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ABSTRACT

This analysis uses data on science achievement and transcript reports of science course taking patterns of students from the National Education Longitudinal Study of 1988 (NELS:88) to estimate the relationship between science course taking and the change in science proficiency levels between 8th and 12th grades. It also explores the extent to which gains in science proficiency are related to student race-ethnicity, gender, and socioeconomic background after accounting for differences among these groups in science course taking. Findings indicate that 54% of students showed an increase in their science proficiency level while 35% stayed at the same level and 11% declined. Generally speaking, taking eight or more semesters of science was positively associated with an increase in science proficiency level and for students who started at the top science proficiency level in eighth grade, taking more advanced science courses was related to increases in science proficiency level. Asian and white students were found to be more likely to increase in science proficiency level, and gender, race, and familial socioeconomic background continued to exhibit a relationship to chances of increasing in science proficiency even after adjusting for differences in science course-taking. Contains 45 references. (JRH)

NATIONAL CENTER FOR EDUCATION STATISTICS

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Foreword

Relatively little attention has been given to the relationship between course taking and achievement in science. This report examines factors related to gains in science proficiency between 8th and 12th grade. This analysis uses achievement testing and transcript data in the National Education Longitudinal Study of 1988 (NELS:88) to investigate how changes in science proficiency are related to science course-taking histories of high school students. Like an earlier report by Rock, Owings, and Lee (National Center for Education Statistics 1994) on changes in the mathematics proficiency of students between 8th and 10th grades, the analysis takes into account initial proficiency of students—a crucial characteristic related to both gains in proficiency and course-taking patterns. This focus enables the reader to understand how course-taking patterns are related to gains in proficiency among students who in eighth grade were at the bottom, middle, and top of the science proficiency distribution. The report also explores the extent to which gains in science proficiency are related to student race-ethnicity, gender, and socioeconomic background, after accounting for differences among these groups in science course taking.

Mary Frase
Acting Associate Commissioner

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Acknowledgments

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Highlights

A number of previous cross-sectional studies have found a strong relationship between a student's course-taking history in science during high school and his or her current achievement in science. However, it has been difficult to interpret this evidence as the effect of course taking. It is equally plausible that students who take more science courses or more difficult science courses would also have been high achievers if tested before high school. With extensive longitudinal data on both achievement and course taking now at hand, a more definitive analysis is possible. This analysis uses data on science achievement and transcript reports of science course taking of students from the National Education Longitudinal Study of 1988 (NELS:88) to estimate the relationship between their science course taking and the *change* in their science proficiency level between 8th and 12th grades.

- *How many students increase in science proficiency level between 8th and 12th grades?*

Fifty-four percent of students showed an increase in their science proficiency level, while 35 percent stayed at the same level and 11 percent declined. The chances of increasing in science proficiency level varied with the demographic and academic characteristics of students.

- *Is taking more science courses related to gains in science proficiency level between 8th and 12th grades?*

Generally speaking, taking eight or more semesters of science was positively associated with increasing in science proficiency level. This result held in most situations even after accounting for the association between socioeconomic status (SES), achievement level in eighth grade, gender, and race-ethnicity on the one hand and both course taking and increasing in science proficiency on the other. The number of science courses taken was not, however, the only information about course taking available in NELS:88. Information on the level of science course taken was also available and proved useful.

- *Is taking advanced level science courses such as physics and chemistry related to gains in science proficiency between 8th and 12th grades?*

For students who started at the top science proficiency level in eighth grade, taking more advanced science courses was related to increases in science proficiency level. Furthermore, after controlling for level of science course taken, evidence of a positive relationship between the number of science courses and chances of increasing in science proficiency level was not found. Taking challenging science courses seems to be crucial for high initial achievers.

For students who started at low to middle levels of science proficiency in eighth grade, both taking advanced level science courses and a higher number of science courses were related to increasing in science proficiency level.

- *Are demographic characteristics of students related to chances of increasing in science proficiency level during high school?*

The answer is yes. Asian and white students were more likely than black and Hispanic students to increase in science proficiency level. Students of parents with high levels of education, occupational rankings, and incomes (i.e., high SES) were more likely to increase in science proficiency level than students of parents with lower levels.

- *After accounting for differences between demographic groups in the number and level of science courses taken, do differences in their chances of increasing in science proficiency level disappear?*

Gender, race, and familial SES continued to exhibit a relationship to chances of increasing in science proficiency level even after adjusting for differences in science course taking. In future research on this topic, researchers might consider alternative intervening variables or ways of extracting more information out of the course-taking variables.

Introduction

Some people are concerned that our nation's students are being out-paced in scientific literacy by students from other advanced, industrial nations.[1] Many education professionals and policymakers have outlined solutions to this problem. Increasing the number of science courses required for high school graduation, some have argued, will help students in the U.S. progress toward becoming first in the world in science achievement.[2] Others have called for an integrated approach to science which continuously exposes all students to science material throughout high school.[3]

These recommendations for more exposure to science are based in part on research that has documented a positive relationship between course taking and achievement.[4] Jones et al.[5] found a positive relationship between total number of science (and mathematics) credits a high school student took and his or her science proficiency level in 12th grade. Mullis and Jenkins[6] also found a positive relationship between course taking and proficiency, but questioned the nature of the relationship because brighter students may simply take more courses.

In the area of mathematics, Rock, Owings and Lee[7] have shown course taking to be positively related to increases in a student's proficiency level between 8th and 10th grades. Among students who started at the same proficiency level in eighth grade, those who took higher level mathematics courses were more likely to increase to higher proficiency levels two years later than students who did not take higher level courses. Their results suggest that course taking affects mathematics proficiency. More importantly, they show that taking more advanced mathematics courses seems to help both low and high achievers.

Differential course-taking patterns may be responsible for part of the gap between the mathematics and science achievement of high school males versus females and of whites and Asians compared to blacks and Hispanics.[8] Blacks and Hispanics take fewer mathematics and science courses than whites and Asians and the science courses they take are clustered at lower levels.[9] High school males are less likely to stop taking science and mathematics courses than females.[10] Indeed, in mathematics, Rock, Owings and Lee found that the types of mathematics courses males and females took explained some of the difference in gains in mathematics proficiency levels between 8th and 10th grades. Furthermore, research comparing public and private schools and on effective schools in general has found that good schools are often organized around a challenging academic or college preparatory curriculum.[11]

This report uses longitudinal data to examine whether students at the same level of science proficiency during eighth grade have higher science proficiency levels four years later if they took more semesters of science in the interim as compared to students who took fewer semesters of science. It will ascertain the relationship between taking challenging science courses in high school and experiencing gains in science proficiency. In addition, the relationships among school and student characteristics, high school curriculum and changes in proficiency level are also examined.

The analysis begins by describing the distribution of students across levels of science proficiency, the amount of change in proficiency between 8th and 12th grades, and the course-taking patterns of students. The relationship between increases in proficiency level and science course taking while controlling initial proficiency level is then examined. Results from this section should be useful to people who ponder whether low-achieving students would benefit from tougher course-taking standards. Finally, the relative influences of family background, student demographic characteristics, and school and course-taking factors on chances of increasing in science proficiency level are modeled with multiple, logistic regression.

Data from the National Education Longitudinal Study of 1988 (NELS:88) were analyzed in this report. These data provide the best available resource to examine growth in science proficiency during high school. Other non-longitudinal national surveys have provided only cross-sectional snapshots of the relationship between course taking and achievement. This does not facilitate the testing of causal relationships. Previous longitudinal surveys sponsored by the National Center for Education Statistics (NCES) spanned only part of a high school student's career and therefore, provided an incomplete picture of achievement during high school.[12]

In NELS:88 the same students were interviewed in eighth grade and 2 and 4 years later when most were in 10th and 12th grades, and detailed course-taking histories of the students were obtained through a transcript study component. These features, combined with measures of student science proficiency at multiple points of time, help make NELS:88 a valuable resource for researchers interested in exploring factors related to gains in achievement or differences in achievement among students.

In 1992, transcripts were collected for a sample (14,283) of the original eighth-grade students. The NELS:88 sample used in this report is comprised of 7,584 students representing the longitudinal panel who had 8th and 12th grade science scores and complete transcript records.[13]

Science Proficiency Levels

To measure change in student achievement over time requires a measure that covers a broad range of achievement, both within a grade level and across grades as students advance through school. A psychometric methodology called item response theory (IRT) is ideal for measuring such change. It characterizes a wide range of items on achievement tests in terms of how difficult they are and, in particular, of how likely students with various levels of proficiency are to answer them correctly. IRT allows for the introduction of new and more difficult test items over time that relate to the performance scale created from items administered earlier during a student's career. Thus, when a cohort of students who were tested in 8th grade reach 12th grade, more difficult test items can be included on the 12th grade test which cover a higher range of performance and yet report test performance on the scale that was constructed for them when they were eighth-graders.

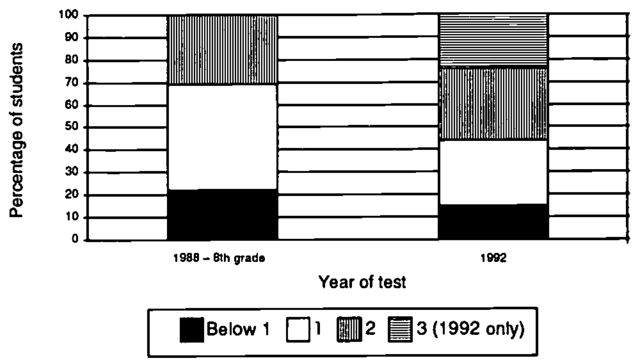
An alternative to calculating an IRT scale score is to assign each student at each grade to a proficiency level. Based upon common difficulty levels of groups of items used on the science achievement test in NELS:88, certain criteria were established to represent thresholds of understanding basic science concepts and applications.[14] In the base year, students were assigned to level "Below 1" if their test results indicated that they did not understand simple scientific facts or information. This was determined if they did not correctly answer at least three out of four test questions relating to basic scientific knowledge. They were assigned to level "1" if their test performance indicated that they understood basic science, i.e., they answered at least three of the level 1 questions correctly. This level of understanding could be obtained through everyday experiences. They were assigned to level "2" if they, in addition to being at level 1, understood science concepts that were fundamental to, or laid the foundation for, the building up of more complex scientific knowledge. They needed to correctly answer at least three items from a group of four representing fundamental science concepts. In a similar manner, in the followup surveys students could have been assigned to the above levels or to level "3," which represents an understanding of complex science concepts and additional problem-solving abilities.[15] These gross levels of proficiency are useful for describing achievement of U.S. students or modeling school and family processes involved with learning.[16]

The Science Proficiency Level of Students and Changes Over Time

Almost half of the 1988 eighth-grade students scored at science level 1 (figure 1 and table A4). Some 22 percent were below level 1 and 31 percent above level 1. Four years later, when they reached 12th grade, 15 percent of the students were below level 1. The majority of students were at level 2 or higher. Based on previous cross-sectional research, it is not surprising to find that over one-fifth of eighth-grade students have little understanding of basic science and that by the end of high school, fifteen percent still do not.[17]

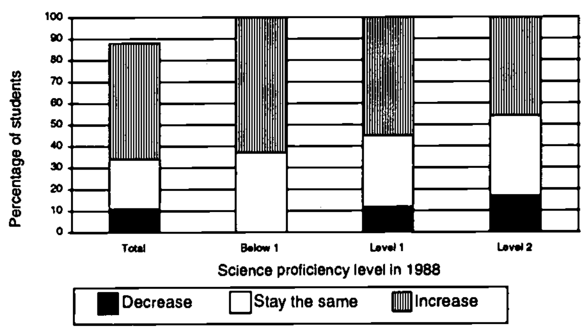
Because NELS:88 is longitudinal and assesses student achievement at multiple points in time, it provides researchers with data ideal for examining how much growth in achievement occurs during high school. Between 1988 and 1992 some 54 percent of students improved their science proficiency by one or more levels (figure 2 and table A7).

Figure 1.—Science proficiency levels of NELS students at two points in time



SOURCE: U.S. Department of Education, National Center for Education Statistics, National Education Longitudinal Study of 1988.

Figure 2.—Change in science proficiency levels of 1988 8th-graders between 1988 and 1992, by proficiency level in 1988



SOURCE: U.S. Department of Education, National Center for Education Statistics, National Longitudinal Study of 1988.

A little more than one-third (35 percent) remained at the same level while 11 percent lost ground. (These results are based on changes from one proficiency level to another and do not take into account changes in proficiency within a level.) Nearly the same proportion of students decreased or simply maintained their science proficiency level as the proportion who increased.

The large percentage of students who did not gain at least one level may reflect a variety of factors. Students may have simply forgotten what they learned by 1988 or during the interim covered in this study, especially if they had not taken any science recently. They may have gained but not enough to cross the threshold to the next level. At any rate, these results are consistent with findings from other research about students: (1) they spend a large amount of time tending to—or being distracted by—maintenance and procedural matters (i.e., announcements, the taking of attendance, the collection of sick notes and assignments, the distribution of hallway passes, the changing of rooms and teachers, the correction of out-of-line students) rather than engaging in instructional activities,[18] (2) they receive inflated grades although their performance on objective tests may not warrant it,[19] and (3) they pursue little advanced science coursework.[20]

The likelihood of students increasing their science proficiency level is a function of their initial science proficiency. Students who started at the highest level were least likely to increase. There are a variety of possible explanations for this pattern.[21] It may reflect regression to the mean.[22] Indeed, students who started at level 2 were more likely than those at level 1 to decrease. The lower chances of increasing among high proficiency eighth-graders might also reflect varying difficulties in moving from one level to the next. Lower levels represent competency in basic, everyday science and higher levels represent more complex problem solving skills in addition to all lower level skills. Thus, it may be possible that moving up may be easier for students who start at the lower end of the proficiency distribution. Finally, more students may have been clumped not far below the threshold for level 1 science proficiency than below that for higher levels. If that were the case, moving up in proficiency level would have been more likely for those at the bottom. Whatever the explanation, the results found here are in agreement with some other longitudinal findings on gains in achievement: students initially low in achievement are more likely to gain than students with higher initial achievement.[23]

By cross-classifying changes in science proficiency level with various student and school characteristics, one can see which groups of students were most likely to change (table 1).[24]

Table 1.—Percent of 1988 8th-grade students whose science proficiency level decreased, remained the same, or increased between 1988 and 1992, by selected school and student characteristics

School and student characteristics	Change in science proficiency level		
	Decrease	Same	Increase
Total	**11**	**35**	**54**
Gender			
Male	11	33	56
Female	11	38	51
Race-ethnicity			
Asian	8	30	62
Hispanic	11	41	49
Black	18	42	39
White	10	34	56
American Indian	15	45	40
SES quartile			
Low	17	42	42
Low-medium	14	39	47
Medium-high	10	35	55
High	6	29	65
Type of school			
Public	12	36	53
Catholic	9	33	58
Other private	4	27	69

SOURCE: U.S. Department of Education, National Center for Education Statistics, National Longitudinal Study of 1988.

Male students were more likely than females to increase their science proficiency level between 8th and 12th grades, 56 and 51 percent respectively. Higher proportions of Asian students than black, Hispanic, or American Indians increased in proficiency levels between 8th and 12th grades. White students were more likely than black and Hispanic students to increase. Students from higher SES backgrounds were generally more likely than students from lower SES backgrounds to increase in science proficiency over the high school years. Non-Catholic, private high school students were more likely than public to increase in level of proficiency and less likely to decrease.

Science Course-taking Patterns and Gains in Science Proficiency Level

Differences in the chances of increasing in science proficiency level may be related to differences in the number and types of science courses taken by students. Indeed, a cross-classification of science course taking by student characteristics reveals considerable variation (table 2).[25,26]

Groups of students who took many science courses or more advanced courses tended to be the same ones who in table 1 were more likely to show an increase in science proficiency level. White students were more likely than blacks to increase in proficiency level and 29 percent of whites took 8 or more semesters of science[27] compared to 18 percent of blacks. Students from high SES backgrounds were more likely to increase in science proficiency level and 42 percent took 8 or more semesters of science. Students from lower SES backgrounds were less likely (26 percent or less) to take 8 or more semesters of science. Males were more likely to increase than females and they were more likely to have taken physics, but did not differ in the number of courses taken.

These patterns suggest the possibility that course taking may account for at least some of the observable differences between groups in the likelihood of increasing in science proficiency level. One exception to this pattern involves the variable representing 1988 science proficiency level. In this case, students who had high science proficiency levels in 1988 took more courses and more rigorous ones but were less likely to advance. This exception to the general pattern illustrates the complexity of the relationship between changes in science proficiency on the one hand and course taking and initial science proficiency on the other hand. This relationship will be investigated in more detail in a multiple logistic regression analysis below.

Both the amount and nature of science course taking is related to likelihood of gains in science proficiency level. Of students who took 8 or more semesters of science during high school, 68 percent increased one or more levels in science proficiency (figure 3 and table A7).

In contrast, among students who took less than 4 semesters of science, 40 percent increased their level of proficiency. Except for the comparison between students who took 4–5.99 versus less than 4 semesters of science, as the number of semesters of science increased, the more likely students were to increase their proficiency.

Table 2.—Percent of 1988 8th-grade students who took various semesters of science and types of science courses in high school by selected school and student characteristics

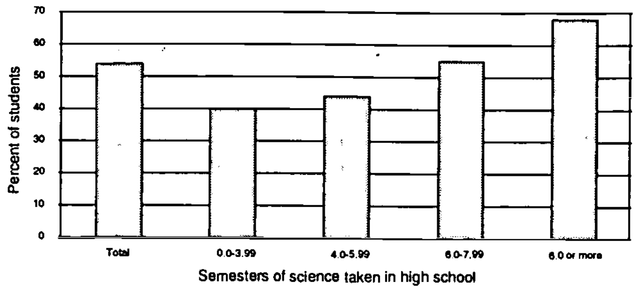
School and student characteristics	Number of semesters of science: 0.0-3.99	4.0-5.99	6.0-7.99	8.0 or more	Science courses taken: No chemistry-physics	Chemistry-no physics	Physics
Total	**6**	**33**	**34**	**27**	**38**	**34**	**28**
Gender							
Male	6	34	32	28	39	30	31
Female	6	33	36	26	37	39	24
Race-ethnicity							
Asian	3	32	29	36	26	33	42
Hispanic	8	46	29	17	52	31	18
Black	6	43	33	18	47	35	18
White	6	31	35	29	36	35	29
American Indian	6	49	31	14	60	19	21
SES quartile							
Low	11	48	29	12	63	26	11
Low-medium	7	41	32	20	48	32	20
Medium-high	5	33	36	26	36	37	27
High	3	19	36	42	17	39	44
Type of school							
Public	6	35	33	26	40	34	26
Catholic	1	25	39	34	17	37	47
Other private	4	20	43	33	16	37	47
Curriculum							
Academic	2	18	39	42	16	42	43
General	9	46	31	15	56	29	15
Vocational	13	57	26	5	73	21	6
Science courses							
No chemistry-physics	14	66	18	2	—	—	—
Chemistry-no physics	1	21	56	22	—	—	—
Physics	1	5	28	67	—	—	—
1988 proficiency level							
Below 1	11	46	31	11	60	29	11
Level 1	5	35	35	24	39	36	25
Level 2	2	21	34	42	20	36	44

— Not available.

SOURCE: U.S. Department of Education, National Center for Education Statistics, National Education Longitudinal Study of 1988.

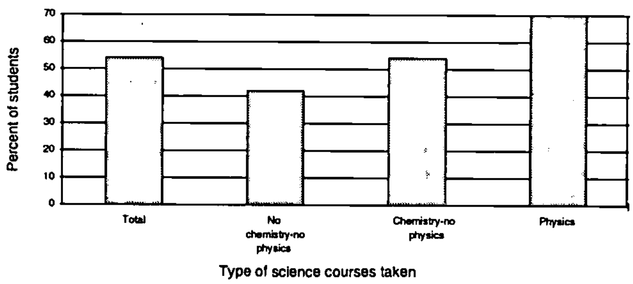
The type of science course taken by students was related to increases in science proficiency level. Students who took physics were significantly more likely to increase in science proficiency than both groups who took less rigorous courses. Those who took chemistry only were more likely to increase than those who took neither chemistry nor physics. Of students whose transcripts indicated that they took physics, 70 percent increased in science proficiency level (figure 4) compared to 54 percent of students who took chemistry but not physics and 42 percent of students who took neither physics or chemistry.

Figure 3.—Percent of 1988 8th-grade students who increased in science proficiency level between 1988 and 1992 by semesters of science taken in high school



SOURCE: U.S. Department of Education, National Center for Education Statistics, National Longitudinal Study of 1988.

Figure 4.—Percent of 1988 8th-grade students who increased in science proficiency level between 1988 and 1992 by type of science courses taken



SOURCE: U.S. Department of Education, National Center for Education Statistics, National Education Longitudinal Study of 1988.

Science Course Taking and Gains in Proficiency Level by 8th Grade Proficiency Level

We have just seen that students who take more science courses are more likely to increase their science proficiency level. We saw earlier that students with high levels of initial proficiency were less likely to increase their science proficiency than students with low initial levels of proficiency (figure 2), and that students with higher initial proficiency levels were more likely than students with low initial proficiency to take more science courses (table 2). In order to unravel how course taking is related to gains in proficiency, the next step in the analysis incorporates students' initial science proficiency level into the examination of the relation between increases in levels of science proficiency and taking science courses.

A strong, positive relationship existed between taking a high number of science courses during high school and increases in level of science proficiency regardless of science proficiency level in 1988 (table 3). Students who took eight or more semesters of science were more likely to increase their science proficiency level than students with the same initial proficiency level who took fewer semesters of science.

Table 3.—Percent of 1988 8th-grade students whose science proficiency increased by one or more levels between 1988 and 1992 by 8th-grade science proficiency level, semesters of science, curriculum, and science courses taken in high school

Course-taking and curriculum	Proficiency level in 1988: Below 1	Level 1	Level 2
Total	**63**	**55**	**46**
Semesters of science			
0.0–3.99	50	35	27
4.0–5.99	60	40	27
6.0–7.99	64	59	42
8.0 or more	85	75	59
Curriculum			
Academic	68	67	53
General	60	45	36
Vocational	63	39	16
Science courses			
No chemistry-physics	58	37	18
Chemistry-no physics	65	59	41
Physics	86	75	63

SOURCE: U.S. Department of Education, National Center for Educational Statistics, National Education Longitudinal Study of 1988.

For students who took less than eight semesters of science a positive relationship between number of semesters of science and increases in science proficiency level was less evident. Among students who scored below science proficiency level 1 in eighth grade, there were no significant differences in chances of increasing in science proficiency if they took anywhere from 0 to 7.99 semesters of science. However, students who were at level 1 in eighth grade and took 6–7.99 semesters of science were more likely to increase in science proficiency level than students at level 1 who took less science. Those who took 4–5.99 semesters were not more likely to increase than those who took 0–3.99 semesters. Among students who scored at level

2 in eighth grade, those who took 6–7.99 semesters of science were more likely to increase in science proficiency than students who took 4–5.99 semesters. These two groups of students were not more likely to increase than students who took 0–3.99 semesters of science.[28]

At every level of initial proficiency a strong, significant relationship was found between taking physics and whether students increased in science proficiency level. Students who took physics were more likely to increase than those who took chemistry but not physics or neither. In addition, students who started at levels 1 and 2 and took only chemistry were more likely to increase than students who did not take chemistry.

The type of high school curriculum reported by the student was also related to increases in their science proficiency level.[29] Students who started out at proficiency levels 1 and 2 in eighth grade and who identified themselves as being in an academic curriculum were more likely than those reporting they were in a general or vocational curriculum to increase their science proficiency level . For students who started below level 1, however, there was no significant relationship between self-reported curriculum and gains in science proficiency level.

Increases in Proficiency Level, Type and Number of Science Courses, and Demographic Factors: A Multiple Logistic Regression Approach

The number and type of science courses taken were found to be related to increases in science proficiency level. These two predicators of increases are related to each other and to other predictors of increases such as self-reported curriculum, socioeconomic status, gender, and race. The ability to sort out which of these predictors has an independent effect on increases while controlling for the effects of the others would prove valuable to our understanding of the complexity of factors related to increases in science proficiency. Logistic regression is an advanced, multivariate statistical technique which allows one to sort out such complexity. It is designed for estimating the relationship of a qualitative or quantitative explanatory variable to a dichotomous outcome variable (in this case, whether a student increased his or her level of science proficiency), taking into account the relationship of other explanatory variables to the outcome variables. A technical description of logistic regression can be found in the appendix.

Table 4 contains the results of three logistic regression models, one for students at each level of eighth-grade science proficiency.[30] The explanatory variables used in each model are listed on the left hand side of the table. For example, variables representing gender, race-ethnicity, SES, type of school, semesters of science, self-identified curriculum, and type of science courses taken are believed to be related to the chances of a student increasing in science proficiency level. Below each variable are its categories and the contrast group is in parentheses. The contrast group is the group that all other groups under a particular variable should be compared with (the comparison group, in other words). The coefficients for each category of every variable are in the center of the table. A positive coefficient indicates that the relationship is in a positive direction (or the group of interest has a greater chances than the contrast group of increasing) and vice versa. An asterisk represents a statistically significant relationship between being in a particular category and the likelihood of increasing in science proficiency level, compared to the contrast category in parentheses.

The level of rigor of science courses taken in high school was related to increases in science proficiency level (table 4). Across all three levels of eighth-grade science proficiency, students who did not take physics or chemistry were significantly less likely to increase in science proficiency level than students who took physics. Among students who started at levels one and two, those who took neither physics or chemistry were less likely to increase than those who took chemistry.

The type of curriculum that students reported being in was related to increases in science proficiency level for students who started at science proficiency levels one and two in eighth grade. Students who reported being in a general

Table 4.—Estimated logistic regression coefficients for the regression of increase in science proficiency level between 1988 and 1992 on student, school, and course-taking characteristics by science proficiency level in 8th grade

	Science proficiency level in 1988					
	Below 1		Level 1		Level 2	
Intercept	2.22	(0.37)	1.75	(0.15)	0.60	(0.15)
Gender (vs. female)						
Male	0.22	(0.17)	0.22 *	(0.09)	0.44 *	(0.11)
Race-ethnicity (vs. white)						
Asian	-0.13	(0.33)	-0.07	(0.23)	0.25	(0.21)
Hispanic	-0.20	(0.16)	-0.28	(0.18)	-0.16	(0.28)
Black	-0.71 *	(0.19)	-0.87 *	(0.17)	-0.82 *	(0.25)
American Indian	-0.30	(0.56)	-0.89 *	(0.43)	0.23	(1.07)
SES (vs. high)						
Low	-0.31	(0.31)	-0.83 *	(0.17)	-0.73 *	(0.20)
Low-medium	0.08	(0.31)	-0.77 *	(0.13)	-0.47 *	(0.18)
Medium-high	-0.15	(0.34)	-0.44 *	(0.13)	-0.22	(0.14)
Type of school (vs. public)						
Catholic	0.17	(0.37)	-0.40 *	(0.20)	-0.14	(0.21)
Other private	-0.02	(0.37)	0.01	(0.24)	0.54 *	(0.20)
Semesters of science (vs. 8.0 or more)						
0–3.99	-1.13 *	(0.34)	-0.71 *	(0.24)	0.34	(0.44)
4.0–5.99	-0.63 *	(0.29)	-0.59 *	(0.16)	-0.20	(0.25)
6.0–7.99	-0.63 *	(0.31)	-0.33 *	(0.13)	-0.21	(0.14)
Curriculum (vs. academic)						
General	-0.04	(0.21)	-0.48 *	(0.10)	-0.37 *	(0.14)
Vocational	0.23	(0.24)	-0.44 *	(0.18)	-0.83 *	(0.29)
Science courses (vs. physics)						
No chemistry-physics	-1.04 *	(0.27)	-0.77 *	(0.15)	-1.60 *	(0.24)
Chemistry-no physics	-0.82 *	(0.30)	-0.33 *	(0.12)	-0.67 *	(0.13)

* $p<0.05$ or $t>1.96$ for the test hypothesis of no difference in science proficiency growth between this group and the omitted group.

NOTE: Standard errors of the estimates are in parentheses.

SOURCE: U.S. Department of Education, National Center for Education Statistics, National Education Longitudinal Study of 1988.

or vocational curriculum were less likely to increase in proficiency than students who reported being in an academic curriculum.

For students in the upper part of the science proficiency distribution, the rigor of courses taken and curriculum appear more related to increases in science proficiency level than the quantity of courses taken. Among students at science proficiency level 2 in eighth grade, the number of semesters of science taken was not related to increases in science proficiency level, whereas both the type of science courses and self-reported curriculum were.

These results call into question the general emphasis on taking more courses for increasing achievement. For high achieving students, this emphasis seems especially inappropriate. The number of courses taken by students who start at the high end of the proficiency distribution is an imperfect indication of the type of courses taken or curriculum enrolled in. If researchers attempt to predict achievement gains with a variable measuring number of courses and do not account for type of courses taken and curriculum, they will probably obtain spurious relationships.

Among students who started at the lower or middle science proficiency levels there is evidence of a positive relationship between the number of science courses taken and chances of increasing in science proficiency level. Those who took less than eight semesters of science were less likely to increase in proficiency level than those who took eight or more semesters.[31]

Differences in the number and rigor of courses taken by students from various demographic backgrounds did not completely eliminate differences in their chances of increasing in science proficiency, especially at levels 1 and 2. When these factors were taken into consideration through multiple logistic regression, significant differences in chances of increasing in science proficiency level remained between males and females who started out at levels 1 and 2 in eighth grade: males were more likely to increase. Significant differences persisted between blacks and whites at all levels of initial proficiency with blacks less likely to increase.

Students from low and low-medium SES backgrounds who started at levels 1 and 2 in high school remained significantly less likely to increase their science proficiency level than students from high SES backgrounds. Students from medium-high SES backgrounds who started at level 1 were also less likely to increase than students from advantaged backgrounds. Students from other (i.e., non-Catholic) private schools who were at proficiency level 2 in eighth grade continued to be more likely to increase in proficiency level than public school students. Students from Catholic schools who started at level 1 were less likely than public school students to increase.[32]

Exploring How Gender, Race-ethnic, and Socioeconomic Differences in Chances of Increasing in Science Proficiency Level Are Influenced by Variation in Science Course Taking

The evidence that course taking is strongly associated with the likelihood of increasing in science proficiency level between 8th and 12th grades is compelling. Equally important is the evidence showing that the chances of increasing are lower for females than for males, for blacks than for whites, and for students from low than those from high SES backgrounds. The next natural question is to ask to what extent do differences in course-taking behavior between these groups account for differences in chances of increasing in science proficiency level. If a student characteristic that is negatively associated with chances of increasing is also negatively related to taking higher levels or numbers of science courses, then one would expect that characteristic to have a smaller negative relationship to chances of increasing once differences in course taking are taken into account.

Characteristics of black students tend to fit the criteria which would lead one to expect a reduction in the (negative) relationship between being black and chances of increasing in science proficiency level. The simple descriptive statistics in tables 1 and 2 indicate that black high school students were less likely than whites to take 8 or more science courses or to take physics (18 versus 29 percent). They were also less likely to increase in science proficiency level (39 versus 56 percent).

In a simple logistic regression model comparing black and white students' chances of increasing in science proficiency level, accounting for differences in science course taking significantly reduces the estimated coefficient representing blacks (table 5, from -.68 to -.56).[33] In other words, being a black student has less of a negative relationship to chances of increasing once adjustments are made for differences between blacks and whites in science course taking.

Males may outperform females on tests of science achievement in part because, as some researchers argue, males were more exposed to science. Above it is shown that males were more likely than females to increase in science proficiency level (table 1). But there is no evidence suggesting that they took a larger number of science courses (table 2). Males were more likely to have taken physics, however. Given these results and considering the logic outlined above, one would not expect course taking to explain a substantial part of the gender gap in chances of increasing.

Results from logistic regression analyses confirm this expectation. In a simple logistic regression model comparing male and female students' chances of increasing in science proficiency level, adding course-taking variables had little effect on the estimated coefficient for gender (table 5, from .21 to .20). The 5 percent decrease in magnitude is not a significant change. Adjusting for differences in course taking does not reduce the relationship of gender to chances of increasing in science proficiency level because the differences in science course taking between males and females were small.

Examining how course taking affects the relationship of gender and race-ethnicity to chances of increasing in science proficiency level would be as easy and straightforward as in the above analyses if course taking was the only explanation for increasing. But chances of increasing are also related to initial science proficiency level and to socioeconomic status (figure 2 and table 1). One can more thoroughly understand how course taking relates to gender and race-ethnicity differences in chances of increasing in science proficiency by also considering the role of such additional correlates.

Towards this end, a logistic regression model was estimated to predict chances of increasing for males and females while adjusting for differences in initial science proficiency level, socioeconomic status, race-ethnicity, and type of school (e.g., "full controls"). When course-taking variables were then added to this model, the relationship between gender and chances of increasing in science proficiency level changed in the direction opposite of what was expected—it increased (.23 versus .28). The coefficient representing the contrast between males and females became 22 percent larger, indicating that males were even *more likely* to increase than females when course taking was controlled.

Table 5.—Logistic regression coefficients for contrasts of interest in models predicting changes of increasing in science proficiency level with and without controls for course taking

Contrast of interest	Control variables: None	Course-taking only[1]	Other predictors only[2]	Course-taking plus other predictors	Percentage difference[3]: Column 1 versus 2	Column 3 versus 4
	1	2	3	4		
Black vs. white	-0.68 (0.12)	-0.56 (0.11)	-0.69 (0.12)	-0.77 (0.12)	18%	12%
Male vs. female	0.21 (0.06)	0.20 (0.07)	0.23 (0.07)	0.28 (0.08)	5%	22%
Low vs. high SES	-0.97 (0.10)	-0.56 (0.11)	-1.12 (0.13)	-0.67 (0.13)	42%	40%
Low-medium vs. high SES	-0.74 (0.10)	-0.45 (0.10)	-0.83 (0.11)	-0.5 (0.11)	39%	40%
Medium-high vs. high SES	-0.44 (0.09)	-0.27 (0.09)	-0.51 (0.10)	-0.32 (0.11)	39%	37%

[1] Course taking is represented by three variables: number of science course, type of science courses, and self-identified curriculum.
[2] The other predictor variables in the model are initial science proficiency level, type of school, and the remaining demographic variables (i.e., for Race-ethnicity, the latter would include Gender and SES).
[3] In log-odds coefficients. Specifically, the absolute value of the coefficient in the reduced model minus the coefficient in the fuller model divided by the coefficient in the reduced model.
NOTE: Coefficients represent the log-odds ratio. Exponentiating the coefficient produces the odds ratio. For example, exponentiating -.69 leads to .50 which implies that the odds of an increase in science proficiency level are one-half as great among blacks compared to whites. Standard errors are in parentheses.
SOURCE: U.S. Department of Education, National Center for Education Statistics, National Education Longitudinal Study of 1988.

There is an explanation behind this increase. In this sample, once adjustments were made for differences in initial proficiency, SES, and type of school, females were slightly more likely than males to take more science courses and to report that they were in an academic curriculum.[34] When this course-taking advantage is statistically removed through regression analysis, the end result is a larger difference between males and females in chances of increasing in science proficiency level.

In contrast to the simple bivariate model where adding course-taking variables *reduced* the negative relationship between black students versus white and chances of increasing in science proficiency level, adding course-taking variables to the model containing additional correlates did not change the black versus white comparison (-.69 versus -.77). Specifically, the logistic coefficient representing chances of increasing for blacks compared to whites appears to be *larger* once course-taking differences are controlled. However, this change is not large enough to be considered substantively important (12 percent is less than the 15 percent criteria described in footnote 33).

Further analyses of the data on black and white course-taking patterns helped to explain why this outcome occurred.[35] There is no abundant evidence that blacks who were at the same SES and proficiency level as whites were more likely than whites in this sample to have taken more of the courses related to increasing in science proficiency level (although the coefficients tended to be in the positive direction, they were either smaller or only slightly larger than their standard errors). Thus, when course-taking variables were added to the model predicting chances of increasing in science proficiency level, the coefficient representing the contrast between blacks versus whites did not become significantly larger.

A large body of literature describes how students from low socioeconomic backgrounds are placed into less demanding groups, courses, and curriculums, a practice which tends to exacerbate differences in achievement among students.[36] One would expect, therefore, that after adjusting for course-taking differences, the fact that students were from low socioeconomic backgrounds would have less of an impact on their chances of increasing in science proficiency level.

Students from low SES backgrounds in NELS:88 were clearly less likely than those from high SES backgrounds to take 8 or more semesters of science or to take physics—even among students who started at the same science proficiency level in eighth grade. This consistent negative correlation is important according to the logic outlined above for it implies that SES will be less related to chances of increasing in science proficiency once course-taking differences are controlled. In fact when course-taking variables were added to the bivariate and full models predicting chances of increasing, large reductions occurred in the coefficients representing students from the lower versus highest socioeconomic backgrounds (table 5, from -.97 to -.56 and -1.12 to -.67 respectively).[37]

In summary, no overwhelmingly strong nor consistent evidence was found to support the hypothesis that differences between males and females or whites and blacks in chances of increasing in science proficiency level are accounted for by differences in the number or level of science course taking. This interpretation is tentative, and additional analysis and data are required to further clarify the evidence. In contrast, a substantial part of the positive relationship between a student's SES background and chances of increasing appears to be due to differences in course taking.

Summary

Previous cross-sectional studies have shown course taking to be related to achievement, with higher performing students tending to take a higher number of and more difficult courses. This relationship, however, may be interpreted in at least two ways. More course taking may lead to higher achievement or students who take more courses may have been higher achievers to begin with.[38] Longitudinal data allows for investigating changes in proficiency while taking initial performance levels into account. This analysis examined the relationship between gains in science proficiency level and science course taking for a group of 8th-graders in 1988 over a 4-year period, taking into account a variety of characteristics of students, including initial science proficiency level.

The major finding from this analysis is that students who take higher level science courses are more likely to gain in science proficiency level than those who do not. This relationship was especially evident for students who started at the top level of proficiency in the eighth grade. Among students who started at the lowest level of proficiency in the eighth grade, this relationship was relatively weaker. However, their chances of gaining in proficiency were also related to the number of science courses that they had taken. Science course taking, therefore, is important for students at all levels of initial science proficiency.

The rigor of course taking was highly related to the likelihood of increasing in science proficiency level over a 4-year period for 1988 eighth-graders, even after taking into account a number of other factors, including number of science courses taken. Among students at similar levels of science proficiency in 1988, those who took physics in high school were more likely to demonstrate a gain in science proficiency level than those who did not. Except for students with low levels of eighth-grade science proficiency, those who took chemistry were more likely to increase than those who took neither chemistry nor physics. Similarly, except for students who started at the lowest level, those who said that they were in an academic curriculum were more likely to increase than those who said they were in another type of curriculum.

The number of science courses taken in high school was also related to gains in science proficiency level, but not consistently across all groups of students. When the rigor of courses and other factors were taken into account, the number of courses taken was not related to gains in proficiency level for those students who had demonstrated relatively high levels of proficiency as eighth-graders. Among students who had low to moderate levels of proficiency in eighth grade, however, those who took many semesters of science (eight or more) were more likely to gain in proficiency level than those who took less than eight. The most consistent pattern seems to be that what science courses students take in high school is more related to increases in science proficiency level than the number of science courses.

Turning to the relationship between demographic characteristics of students and chances of increasing in science proficiency level, some findings seem noteworthy. While some analysts have argued that differences in course-taking patterns are the reasons for differential achievement among students from various demographic backgrounds, the evidence presented here casts some doubt on this argument. Even after taking differences in course taking and self-identified curriculum into account, students from high SES backgrounds who started high school at middle or high levels of science proficiency were more likely to increase in level than students from low SES backgrounds. In addition, males who started at middle or high levels of proficiency were more likely than females to increase, and white students were more likely to increase than black students. These findings from demographic comparisons point to the need for more comprehensive research on gender, race, and SES differences in science achievement growth.

Although transcripts from NELS do not reveal what was taught in specific courses, they do indicate the course level, e.g., whether it was remedial, general, honors, or advanced placement. In future analysis of factors related to proficiency growth, researchers might want to pursue such descriptive details about the courses taken by students. They might also explore whether the motivations that students have toward pursuing a career in science affects their gains in science proficiency. Do motivations explain part or all of the gender, race-ethnic, and SES differences in chances of gaining in science proficiency? Or are characteristics of science teachers such as credentials, experience, or attitudes toward equitably teaching all students responsible for the differences? What role do parents play in the learning of science during high school? Many interesting questions await to be answered. This analysis only has tapped into a tiny part of the enormous information in NELS:88 about student achievement over time.

Notes

1. *International Mathematics and Science Assessments*, U.S. Department of Education, National Center for Education Statistics (NCES) 1992.

2. National Commission on Excellence in Education, *A Nation at Risk*, 1983; see also Walberg 1984.

3. Aldridge 1992; National Science Teachers Association (NSTA) 1990.

4. See Welch, Anderson, and Harris 1982; Rock, Owings, and Lee, U.S. Department of Education 1994; relating to the ACT see Garibaldi 1992.

5. 1992 in *The 1990 Science Report Card*; see also table 2 below.

6. 1988, p.90 in *The Science Report Card* by Mullis and Jenkins.

7. See note 4 above. Also see Hoffer et. al, U.S. Department of Education 1995.

8. See *The 1990 Science Report Card* for evidence of the gap and some evidence of differential course taking; see also Levin, Sabar and Libman 1991.

9. Hill, Pettus and Hedin 1990.

10. Crawley and Coe 1990.

11. Mackenzie 1983; Purkey and Smith 1983; Walberg and Shanahan 1983; Coleman and Hoffer 1987; Lee and Bryk 1989, Chubb and Moe 1990; Mullis et. al. 1994.

12. In fact, results from preliminary analyses of NELS:88 achievement data suggest that less growth in achievement occurred over the last two years of high school than the first two (Ralph et. al 1996; see also Alexander, Entwisle and Dauber 1994 for evidence of decreasing gains in achievement as students proceed through school). The High School and Beyond longitudinal survey of 1980, which produced data that is used widely by education researchers, covered only the last two years of high school—the least productive in terms of overall gains in achievement across students. It was, however, an improvement over the National Educational Longitudinal Survey of 1972, which covered only the final year of high school.

Some 24,599 eighth-grade students from across the nation were interviewed in the base year (1988). Followup studies attempted to re-interview these same students 2 and 4 years later when most, but not all, were in 10th and 12th grades, respectively. Descriptions of the sampling design, item nonresponse, and the variables included in the report are reported in Appendix B.

13. Both base year and second followup science proficiency scores were available for 9,832 of the 24,599 base year students. Of these students, 9,322 did not drop out of high school permanently between the surveys (i.e., they could be dropouts who returned to school or alternative completers). Of these students, 7,584 had complete transcript information available. Thus, the scope of the report is limited to a longitudinal sample of 1988 eighth-graders who had science test scores available at two points in time, had complete transcript records, and were enrolled in school during the spring of 1992. (Students who did not reach 12th grade by 1992 were excluded from this analysis because they had incomplete transcript data.) The data were weighted by a relative weight which was created by dividing the expansion panel weight (F2PNLWT) by the average expansion panel weight. The weighing scheme did not compensate for test or transcript non-response. Additional information about the sample is presented in Appendixes A and B.

14. For details see the *Psychometric Report* by Rock et. al., U.S. Department of Education 1991 and the *Second Followup: Student Component Data File User's Manual*, U.S. Department of Education 1992.

15. Levels have the same interpretation in both years. Note, however, that level 3 was not part of the base-year test. The skills or abilities needed to correctly answer questions that were used as indicators for each level do not depend on participation in a particular course. Instead, they transcend such knowledge by tapping into broader conceptual understandings of science and related problem-solving skills.

16. By forcing all students into a few groups, students with differing degrees of understanding of science are combined into a single level. The aim was to create measures of science proficiency with more practical utility than alternative continuous measurements such as ones created using Item Response Theory (IRT). Some students may increase (or decrease) in science proficiency during high school and yet not change their level of science proficiency. See the appendix for a discussion of the reliability of the proficiency levels.

17. U.S. Department of Education, Office of Research 1992.

18. Cusik 1973.

19. U.S. Department of Education, Office of Research 1994; Goldman 1985.

20. *The National Education Goals Report 1993*; Feldman and Atkin 1993.

21. The relatively lower chances of gaining for those at the top level of proficiency in eighth grade was not due to a ceiling effect. The 1992 science test included questions that covered proficiency one level higher than the highest one covered by questions on the 1988 eighth grade test.

22. Regression to the mean has a special statistical interpretation. The lack of perfect reliability in measuring ability means that in the absence of any changes in underlying true ability, persons who scored far from their true score are likely to score closer to the true score when re-tested, so that high scores will tend to go down and low scores will tend to go up.

23. See for instance Epstein 1991 or Lee et. al. 1995. Note that this is not the case with Rock, Owings and Lee's (1994) findings, perhaps because in their analysis students in the lowest two categories of eighth-grade proficiency were combined and students were only tracked until 10th grade. In the future, researchers might want to explore this issue in more detail.

24. A breakdown of the science proficiency level of students in 1992, when they are about to leave high school, by course taking and demographic characteristics is reported in appendix table A6.

25. Course taking in science is limited to a few broad areas. Descriptive frequencies indicate that relatively few students take physics (roughly one-fourth), nearly half take chemistry, and over 80 percent take biology. Earth science is taken by a little more than one-fifth of students. Approximately 60 percent of students take courses outside these areas of science with only 8 percent of such students taking more than 2 courses. See the second followup transcript component data file user's manual for exact figures (U.S. Department of Education 1994).

The breakdown used here of the types of science courses taken by students probably reflects the most common sequence of courses taken in science. It is a parsimonious breakdown which facilitates exploring how course taking is related to gains in achievement. More detailed breakdowns are possible, such as one which encompasses AP biology or zoology course taking. However, students who take physics are probably the ones taking such courses and would be picked up in this analysis. At any rate, pursuing detailed breakdowns in future research might further enrich our understanding of how course taking is related to gains in achievement.

Based primarily on the fact that they are offered later in the high school curriculum and fewer students take them, physics and chemistry are assumed to be more rigorous than other types of science courses.

26. The percentage of high school seniors who have taken physics has increased by 11 percentage points from the beginning of the 1980s (U.S. Department of Education, NCES, 1995). One might attribute part of this increase to the fact that states have been increasing their science requirements (Suter 1993).

27. Two semesters of science equal one Carnegie unit of science. A Carnegie unit represents one credit for the completion of a 1-hour per day/5 days per week, 1-year course. Twenty-seven percent of NELS:88 students took 8 or more semesters of science.

28. The reader is cautioned about interpreting the comparison between students at level 2 in eighth grade who took 6–7.99 semesters of science versus those who took 0–3.99 semesters and increases in science proficiency level. The cell representing students at level 2 in eighth grade who took 0–3.99 semesters of science contains a small number of cases. This leads to a large standard error for the estimated percent of these students who increased in science proficiency level. Consequently, finding a significant difference when making comparisons involving this group is difficult. This caution applies also to other parts of this analysis where relatively large standard errors were generated.

29. Note that in table 3 curriculum also is related to both number and type of science courses taken.

30. Results from an overall regression (all students combined) which includes 1988 proficiency level as a predictor can be found in the appendix (table A10). Except for a small loss of detail, the results generally reflect the relationships described in table 4. In addition, they also indicate that, with all other variables controlled, students who started at lower initial proficiency levels were more likely to increase than those who started at higher levels.

31. When a set of inferences come from the same set of sample data they are not independent. Thus, determining the probability of the set of estimates being correct is more difficult than in the case when there is only one inference. The Bonferoni procedure, a general procedure for making inferences in this situation, involves adjusting the statement confidence coefficients for each inference to reflect the probability that after repeated sampling the entire set of coefficients would be correct (Neter, Wasserman, and Kutner 1990). Applying this logic to all possible inferences that could be made about the relationship between the four categories of number of science courses taken and chances of increasing in science proficiency level (from results of the multiple logistic regression analysis), the necessary critical t-value for testing inferences would be 2.64. Using this value would lead one to conclude that only one in the set of six inferences for students who started below level 1 and only two for those who started at level 1 indicate a significant relationship between number of courses and increasing. This would lead to a slightly different interpretation of the relationship, mainly that evidence of a positive relationship is not so strong. In practice, however, few researchers make any type of adjustment (Johnson and Wichern 1988).

32. Some caution should be exercised in interpreting this coefficient. For example, adjusting the significance level to account for multiple comparisons, as described in footnote 31, would lead one to accept the null hypothesis of no relationship.

33. To determine whether changes in the coefficients in table 5 were statistically significant would require applying sophisticated statistical tests (see Clogg et al 1995; Clogg and Petkova 1995; Allison 1995) that are beyond the scope of this report. Instead, a simple rule of thumb is used to determine if the change is important: if the coefficient changed by at least 15 percent, the change is deemed to be of substantive interest.

34. Based on regressions not reported here but available upon request from the author.

35. Based on regressions not reported here but available upon request from the author.

36. See, for example, Gamoran et. al. 1995, Oakes 1985 and Rist 1970.

37. Gamoran and Mare 1989 found somewhat similar results in their analysis of the effects of tracking on math achievement in the High School and Beyond survey data. Blacks and females were more likely than non-Blacks and males respectively to be found in the academic track when initial achievement, SES, and other variables were controlled. This tended to compensate for the disadvantage associated with the gross (i.e., without adjustments for initial achievement, SES, etc.) higher probability of blacks and females not to be in the academic track. Compensation of this type was not found for students from low SES backgrounds, however. Tracking reinforced initial differences in achievement among students from various SES backgrounds.

38. In real life this relationship could go in both directions. Although I have not tested whether gains cause course taking, I have shown that course taking is related to gains, controlling for initial achievement. This is an important finding to note, especially if one is inclined to believe that the only explanation for the relationship between achievement and course taking is that smarter students take more courses.

Appendix A

Table A1.—Standard errors for table 1

School and student characteristics	Change in science proficiency level		
	Decrease	Same	Increase
Total	**0.6**	**0.8**	**0.9**
Gender			
Male	0.9	1.2	1.3
Female	0.6	1.0	1.0
Race-ethnicity			
Asian	1.8	2.7	2.9
Hispanic	1.4	2.6	2.4
Black	3.6	2.8	2.7
White	0.5	0.9	1.0
American Indian	6.3	6.7	6.2
SES quartile			
Low	1.3	1.8	1.7
Low-medium	1.6	1.6	1.6
Medium-high	0.8	1.3	1.3
High	0.5	1.7	1.7
Type of school			
Public	0.6	0.9	0.9
Catholic	1.5	3.4	3.2
Other private	1.2	4.5	4.7

SOURCE: U.S. Department of Education, National Center for Education Statistics, National Education Longitudinal Study of 1988.

Table A2.—Standard errors for table 2

School and student characteristics	Number of semesters of science: 0.0–3.99	4.0–5.99	6.0–7.99	8.0 or more	Science courses taken: No chemistry-physics	Chemistry-no physics	Physics
Total	**0.4**	**1.0**	**0.8**	**1.0**	**1.0**	**0.9**	**1.0**
Gender							
Male	0.5	1.4	1.2	1.2	1.4	1.3	1.3
Female	0.5	1.1	1.0	1.1	1.1	1.2	1.1
Race-ethnicity							
Asian	1.3	4.0	2.7	3.8	3.5	3.6	4.0
Hispanic	1.8	2.6	2.2	2.1	3.0	2.9	2.0
Black	1.3	3.5	2.5	2.6	3.4	2.8	2.5
White	0.5	1.1	1.0	1.1	1.0	1.0	1.1
American Indian	3.9	6.4	7.1	4.1	7.9	5.9	6.6
SES quartile							
Low	1.3	1.9	2.0	1.1	1.8	1.7	1.0
Low-medium	0.8	1.8	1.3	1.2	1.7	1.6	1.2
Medium-high	0.6	1.4	1.4	1.6	1.4	1.5	1.3
High	0.4	1.3	1.7	1.8	1.2	1.9	2.0
Type of school							
Public	0.5	1.0	0.8	0.9	1.0	0.9	0.9
Catholic	0.8	3.6	3.7	4.4	2.9	3.8	4.4
Other private	1.9	4.7	6.0	7.6	4.7	6.0	7.9
Curriculum							
Academic	0.3	1.1	1.3	1.5	0.8	1.4	1.5
General	0.8	1.5	1.2	1.0	1.5	1.2	1.0
Vocational	1.6	2.5	2.2	1.4	2.3	2.1	1.4
Science courses							
No chemistry-or physics	1.0	1.5	1.1	0.4	—	—	—
Chemistry-no physics	0.2	1.4	1.6	1.4	—	—	—
Physics	0.3	0.7	1.6	1.8	—	—	—
1988 proficiency level							
Below 1	1.1	1.8	1.9	1.1	1.9	1.9	1.1
Level 1	0.5	1.3	1.2	1.1	1.3	1.2	1.2
Level 2	0.4	1.3	1.3	1.6	1.1	1.5	1.6

— Not applicable.
SOURCE: U.S. Department of Education, National Center for Education Statistics, National Education Longitudinal Study of 1988.

Table A3.—Standard errors for table 3

Course taking and curriculum	Proficiency level in 1988		
	Below 1	Level 1	Level 2
Total	**1.9**	**1.2**	**1.6**
Semesters of science			
0.0–3.99	5.0	3.7	7.0
4.0–5.99	2.1	2.0	2.9
6.0–7.99	4.5	1.8	2.4
8.0 or more	2.8	2.0	2.5
Curriculum			
Academic	4.4	1.4	2.0
Vocational	3.6	3.3	3.6
General	2.0	2.0	2.6
Science courses			
No chemistry-or physics	1.9	1.8	2.2
Chemistry-no physics	4.9	1.7	2.5
Physics	2.7	1.8	2.0

SOURCE: U.S. Department of Education, National Center for Education Statistics, National Education Longitudinal Study of 1988.

Table A4.—Data for Figure 1: Percent of NELS students at different levels of science proficiency: 1988 and 1992

Year	Proficiency level: Below 1	Level 1	Level 2	Level 3
1988 8th-grade	22	47	31	—
1992	15	29	32	24

— Not applicable.
SOURCE: U.S. Department of Education, National Center for Education Statistics, National Education Longitudinal Study of 1988.

Table A5.—Standard errors for table A4

Year	Proficiency level: Below 1	Level 1	Level 2	Level 3
1988 8th-grade	0.8	0.8	0.8	—
1992	0.7	0.7	0.8	0.7

— Not applicable.
SOURCE: U.S. Department of Education, National Center for Education Statistics, National Education Longitudinal Study of 1988.

Table A6.—Percent of NELS students at various levels of science proficiency in 1992

School and student characteristics	Below level 1	At or above: Level 1	Level 2	Level 3
Total	**15 (0.7)**	**85 (0.7)**	**56 (0.9)**	**24 (0.7)**
Gender				
Male	13 (1.1)	87 (1.1)	59 (1.3)	28 (1.0)
Female	17 (0.8)	83 (0.8)	53 (1.1)	19 (0.8)
Race-ethnicity				
Asian	12 (1.7)	88 (1.7)	61 (3.5)	32 (3.1)
Hispanic	22 (1.8)	78 (1.8)	43 (2.4)	13 (1.7)
Black	35 (3.5)	65 (3.5)	29 (2.8)	6 (0.9)
White	11 (0.7)	89 (0.7)	61 (0.9)	27 (0.8)
American Indian	31 (7.1)	69 (7.1)	27 (6.1)	12 (3.9)
SES quartile				
Low	27 (1.6)	73 (1.6)	33 (1.7)	9 (1.0)
Low-medium	18 (1.6)	82 (1.6)	47 (1.6)	17 (1.1)
Medium-high	13 (0.9)	87 (0.9)	58 (1.4)	23 (1.2)
High	7 (1.4)	93 (1.4)	74 (1.5)	38 (1.5)
Type of school				
Public	15 (0.8)	85 (0.8)	55 (1.0)	23 (0.7)
Catholic	10 (1.9)	90 (1.9)	64 (3.4)	30 (3.1)
Other private	9 (3.7)	91 (3.7)	71 (5.3)	35 (5.0)
Semesters of science				
0.0–3.99	31 (0.4)	69 (0.4)	26 (2.3)	7 (1.4)
4.0–5.99	22 (1.3)	78 (1.3)	39 (1.4)	11 (0.8)
6.0–7.99	13 (1.3)	87 (1.3)	59 (1.5)	23 (1.2)
8.0 or more	5 (0.6)	95 (0.6)	80 (1.1)	44 (1.7)
Curriculum				
Academic	8 (0.9)	92 (0.9)	70 (1.1)	34 (1.1)
Vocational	23 (1.8)	77 (1.8)	36 (2.1)	7 (1.1)
General	21 (1.2)	79 (1.2)	44 (1.3)	15 (1.0)
Science courses				
No chemistry-no physics	26 (1.2)	74 (1.2)	34 (1.2)	7 (0.6)
Chemistry-no physics	12 (1.3)	88 (1.3)	61 (1.5)	23 (1.1)
Physics	4 (0.5)	96 (0.5)	81 (1.1)	46 (1.6)
1988 proficiency level				
Below 1	37 (1.9)	63 (1.9)	23 (1.2)	4 (0.5)
Level 1	12 (0.9)	88 (0.9)	55 (1.2)	18 (0.8)
Level 2	3 (0.5)	97 (0.5)	83 (1.1)	46 (1.6)

NOTE: Standard errors are in parentheses.

SOURCE: U.S. Department of Education, National Center for Education Statistics, National Education Longitudinal Study of 1988.

Table A7.—Percent of 1988 8th-grade students whose science proficiency level decreased, remained the same or increased between 1988 and 1992

Course-taking, curriculum, and 1988 science proficiency level	Change in science proficiency level		
	Decreased	Same	Increased
Total	**11 (0.6)**	**35 (0.8)**	**54 (0.9)**
Semesters of science			
0.0–3.99	14 (1.9)	46 (3.1)	40 (3.1)
4.0–5.99	15 (1.2)	42 (1.4)	44 (1.3)
6.0–7.99	11 (0.8)	35 (1.4)	55 (1.4)
8.0 or more	7 (0.7)	26 (1.5)	68 (1.6)
Science courses			
No chemistry-no physics	16 (1.1)	42 (1.2)	42 (1.2)
Chemistry-no physics	9 (0.8)	36 (1.5)	54 (1.5)
Physics	6 (0.6)	24 (1.2)	70 (1.3)
Curriculum			
Academic	8 (0.5)	31 (1.2)	62 (1.2)
Vocational	16 (1.9)	40 (2.2)	43 (2.2)
General	14 (1.1)	39 (1.2)	47 (1.3)
1988 proficiency level			
Below 1	—	37 (1.9)	63 (1.9)
Level 1	12 (0.9)	33 (1.0)	55 (1.2)
Level 2	17 (1.1)	37 (1.5)	46 (1.6)

— Not applicable.

NOTE: Standard errors are in parentheses.

SOURCE: U.S. Department of Education, National Center for Education Statistics, National Education Longitudinal Study of 1988.

Table A8.—Estimated logistic regression coefficients for the regression of increase in science proficiency level between 1988 and 1992 on student, school, and course-taking characteristics

Intercept	0.71 *	(0.10)
Gender (vs. female)		
Male	0.28 *	(0.08)
Race-ethnicty (vs. white)		
Asian	-0.02	-0.14
Hispanic	-0.20	-0.12
Black	-0.78 *	(0.12)
American Indian	-0.57	-0.32
SES (vs. high)		
Low	-0.67 *	(0.13)
Low-medium	-0.50 *	(0.11)
Medium-high	-0.31 *	(0.11)
Type of school (vs. public)		
Other private	0.22	-0.17
Catholic	-0.20	-0.15
Semesters of science (vs. 8 or more)		
0.0–3.99	-0.63 *	(0.17)
4.0–5.99	-0.45 *	(0.11)
6.0–7.99	-0.32 *	(0.10)
Curriculum (vs. academic)		
General	-0.36 *	(0.09)
Vocational	-0.28 *	(0.12)
Science courses (vs. physics)		
No chemistry-or physics	-1.05 *	(0.10)
Chemistry-no physics	-0.58 *	(0.09)
1988 proficiency level (vs. 2)		
Below 1	1.79 *	(0.17)
Level 1	0.91 *	(0.09)

* p<.05
NOTE: Standard errors are in parentheses.
SOURCE: U.S. Department of Education, National Center for Education Statistics, National Education Longitudinal Study of 1988.

Table A9.—Estimated odds ratios for the logistic regression coefficients in table 4

Selected characteristics	Science proficiency level in 1988		
	Below 1	Level 1	Level 2
Gener (vs. female)			
Male	1.25	1.25	1.55
Race-ethnicity (vs. white)			
Asian	0.88	0.93	1.28
Hispanic	0.82	0.76	0.85
Black	0.49	0.42	0.44
American Indian	0.74	0.41	1.26
SES (vs. high)			
Low	0.73	0.44	0.48
Low-medium	1.08	0.46	0.63
Medium-high	0.86	0.64	0.80
Type of school (vs. public)			
Catholic	1.19	0.67	0.87
Other private	0.98	1.01	1.72
Semesters of science (vs. 8.0 or more)			
0.0–3.99	0.32	0.49	1.40
4.0–5.99	0.53	0.55	0.82
6.0–7.99	0.53	0.72	0.81
Curriculum (vs. academic)			
General	0.96	0.62	0.69
Vocational	1.26	0.64	0.44
Science courses (vs. physics)			
No chemistry-or physics	0.35	0.46	0.20
Chemistry-no physics	0.44	0.72	0.51

SOURCE: U.S. Department of Education, National Center for Education Statistics, National Education Longitudinal Study of 1988.

Logistic Regression

The logistic regression model is of the following form:

$\log[p/(1-p)]=B_0 + B_1x_1 + ... + B_ix_i$

An odds ratio is computed by dividing the probability that an event occurred by the probability that it did not (p/1-p). In this analysis the event of interest is whether a student's science proficiency level increased. The log of the odds ratio is then taken and used as the outcome variable in logistic regression. In the above model, B_0 represents the intercept which can be interpreted as the log-odds of the outcome variable when all the explanatory variables are zero, B_1x_1 represents the increase in the log-odds of the outcome variable accounted for by an increment in the explanatory variable x_1, and B_ix_i represents the increase in the log-odds of the outcome variable accounted for by an increment in the explanatory variable x_i. If more than one explanatory variable is included in the logistic regression model (as in this analysis), then B_ix_i represents the effect of x_i on the outcome after adjusting for the effects of the other explanatory variable(s).

One can determine the change in the odds of increasing in science proficiency by going from one category of an independent variable to another, a statistic easier to interpret than the log-odds, by exponentiating the appropriate coefficient of interest. For example, at initial proficiency level 1, in terms of odds ratios, males were 1.25 times more likely than females to increase in proficiency, controlling for demographic and course-taking factors. Likewise, in terms of odds ratios, students from high SES backgrounds were over two times as likely to increase in proficiency compared to their low SES background peers. Among students who were at level 2 in eighth grade, in terms of odds ratios, those who took physics were five times as likely to increase in proficiency level than those who took neither chemistry nor physics. See table A9 for the odds ratios of other variables in table 4.

Appendix B: Technical Notes for NELS:88*

The NELS:88 base year survey comprised a national probability sample of all regular public and private 8th-grade schools in the 50 states and the District of Columbia in the 1987–88 school year. During the base year data collection, students, parents, teachers, and school administrators were selected to participate in the survey. The total 8th grade enrollment from 1,052 NELS:88 sample schools was 202,996. During the listing procedures (before 24–26 students were selected per school), 5.35 percent of students were excluded because they were identified by school staff as being incapable of completing the NELS:88 instruments because of limitations in their language proficiency or because of mental or physical disabilities. Ultimately, 93 percent, or 24,599, of the sample students participated in the base year survey in the spring of 1988.

The NELS:88 second followup survey was conducted during the spring of 1992. Students, dropouts, parents, teachers, and school administrators participated in the followup, which set a target subsample of 21,188 students. Some 97 percent of these students were successfully located. For the current report, data from base year ineligibles (BYI), students deemed not capable of answering the questionnaire due to language or mental difficulties, were not used because measures that reflect science proficiency for two points in time (base year and second followup), a necessary requirement for determining the progression of science skills of students, are not available for these students.

The scope of the cohort data presented in this report is limited to students who were sampled and attending schools both during the base year and second followup surveys. Excluded from this study are sampled eighth graders who dropped out of school. Also excluded from this analysis are BYI students and freshened students (ones in followup surveys who did not have the opportunity to participate in 1988 for various reasons including not being in country) who were not selected in the base year sample. Altogether, the in-scope sample consists of 14,814 cases. Among them, 7,230 either did not have complete transcript information (which was obtained from a special transcript component of the second followup survey) or did not complete sufficient numbers of test items so that their science proficiency could be determined in the base year and/or the second followup. Due to the absence of these key pieces of data, they were treated as missing. Thus, 7,584 cases were used for this analysis. (Due to decisions that were made in conducting various parts of the NELS:88 survey, these numbers should not be used to construct a survey "response rate.")

A brief sketch of the number of students involved in NELS:88 and the final number used in this analysis is as follows:

1) Target base year sample size 26,432
   Realized sample size 24,599
2) Target second followup (F2)
   sample size 21,188
   Realized sample size 20,623
3) Number of realized F2 students
   representing the 8th-grade panel.... 16,489
4) Number of above (3) students who
   did not drop out.................................. 14,814
5) Number of above (4) students with
   base year cognitive tests, second
   followup cognitive tests, and
   complete transcripts (number used
   in analyses) 7,584

The results of these analyses apply to the population of children who were in 8th grade in 1988 and in 12th grade four years later.

*Parts of these notes can be found in Rock, Owings, and Lee (1994). In addition, Judy Pollack from Educational Testing Services in Princeton, N.J. provided technical information on the psychometric properties of the NELS:88 science proficiency levels.

Respondents Who Were Missing Key Information

Certain patterns were noted in the types of students who were missing information. Females were less likely than males; Hispanics, blacks, and American Indians were less likely than whites; and low SES students were less likely than high SES students to have complete key information (Appendix Table B1). These groups of students, therefore, were more likely to be excluded from the analyses. Aggregate results may tend to over-represent patterns for whites, males and students from high SES family backgrounds.

Additional comparisons reveal that the group without key information was slightly less likely than the group with such information to: (1) be classified at a higher proficiency level in the 8th grade; (2) be classified at a higher proficiency level in 12th grade; (3) take more science courses; (4) report being enrolled in an academic curriculum; and (5) take physics or chemistry as opposed to neither of these courses.

Because students without key information were less likely to be proficient at higher levels in eighth grade, the distribution of the eighth-grade science proficiency levels reported in this analysis may be biased upward. Similarly, the distribution of 12th-grade science proficiency reported here may also be biased upward.

The estimated effects of these variables in the analysis sample may or may not differ from their effect in the full population. If the average increase in science proficiency level for students with incomplete data was similar to that of their counterparts with complete data, the analysis reported here is not affected by excluding these students. However, if among students with the same characteristics, i.e., eigth-grade science proficiency, sciences courses taken, etc., those with incomplete data had a substantially different average increase in science proficiency from those with complete data, the analysis may under or overestimate the effects of these variables depending on the direction of the difference. For example, if among excluded students with few science courses taken the average increase in science proficiency was less than among included students with few science courses taken, the effect of courses taken would have been underestimated.

Table B1.—Percentage of respondents[1] who were missing key information, by demographic and schooling characteristics

Student and school characteristics	Did not have key information: Unweighted number	Weighted number	Percent[2]	Standard error
Total	**6,786**	**7,230**	**49**	**(0.8)**
Gender				
Male	3,286	3,563	47	(1.1)
Female	3,500	3,667	50	(1.1)
Race-ethnicity				
Asian	407	227	42	(2.9)
Hispanic	890	782	56	(1.9)
Black	771	1,137	60	(2.7)
White	4,621	4,955	46	(1.0)
American Indian	75	98	62	(4.7)
Missing[3]	32	47	—	—
SES quartile				
Low	1,571	1,699	57	(1.5)
Low-medium	1,631	1,808	49	(1.4)
Medium-high	1,664	1,877	48	(1.4)
High	1,920	1,846	44	(1.5)
Type of school				
Public	5,650	6,112	47	(1.0)
Catholic	330	385	46	(3.7)
Other private	506	291	50	(4.9)
Missing[3]	461	450	—	—
Curriculum				
General	2,714	3,249	52	(1.2)
Academic	2,935	2,602	41	(1.2)
Other	717	797	49	(2.1)
Missing[3]	307	628	—	—
Semesters of science				
0–3.99	789	937	71	(2.1)
4.0–5.99	1,634	1,592	39	(1.2)
6.0–7.99	1,474	1,289	33	(1.2)
8.0 or more	1,003	766	26	(1.1)
Missing[3]	1,886	2,646	—	—
Science courses				
No chemistry-no physics	2,415	2,585	47	(1.2)
Chemistry-no physics	1,347	1,170	31	(1.2)
Physics	1,138	830	28	(1.2)
Missing[3]	1,886	2,646	—	—
1988 proficiency level				
Below 1	1,505	1,719	50	(1.4)
Level 1	2,427	2,708	43	(1.2)
Level 2	1,278	1,267	35	(1.4)
Missing[3]	1,576	1,535	—	—
1992 proficiency level				
Below 1	506	559	33	(2.0)
Level 1	841	969	31	(1.7)
Level 2	718	747	23	(1.5)
Level 3	446	459	20	(1.6)
Missing[3]	4,275	4,496	—	—

—Not applicable.

[1]Out of 14,814 8th-grade longitudinal panel respondents who did not drop out of school. See Appendix B for more information on the sample. Students were classified as missing key information if they did not have both base year and second followup cognitive tests. In addition, students who were involved in the transcript component of NELS:88 but did not have complete or only partial traynscript information were classified as missing key data.

[2]If students were missing information on a stratification variable such as race or school sector, then they were not used to calculate the percentage without key information for that particular variable.

[3]This variable code represents missing cases on the stratification variable. For example, no student was missing information on gender and 47 were missing race information. Note that 2,646 respondents were not involved in the transcript study, and show up as missing for the variables Science courses and Semesters of science. In addition, the number of respondents who were missing 1992 proficiency level information is relatively large because the response rate on the cognitive tests in the second followup was only 77 percent, as compared to 97 percent in the base year.

NOTE: Frequencies were weighted with a relative weight.

SOURCE: U.S. Department of Education, National Center for Education Statistics, National Education Longitudinal Study of 1988.

Sampling Errors

The data were weighted using the second followup panel weight (F2PNLWT) divided by the average panel weight to reflect the sampling rates (probability of selection) and adjustments for unit non-response.* The complex sample design was taken into account when a Taylor series approximation procedure was used to compute the standard errors in this report. The standard error is a measure of the variability of a sample estimate due to sampling. It indicates, for a given sample size, how much variance there is in the population of possible estimates of a parameter.

If all possible samples were selected under similar conditions, intervals of 1.96 standard errors below to 1.96 standard errors above a particular statistic would include the true population parameter being estimated for about 95 percent of these samples (i.e., 95 percent confidence interval). Comparisons noted in this report are significant at the 0.05 level. Except for results in the logistic regression section, all comparisons were determined using Bonferroni adjusted t-tests. (See the footnote above for a discussion of the procedures followed in the logistic regression section.)

* I used the only longitudinal weight available at the time when the analyses were being conducted. An alternative longitudinal weight, the transcript panel weight, has recently become available. Although for this report I obtained similar results with either weight (not reported here), future analyses like this should use the transcript panel weight (F2TRP1WT on the transcript data file).

Variables Used in Analysis

Science proficiency. Proficiency levels in science achievement form a hierarchical scale with each succeeding level characterized by increased complexity. A proficiency at a given level implies proficiency at all levels below it.

Each proficiency level is marked by a block of four items that have similar difficulty. For example, the level 1 items mostly deal with knowledge of simple scientific concepts.

Item #1 - Identify components of the solar system.

Item #2 - Read a graph depicting the solubility of chemicals.

Item #3 - Choose a statement about the source of the moon's light.

Item #4 - Identify the example of a simple reflex.

In addition to requiring the same cognitive operations, the items for a particular level exhibit similar item difficulty parameters. Since the underlying cognitive demand model is assumed to be hierarchical, students who are proficient on the level 2 items should also demonstrate proficiency on the level 1 items. While four items may seem like a relatively small number of items, they do prevent the chances of guessing correctly at a level and are essentially parallel measures of the same content or processing skill. The four items are not a subscale that attempts to discriminate individuals along a continuous dimension but are simply used to make a "know/can do" versus "do not know/cannot do" determination at a certain point referencing a specific skill. A full description of the psychometric properties of the NELS:88 base year test battery is presented by Rock & Pollack (1991). Descriptions of followup batteries are available in forthcoming followup NELS:88 psychometric reports.

Reliability of proficiency levels. An estimate of the reliability of a set of hierarchically ordered proficiency levels must take into account the hierarchical nature of the underlying cognitive model and consider the reproducibility of the response pattern. In a three-level model as used in science a person who demonstrates proficiency on two of those levels should show a response pattern consistent with the hierarchical nature of the proficiency levels. For instance, a response pattern where students fail to pass the lowest level but succeed at the higher levels would not be consistent with the assumed cognitive model where the increased difficulty goes from low to high. Guttman's coefficient of reproducibility is one measure of the deviation of response patterns from the ideal when there is an underlying order hierarchy. Guttman's coefficient of reproducibility is equal to one - [total number of deviations from the ideal across all respondents/(number of respondents)(number of levels)]. A corrected version of this coefficient of reproducibility, one which removes those individuals who had either a perfect score on the three levels or a zero score since they would have no opportunity for having deviations from the ideal response pattern, was found to be .95. Coefficients over .90 are considered quite high. However, when the measuring instrument has only three ordered and well spaced levels there is less opportunity for errors to occur.

Semesters of science. Measured in Carnegie units. A Carnegie unit represents one credit for the completion of a one-hour, one-year course five days a week. This measure was converted into semesters by assuming that one Carnegie unit represents two semesters of science. Approximately 27 percent (s.e.=.96) of the students took 8 or more, 34 percent (s.e.=.82) took at least 6 but fewer than 8, 33 percent (s.e.=.98) took at least 4 but less than 6, and the rest (6 percent) less than 4 semesters of science.

Science courses. If a student's transcript indicated that she or he took a physics course, then they received the value of "3" on this variable. Students who took chemistry but not physics received a two and those who took neither chemistry nor physics received a one.

Curriculum. Categorical variable coded as general, academic, or vocational from student self-reports of high school curriculum in 1992. Students who could not identify their type of curriculum were included in the general category.

Type of school. Categorical variable created from responses to the second followup school questionnaire coded as public, Catholic, and other private. Other private schools are composed of both non-Catholic religious and non-religious private.

Gender. Male and female.

Race-ethnicity. Asian-Pacific Islander, Hispanic, Black-not Hispanic, White-not Hispanic, and American Indian.

SES (Socioeconomic status). Base-year parent data on father's education level, mother's education level, father's occupation, mother's occupation, and family income were standardized and a continuous scale was created. This scale was then divided into four to create quartiles. Parent data were used unless parent information was missing, then student responses to questions about their parents were used. In a few cases where data on all five components of SES were not available, scale scores were constructed based on the components that were available.

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