(0.12)***	1.34(0.11)***
	2 years				1.58(0.42)*	1.84(0.40)**	1.84(0.40)**
Other	1 year				0.97(0.09)	0.97(0.09)	
AP Course	Calculus			1.57(0.18)***	0.98(0.17)		
	Biology			1.01(0.15)	1.20(0.24)		
	Chem.			1.65(0.26)**	1.14(0.27)		
	Physics			1.68(0.26)*	1.24(0.24)		
	Other			1.08(0.30)	1.08(0.32)		
	# Var.		6	11	20	15	11
	N	4691	4691	4691	4691	4691	4691
McFadden Pseudo R^2	regular		0.191	0.201	0.208	0.207	0.207
	adjusted		0.189	0.197	0.201	0.202	0.203

Note: The McFadden Pseudo R^2 adjusted statistic increases with each model. Differences in the amount of variance explained by models 4, 5, and 6 are not significant, however the most parsimonious model, Model 6, includes only statistically significant variables. Statistical significance noted: * ≤0.05 , * ≤0.01, *** ≤0.001.

Figure 3

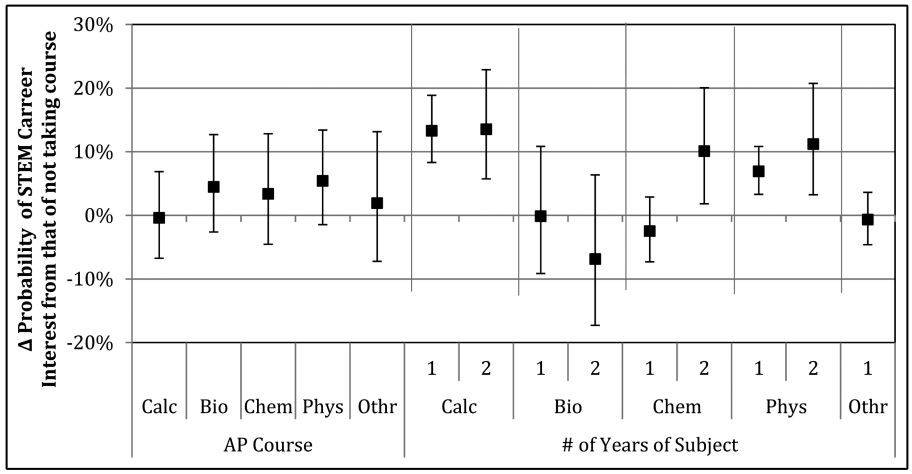

Figure 3: Modeled increase of probability of STEM career interest based on high school course taken. We convert odds-ratios to the difference in probability of taking or not taking an AP course for a composite average student and the difference in probability of taking each additional year of a subject-matter course. Error bars enclose 2 standard errors. The intersection of an error bar with the 0% level indicates no significant difference (at the p=0.05 level) observed in taking the course over not taking it.

results: *AP Calculus*, *AP Chemistry*, and *AP Physics* are no longer significant in the model, while the taking of calculus, chemistry, and physics is important; and the McFadden Adjusted R^2 has improved significantly over Model 3.

Model 5 removes the AP course variables leaving only the *number of years* variable set. We achieve similar results for each subject to those in Model 4; *Years of Calculus*, *Years of Chemistry*, and *Years of Physics* are significant, while *Years of Biology* and *Years of Other Science* are not. The removal of the AP course variables does not degrade model fit. Putting it differently, the AP variable set appears to add nothing to the explanation if the *number of years* set is in the model (i.e., Model 4 does not improve upon Model 5). At this point, it appears that there may be an interesting story to tell about the possible impact of high school calculus, chemistry, and physics on increasing student interest in a STEM career.

Model 6 excludes variables that are not significant and produces the best adjusted R^2. We find no significant interactions between variables at the p=0.01 level, a reasonable cut-off for a sample of this size.

Next, we calculated the odds ratios for each of the important variables in our models. Odds ratios are relatively stable from one model to the next for variables that are significant in Model 6 (*Years of Calculus*, *Years of Chemistry*, and *Years of Physics)* indicating that these values differ little, irrespective of which other variables are included in the model.

The odds ratios in Model 5 can be interpreted as a comparison of odds between the particular conditions represented by the variables (e.g., taking AP calculus vs. not taking AP calculus). In the case of AP calculus, this ratio is 1.02:1.00 and is not significant. **Students who take AP calculus do not have significantly greater odds of being interested in a STEM career than those who do not,** after controlling for all the other variables in the model. By eliminating from the model all non-significant variables, Model 6 produces the clearest picture of the association of high school coursework with interest in a STEM career. We can see a large difference in the odds for three subjects in this parsimonious model:

- Calculus – Large difference between no calculus and one year (non-significant difference between one year and two years)
- Chemistry – Large difference between one year and two years (non-significant difference between zero and one year)
- Physics – Large difference between no physics and one year. Also, large difference between one year and two years.

We convert the differences between the odds of not taking a course and taking it (for either one or two years) into an illustrative graph of changes in the probability of STEM career interest (Figure 3). We can see that the increase in probability is not significant for any AP course examined, but is significantly different from zero for taking calculus, for a second year of chemistry, and for taking physics. One should keep in mind that these are the results of Model 4 in which we control for student background variables.

Limitations

As in all epidemiological-style studies, caution should be exercised owing to possible limitations in our analysis:

- *Sample Size of the Current Study.* Although 4,691 students is a small fraction of the total population, in statistical terms, it is a fairly substantial sample size. Given our use of multiple linear regression, the statistical power calculations indicate that we have a greater than 99% chance of detecting effects with a significance level of α = 0.05 or higher (Olofsson, 2012).
- *Variance Explained.* Three-quarters of the variance in STEM interest at the end of high school remains unexplained in our best model. There are clearly other variables at play that we have not measured, such as the specific experiences that students have within their high school mathematics and science courses.
- *Inferring Causality.* Our study is associative. Although we do address alternative hypotheses that account for STEM career interest, we note that this research cannot prove causal connections between

variables and outcomes. However, we are able to test simultaneously the strength of associations for many hypotheses for which experimental trials would be difficult to perform. The relationships revealed by this kind of study are then worthy of controlled, experimental studies (to the extent possible) that may establish, with increasing certainty, the postulated causal connections. Causality rarely exists in the absence of association.

Conclusion

Our findings offer evidence that may appear to contradict the views that many students, parents, and educators hold about the value of advanced coursework in high school. In constructing our beliefs about what makes education effective, we have few true experiments in which all relevant factors can be controlled. Therefore, we tend to rely more on anecdotes and simple associations because it is impossible to control for a large number of confounding variables mentally. Yet, large-scale studies relying on statistical models that control for covariates can help to strip away the noise to reveal underlying patterns.

Using data from our nationally representative sample of college students, we examined the connection between high school science and calculus coursework on student interest in pursuing a STEM career. Our analysis disentangles the taking of advanced coursework (often as a second year in a subject) from that of taking an Advanced Placement course. Controlling for relevant background characteristics (including interest in a STEM career at the start of high school), **we find evidence that students who take one or two years of calculus, a second year of chemistry, and one or two years of physics in high school exhibit a significantly higher STEM career interest, as a group, than do students who do not take these courses. Those who take a course in another science or an additional year of biology show no significant increase, on average, in their intention to pursue a STEM career. Apart from the effect of the number of years taking calculus, chemistry, or physics, we find no evidence that students' taking an Advanced Placement science or calculus course increases their likelihood of having a STEM career interest.**

Most research in the area of the impact of Advanced Placement relies too heavily on AP exam data. AP exams are given once a year, in May. Student who may be performing poorly in an AP course (based on teacher-awarded grades) have little reason to sit for an AP exam. If they score poorly, they have no chance of earning the potential benefit of college credit or raising their chances of impressing college admission officers (if they are taking the course earlier than their senior year in high school). We are troubled that much of prior research on the impact of AP courses on students may be compromised by the selection effect inherent in using data only from students who have taken an AP examination. This excludes an estimated 36% of typically lower performing students who opt out of taking the AP exam. Moreover, AP exam data also include typically stronger students (representing 8% of exam takers) who did not enroll in an AP course, but who were exposed to alternate forms of preparation. Whenever possible, future studies that seek to buttress claims of the superiority of an intervention or program should use data from the full complement of students who have been exposed, not only the ones who have performed the best, so as to reduce sample bias.

We find that students' background, outside of the courses that they take in high school, plays a substantial role, especially students' initial career interest when they enter high school. Yet, even after controlling for initial interest, **we find that exposure to advanced science and mathematics coursework in high school is associated with an increase in STEM interest**. Because we find no advantage of Advanced Placement coursework over other types, we cannot recommend that high schools cease offering non-AP advanced coursework (or the option of dual credit courses through local colleges) in science or calculus and move exclusively to AP courses. **Advanced Placement coursework appears to be indistinguishable from non-AP coursework in its effect on STEM persistence when one accounts for the number of years that students take a science or mathematics subject.**

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