DOCUMENT RESUME

ED 374 970 SE 054 923

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TITLE	Teachers' Academic Backgrounds and Student Outcomes in Science and Mathematics: NSF/NELS:88 Teacher Transcript Analysis.
INSTITUTION	Westat, Inc., Rockville, MD.
SPONS AGENCY	National Science Foundation, Washington, D.C.
PUB DATE	Apr 94
CONTRACT	NSF-RED-9255255
NOTE	35p.
PUB TYPE	Reports - Research/Technical (143)
EDRS PRICE	MF01/PC02 Plus Postage.
DESCRIPTORS	Academic Records; Content Analysis; *Educational Background; Grade 8; Higher Education; Junior High Schools; *Junior High School Students; *Mathematics Achievement; Mathematics Instruction; *Mathematics Teachers; Preservice Teacher Education; Science Instruction; *Science Teachers; Teaching Methods
IDENTIFIERS	*Science Achievement

ABSTRACT

This study focused on teachers' academic preparation for teaching science and mathematics, as measured by the National Education Longitudinal Study of 1988 (NELS:88) which collected data for a nationally representative sample of 26,435 8th-grade students clustered within 1,052 schools. The relationship between teachers' academic preparation, their subsequent teaching methods, and student outcomes as measured by student scores on proficiency exams was examined. On average, student proficiency scores were best if their teachers had grade point averages above 3.0 in science or mathematics. Further, students in mathematics performed best if their teachers had taken advanced mathematics courses, while courses in mathematics pedagogy only provided an extra benefit if teachers had also taken advanced mathematics courses. Students in science showed small differences based on the number of science courses their teachers had taken, but no difference based on courses in science education. (MKR)

Teachers' Academic Backgrounds and Student Outcomes in Science and Mathematics

NSF/NELS:88 Teacher Transcript Analysis

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NSF Grant RED-9255255

April 1994

Abstract

Using college transcript data from the National Education Longitudinal Study of 1988 (NELS:88), teachers' academic backgrounds in science and mathematics appeared related to teachers' approaches within the classroom, to teachers' feelings of preparedness, and to student proficiency scores. On average, student proficiency scores were best if their teachers had grade point averages above 3.0 in science or mathematics. Further, students in mathematics performed best if their teachers had taken advanced mathematics courses, while courses in mathematics pedagogy only provided an extra benefit if teachers had also taken advanced mathematics courses. Students in science showed small differences based on the number of science courses their teachers had taken, but no difference based on courses in science education.

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Background

Great concern has been expressed recently over the state of science and mathematics education in the United States, to the degree that the President and the State Governors established improvement in science and mathematics education as one of the top education priorities in the 1990s.

By many measures, success in education has been a major element of progress in the United States. The top U.S. researchers have performed at the highest levels, winning a disproportionate share of Nobel Prizes and other recognitions of science and mathematics achievement. The large scale, openness, and quality of higher education have drawn a vast number of foreign students to the U.S. higher education system. The use of science by industry has been cited as a critical factor in the international competitiveness of the U.S. economic system.

Yet there are signs of a decline in the U.S. position in science and mathematics. Some worry that the successes above are a result of past programs, and do not reflect the state of science and mathematics today. International tests of science and mathematics skills show U.S. students comparing poorly to those of many other countries. Graduate programs in science and mathematics increasingly depend on foreign students, with the number of U.S. students declining. Of entering college freshmen, one-fourth anticipate they will need special tutoring or remedial help in mathematics, and one-tenth anticipate this need in science. For some programs such as engineering, few entering college freshmen have the background to begin the programs.

Much of the United States' potential to improve science and mathematics education depends on affecting students at an early age. By the time students begin attending college, their background may already be inadequate for careers in either field. Further, students' attitudes toward science and mathematics may already be well set, ranging from those who have chosen to pursue careers in mathematics and science to those who have given up even on achieving competency. The eighth grade in particular, the subject of this study, may represent a critical branching point, when students decide the degree to which they are interested in pursuing additional education in science and mathematics.

Yet influencing students in science and mathematics is difficult because of the many sources of influence and their complex interrelationships. Parents are important, through the attitudes they convey toward education, their ability to help their children with education, and their ability to provide a stable home environment. Schools vary in the resources available to students, the environments provided for learning, and the characteristics of the students' peers, who will affect both students' ability to learn and students' attitudes toward learning. Teachers have varying levels of training, both in the subject areas being taught and in knowledge of the educational process, and differ in the teaching techniques used. Teachers may be important both for the skills they use and also for the attitudes they communicate about science and mathematics. Perhaps most important, students vary in their backgrounds and abilities to such an extent that research on education is often overwhelmed by the degree and importance of the differences already existing among students.

While other data about students and teachers are also incorporated, this study focuses especially on teachers' academic preparation for teaching science and mathematics, as measured through the data provided on their college transcripts. This study examines the relationship between teachers' academic preparation, their subsequent teaching methods, and student outcomes as measured by student scores on proficiency exams. Transcript data cannot be expected to provide a complete picture of teaching quality, and there are intangibles (such as personality and teaching style) for which transcript-based measures are inadequate. Nevertheless, a focus on transcript-based data has many advantages: (1) transcripts are not subject to biases in self-reporting or problems related to poor memories that might appear with questionnaire-based data; (2) transcripts provide a readily available source of information that can be used when hiring teachers; and (3) transcripts provide data on some of the aspects of teaching that are most subject to policy intervention in attempts to reform education -- the design of teacher education programs and the establishing of certification or other requirements in the hiring of teachers.

Methodology

This report is an analysis of the transcript data and a limited number of other variables from the National Education Longitudinal Study of 1988 (NELS:88). NELS:88 is particularly useful because of its comprehensiveness in the types of data collected. For a nationally representative sample of 26,435 eighth-grade students clustered within 1,052 schools, questionnaires were completed by the students and by their parents, teachers (in either science or mathematics, and in either English or social studies), and schools. Additionally, students were given standardized tests to measure their proficiency in science, mathematics, reading, and history/citizenship.

A complementary component of NELS:88 was the Teacher Transcript Study, funded by the National Science Foundation. This component further expanded the information available on teachers by permitting analysis of science and mathematics teachers' academic preparation for teaching. For each of the 1,873 science and mathematics teachers within the NELS:88 study who gave permission, colleges were asked to provide transcripts of their academic records. Initially, only colleges identified in the NELS questionnaire as the *primary* colleges attended (*i.e.*, the colleges granting the sampled teachers their bachelor's and graduate degrees) were contacted. However, when students transferred from one college to another, some institutions recorded all course information from students' previous transcripts, while others noted only the name of the institution(s) previously attended and the total number of credits earned. To develop a complete picture of the teachers' academic preparation, the transcripts from the primary colleges attended were used to develop a list of all colleges that had been attended, and additional transcripts were requested from these extra colleges. Overall, 3,088 (91 percent) of all originally requested transcripts were received, as well as 786 additional transcripts from the other colleges attended. At least one transcript was received for 1,803 (96 percent) of the 1,873 teachers for whom transcripts were requested, and all transcripts were received for 1,401 (75 percent). The 1,803 teachers consisted of 737 science teachers and 1,066 mathematics teachers.

Each course listed on a received transcript was coded into one of 92 two-digit subject categories based upon the Classification of Instructional Programs (CIP) coding system. Courses in science or mathematics were coded in additional detail, using a total of 96 four-digit codes.[1]

This analysis will focus on teachers' backgrounds in terms of their own college-level preparation in science and mathematics as a predictor of their students' achievement. Teachers' differences in background might be hypothesized to have three effects on teachers' performance in the classroom: on the actual content of their instruction, on their methods of presentation, and on their attitudes towards the subject matter (which also may be communicated to their students). The net result may be differences in student outcomes. To examine this hypothesis, the summary measures of teachers' academic backgrounds were linked to teachers' own responses on NELS teacher questionnaires concerning the instructional materials used, the major topics covered in the eighth-grade science and mathematics classes, teachers' use of instructional time, and teachers' feelings of preparedness to teach the eighth-grade courses. Additionally, the summary measures were linked to

[1]Additional information on the coding and on other aspects of the research methodology can be obtained from the *Methodology Report* for the NSF/NELS:88 Teacher Transcript Study.

the NELS cognitive tests in science and mathematics. All estimates presented in this report are from one of those three sources (transcript data, teacher questionnaires, or the student questionnaires and cognitive tests).

Several limitations of this study must be noted. First, while additional analyses that use more of the NELS student data are planned, this initial report primarily focuses on the data collected through the NELS teacher questionnaire and the teacher transcript data. Student-level data are primarily used in this report to examine whether some types of students are more likely to have teachers with strong academic backgrounds than other students, and not to establish a larger context for student learning.

Second, NELS:88 was designed to provide a nationally representative sample of students, not of teachers. The data still may be used meaningfully to examine teacher characteristics (including the transcript data), but statistics are most properly presented in terms of the number of *students* affected, rather than the number of teachers. This sometimes leads to awkward phraseology in describing the survey results.

Third, the NELS student weights do not always sum to the total number of eighth-grade students. One reason is that, at any sampled school (and thus for any student), the NELS sampling design provided for either science or mathematics teachers to be sampled, but not both. Weighted frequencies on science or mathematics teachers thus represent only half of all students. The student weights also do not correct for that portion of nonresponse due to teacher nonresponse on the teacher questionnaire, the refusal of some teachers to give permission for their transcripts to be collected, or the failure of some colleges to send all transcripts that were collected. The cumulative effect of these factors is that, of the weighted total of 3,008,080 students, transcript data are available for 947,805 science students and 925,915 mathematics students. Rather than reweighting the data to allow for this half-sampling and nonresponse, this report will present statistics primarily in terms of percentages of these smaller numbers of science and mathematics students. These percentages are not expected to change dramatically with reweighting.

Fourth, because of the large number of cases in the NELS data base, the simple statistical tests of significance that were used (e.g., chi-square and t-tests) typically showed statistical significance at the 0.05 level, whether or not the differences appeared substantively important.[2] However, the data contain a hierarchical structure in which a single teacher is associated with a number of students, effectively overstating the number of teachers involved in the study, and statistical tests must allow for this hierarchical structure. Such analyses are planned for a later part of this study.

Finally, measures of student outcomes are based on the cognitive tests in science and mathematics that were administered in NELS:88. These test scores reflect not only learning that occurred in the eighth grade, but also learning in previous years. To measure the incremental gain in knowledge obtained in the eighth grade, it would have been necessary to administer tests both when students began the eighth grade and also after they completed eighth grade. The general effect of this weakness in the NELS data (common to most studies of student achievement) will be a reduced ability to relate differences in student outcomes to teachers' backgrounds.

Teachers' Backgrounds in Science and Mathematics

Two different types of academic preparation were considered: one based on the types and number of courses which science and mathematics teachers had taken, and another on the grade point averages they had earned for courses in the subject area.

Types of courses taken. To measure the types and number of courses taken, a first distinction was to differentiate between coursework in the particular subject matter being taught (*i.e.*, in science or mathematics) and courses in science or mathematics education. Additionally, teachers were classified based on the depth of their preparation. For mathematics, where course topics form somewhat of a hierarchy, teachers were classified as those who took courses only at the calculus level or below, or those who took advanced courses in mathematics. Science courses were less easily classified into a hierarchy based on the coding that was used, because a given course topic (*e.g.*, physics or biology) may have been either an introductory course or an advanced course. Thus, science

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[2]The number of completed NELS student questionnaires was quite large (24,599), so previously reported standard errors of student-level statistics have been small even within subgroups of students. For example, Asians comprised only 6.2 percent of the sample, yet the standard errors for their mean formula scores were still quite small (0.29 for their overall mean of 10.76 in science, and 0.60 for their overall mean of 19.75 in mathematics). Standard errors for teacher-level statistics will be larger because of the smaller sample sizes.

teachers were classified based on the number of semester credits earned in science and science education.[3]

The distinction between "advanced" and "limited" coursework in the subject area allows four characterizations of the teachers surveyed:

		Coursework in Education	
		Yes	No
Coursework in Subject Area	Advanced	I	II
	Limited	III	IV

One would hypothesize that teachers in Category I (*i.e.*, those who took advanced coursework in the subject area and also took courses in science or mathematics education) would be the best prepared, and teachers in Category IV the least prepared. Teachers in Categories II and III would fall somewhere in the middle, depending on the relative importance of coursework in the subject area versus coursework in education.[4]

Typically, students were taught by teachers who have had college-level instruction both in science (or mathematics) and in science (or mathematics) education (Figure 1).

- In science, 60 percent of science students had teachers with courses both in science and science education, 39 percent with a science background but no courses in science education, and only 1 percent with no course work in science, or course work in science education only. Roughly half (49 percent) of the students had teachers with more than 40 credits combined across both science and science education.

- In mathematics, a somewhat higher percentage of students had teachers with courses both in mathematics and in mathematics education (67 percent, compared with 60 percent in science). However, there were also higher percentages of students whose teachers had taken courses neither in mathematics nor mathematics education (5 percent), or had taken courses only in mathematics education (5 percent, compared with 1 percent for both groups combined in science). Roughly two-thirds (69 percent) of the students had teachers who had taken at least some courses in advanced mathematics.[5]

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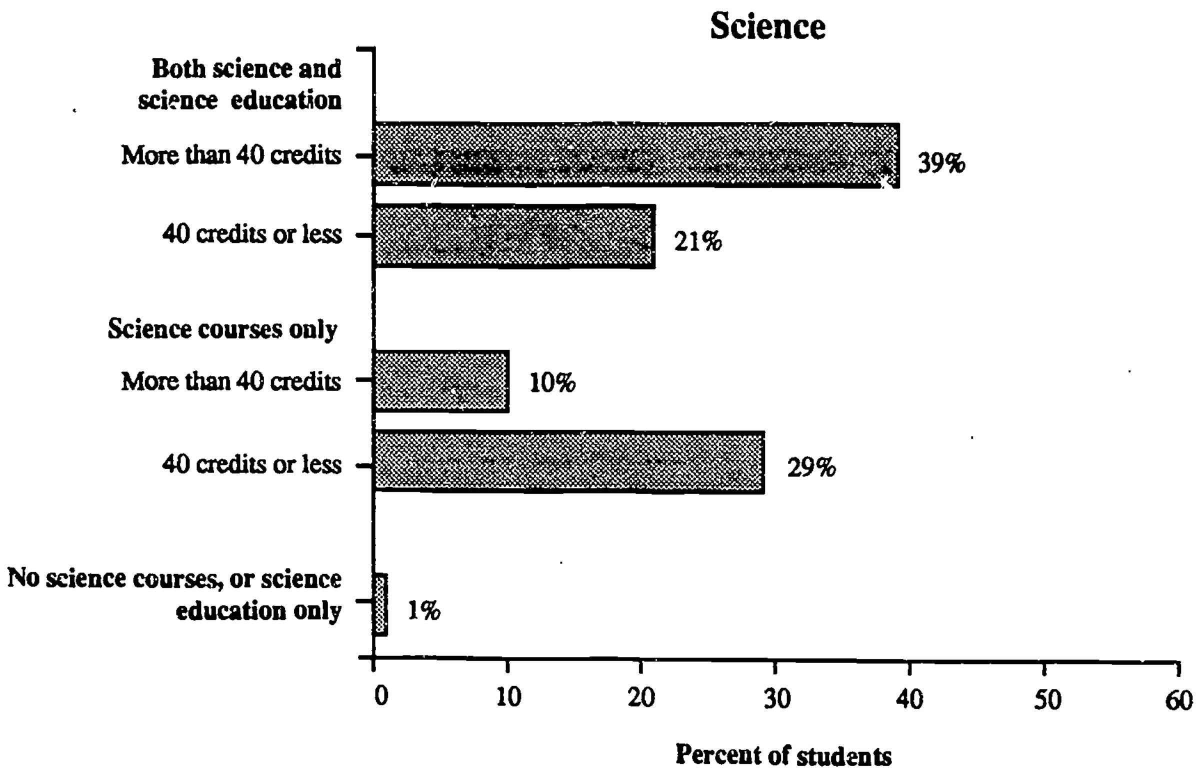
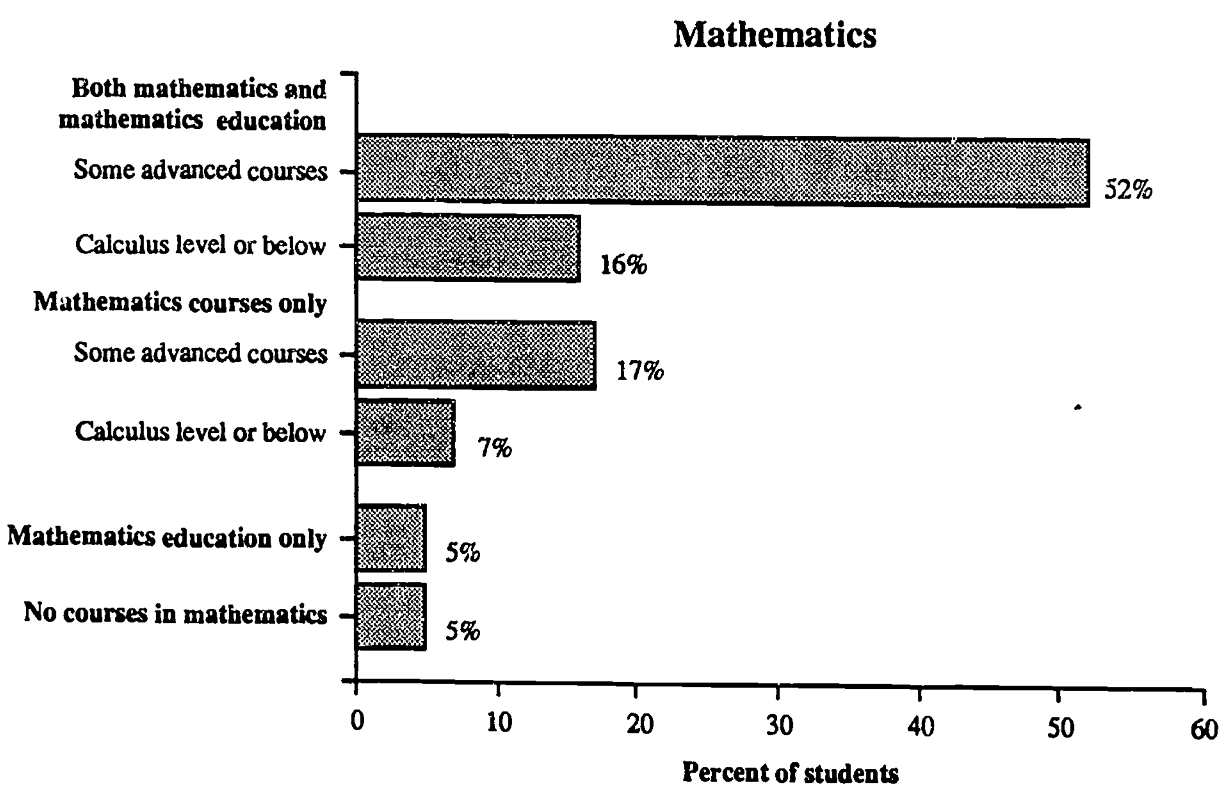
[3]Credits that were recorded using the quarter system were converted to semester credits. The cutoff point (40 credits) was based on a frequency listing of the number of total credits received in science and science education.

[4]When the data are presented, several cases will appear where a relationship is inconsistent with this model. That is, Categories II and III sometimes produce results outside of the expected range based on categories I and IV. This report will assume that such inconsistencies are due to random variation or to complexities not captured in this simple model, rather than trying to explain the results. However, if these inconsistencies persist in later analysis, more complex models should be examined.

[5]It is difficult to compare these percentages with those in science because of the different methods used for defining advanced preparation.

Figure 1. Academic preparation of science and mathematics teachers of eighth-grade students: United States





NOTE: Percentages may not add to 100 due to rounding.

Because of the relatively small number of students in classes whose teachers had taken no science or mathematics courses, and the even smaller number of sampled teachers upon whom those statistics are based, the remaining analysis will focus on teachers who had taken some science or mathematics courses. Tables at the end of this report provide statistics for all categories of teachers, but readers are cautioned that statistics concerning teachers with no science or mathematics courses in their backgrounds are subject to greater standard errors than other statistics.[6]

Grade point averages in science or mathematics. It is possible that a teacher could take a small number of required courses in science or mathematics, while performing poorly and never acquiring a high level of proficiency in the subject area. To allow for this possibility, a second measure of teachers' academic preparation was also created, based on teachers' grade point averages within science or mathematics.[7] This measure differs from the previously described measure in providing a measure of the teacher's "success" within the subject area, independent of the number or level of the courses taken.[8]

Most commonly, students had science teachers who received a grade point average in the "B" range (between 2.6 and 3.5; 48 percent of the students), while 36 percent had teachers who received averages in the "C" range (between 1.6 and 2.5), 13 percent in the "A" range (above 3.5), and 3 percent an average of "D" or below (below 1.5; Figure 2). Students' mathematics teachers had a similar distribution: 48 percent of students had teachers with mathematics GPAs between 2.6 and 3.5, though mathematics students were somewhat more likely than science students to have teachers with an average of 3.6 or higher (19 percent), and less likely to have teachers with an average between 1.6 and 2.5 (29 percent).[9]

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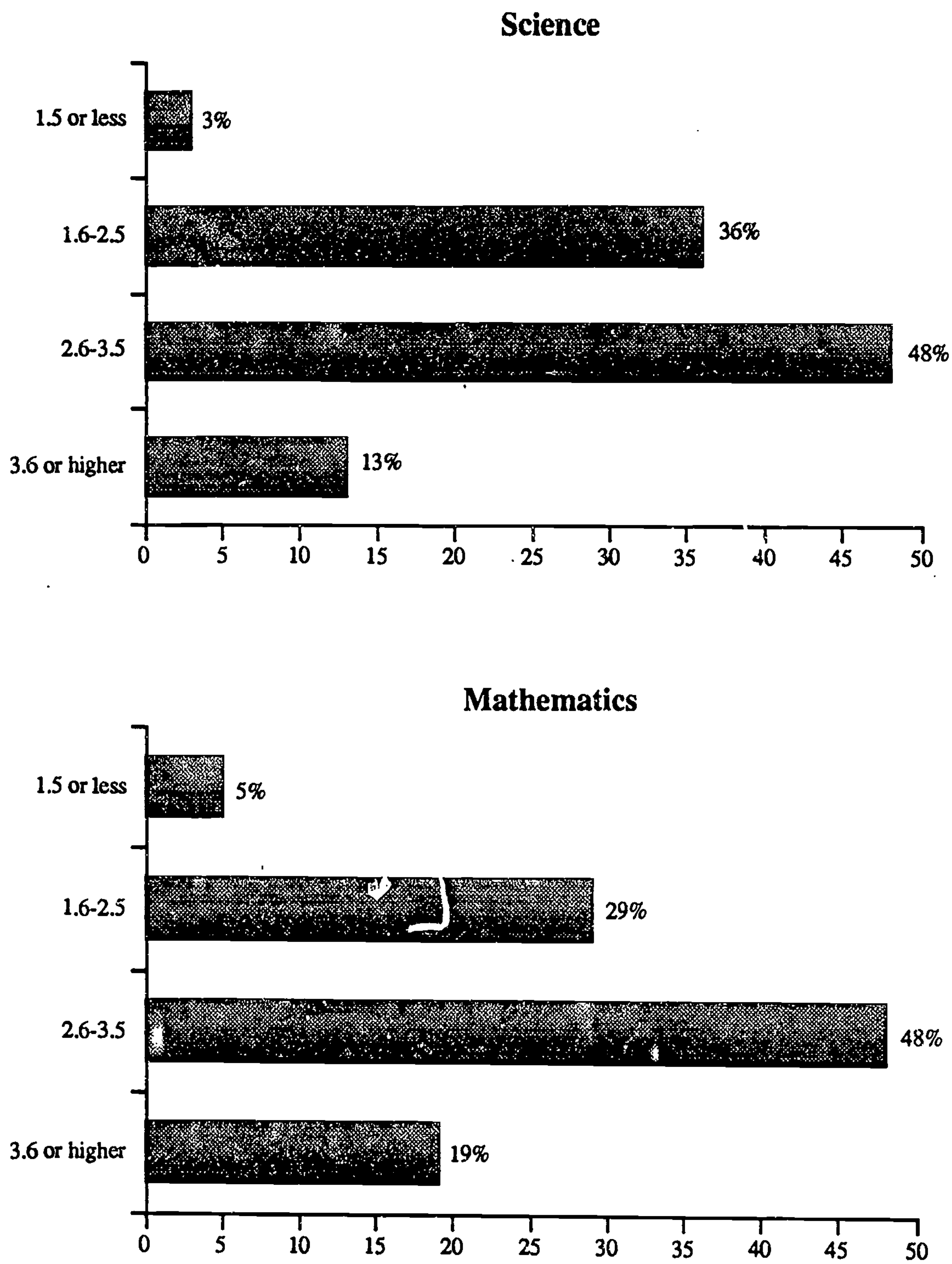
[6]The statistics are more stable for mathematics than for science because a greater proportion of teachers fall in the category of having completed no subject area coursework, and because the sample of mathematics teachers was larger than that for science teachers.

[7]Only courses within the subject area were included when calculating the grade point averages, while courses in science or mathematics education were excluded. Teachers who took no courses in science or mathematics were excluded from this measure, but statistics on these teachers can be found in the measure based on the types of courses taken. Grade point averages were calculated on a four-point scale ("A"=4.0, and "F"=0.0), with pluses and minuses accounted for though an increment of 0.3 (e.g., "B+"=3.3).

[8]Obviously, courses differ in academic difficulty, and the same course may have differing levels of difficulty at different institutions. Nevertheless, grade point averages provide a useful summary measure of a student's success. Separate analyses were performed to examine the usefulness of a combined measure based on both grade point averages and the number and types of courses taken; the analyses showed that grade point averages could meaningfully be used as an additional subcategory within each group of types of courses taken, with sometimes substantial differences appearing based on the grade point average. For simplicity, grade point averages are here treated separately rather than in combination with the other measure of teachers' academic backgrounds.

[9]Later references to teachers' grade point averages in this report will use a slightly different set of categories (2.5 or lower, 2.5001-3.0, and higher than 3.0) in order to have a more equal distribution among the categories.

Figure 2. Grade point averages of science and mathematics teachers of eighth-grade students in their subject areas: United States



NOTE: Percentages may not add to 100 due to rounding. Teachers who did not take courses in the subject area are excluded.

Teaching Methods and Teachers' Backgrounds

This section will examine how the differences found in teachers' academic backgrounds might be related to what happens in the classroom. Teachers' backgrounds may affect the content of their teaching through their use of instructional materials (*e.g.*, is the teacher able to go beyond the information provided in the textbook?), or through their choice of topics (*e.g.*, will teachers emphasize simpler topics if they have weaker academic backgrounds?). Less directly, teachers' academic backgrounds may affect teachers' allocation of time in the classroom, such as their ability or willingness to use labs within science courses. Finally, teachers' backgrounds may also affect their attitudes toward science and mathematics: if a teacher feels well prepared and comfortable with an instructional area, his or her own attitude may affect student attitudes toward the material.

Instructional materials. Little difference was found among teachers in their use of instructional materials based on the types of courses they had taken (Table 1). In mathematics, the percentage of students in classes where the textbook was used frequently varied only from 94 to 98 percent. In science, the differences were somewhat larger, but still not sizable. Students of teachers with 40 or fewer credits in science were somewhat more likely to be in classes where the textbook was used frequently (90 to 92 percent) than students of teachers with more than 40 credits (82 to 84 percent).

The variations were larger, but not entirely consistent, when comparing teachers based upon their grade point averages in mathematics or science. In mathematics, students whose teachers had GPAs of 2.5 or lower were more likely to use other instructional materials frequently (13 percent) than students whose teachers had higher GPAs (4-7 percent); however, in science, it was the students whose teachers had the highest GPAs that were the most likely to use other instructional materials frequently (21 percent versus 8-11 percent).

Choice of major topics. NELS also asked teachers which of several listed areas were treated as major topics in their classes. The largest differences based upon the types of courses taken among teachers were for the topics of algebra and probability/statistics (Table 2). Students whose teachers had taken mathematics but not mathematics education were more likely to see algebra treated as a major topic if their teachers had taken advanced courses (68 percent) than if their teachers had taken courses only at the calculus level or below (54 percent). Differences were smaller among teachers who had taken both mathematics and mathematics education (66 percent versus 63 percent);

still, they might be consistent with the hypothesis that a background of *either* advanced courses or mathematics education is related to an increased emphasis on algebra, with no additive effect if both are taken. The differences for probability and statistics are less easily interpreted. Advanced teacher training was related to an *increased* emphasis on probability and statistics among students having teachers with no courses in mathematics education (24 percent versus 10 percent), but a *decreased* emphasis among students whose teachers had taken both mathematics and mathematics education (13 percent versus 24 percent). Given the lack of a systematic pattern, it is difficult to attribute the differences to differences in academic preparation. A similar type of inconsistency appeared with common fractions.

When teachers were compared based upon their grade point averages, the variations were sometimes more consistent. There again was a strong difference among teachers in treating algebra as a major topic, with 70 percent of students in classes where it was a major topic if their teachers had GPAs above 3.0, and only 59 percent if their teachers had GPAs for 2.5 or lower. There also were consistent but smaller differences in other areas; students with teachers having high GPAs were less likely to receive major emphasis on common fractions (58 percent versus 64 percent) and decimal fractions (56 percent versus 63 percent), and more likely on geometry (56 percent versus 45 percent). Only small differences appeared in the emphasis on probability and statistics (a range of 16 to 19 percent), further reinforcing the likelihood that the inconsistent differences that were found based on the types of courses taken were not important.

For science, differences tended to be small or inconsistent in the choice of major topics, so no major patterns are immediately apparent based upon the types of courses taken (Table 3). Some stronger differences appeared based on teachers' GPAs: if students' teachers had high GPAs, then chemistry (49 percent versus 38 percent) and atomic theory (45 percent versus 34 percent) were more likely to be treated as major topics than for students whose teachers had low GPAs, while plants, animals, human biology, and environmental science were less likely to be treated as major topics.

Use of time. Little difference was found among teachers in their use of time based on the types of courses they had taken (Table 4). An exception was in the amount of time devoted to lab periods relative to whole class instruction, but here the results were inconsistent. Students whose science teachers had taken courses in science but not in science education tended to have more time devoted to lab periods and less in whole class instruction if their teachers received more than 40 credits of science instruction. That is, 32 percent (versus 15 percent) were in classes with two or more hours of lab periods, and 69 percent (versus 82 percent) received two or more hours of instruction directed to the whole class.[10] However, the results were quite different for students whose teachers who had taken courses both in science and science education; among that group, students were *less* likely to have two or more hours of lab periods when they had teachers with more than 40 credits. Thus, it is difficult to generalize about the effect of teachers' backgrounds on their use of time.

The differences based on teachers' grade point averages were sometimes smaller, but more consistent. If students had teachers with high GPAs, then they were more likely than those whose teachers had low GPAs to receive two or more hours of instruction in mathematics as a whole class (83 percent versus 76 percent), and less likely though individual instruction (15 percent versus 22 percent). In science, the students whose teachers had high GPAs were less likely than others to receive two or more hours of lab periods (16 percent versus 22-23 percent).

Feelings of preparedness. One area where some of the clearest differences appeared based upon the types of courses taken was in teachers' feelings of preparedness for teaching science or mathematics (Table 5). When teachers had taken advanced classes in mathematics and courses in mathematics education, 91 percent of students were in classes where the teacher felt very well prepared. But when teachers either had not taken advanced courses in mathematics or had not taken courses in mathematics education, only 60 to 78 percent of students had teachers who felt very well prepared. Also, unlike many of the previous findings where teacher's grade point averages were more likely to provide consistent differences than the types of courses taken, for teacher preparedness in mathematics the important differences were based entirely on the types of courses taken: the range based on GPA varied only from 84 to 87 percent.

For science, no differences appeared based on whether teachers had taken science education courses. However, there were strong differences based on the number of credits in science that teachers had taken. Two-thirds of students had teachers who felt very well prepared if the teachers had taken more than 40 credits in science, compared with one-third of students with teachers having 40 credits or fewer. There also were differences based upon teachers' grade point averages, with 53 percent of students having teachers who felt well prepared if the teachers had science GPAs higher than 3.0, compared with 46 percent if the teachers had GPAs of 2.5 or lower.

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[10] These categories were not mutually exclusive, and some students did appear in both categories.

Student Outcomes

The above findings provide some basis for anticipating that teachers' academic backgrounds might be related to student outcomes. Teachers' grade point averages in science and mathematics sometimes were related to differences in teaching practices, and either teachers' course taking patterns or their grade point averages were related to teachers' feelings of preparedness.

Table 6 shows that teachers' academic backgrounds can be related to student outcomes. Students whose teachers had taken advanced courses in mathematics performed better than those whose teachers had taken courses only at the calculus level or below. For example, the mean standardized score for students was highest (51.4) for students whose teachers had taken both advanced courses in mathematics and courses in mathematics education. Next highest were students whose teachers had taken advanced courses in mathematics but no courses in mathematics education (50.7), while students whose teachers had taken mathematics courses only at the calculus level or below received mean scores of 48.6 (if the teachers had taken mathematics education courses) and 48.5 (if the teachers had not taken mathematics education courses). Generally, throughout the various measures of student proficiency offered in Table 6, students whose teachers had taken advanced courses in mathematics performed best, while teachers' experience in mathematics education was related to improved student test scores only if the teachers also had taken advanced mathematics courses. The measure of teachers' grade point averages in mathematics also proved useful, with students whose teachers' GPAs were high performing the best: for example, when teachers had a GPA above 3.0, their students had a mean standardized score of 51.8, while teachers with a GPA of 2.5 or lower had students with a mean score of 49.5.

In science, the differences in test scores were smaller than those found for mathematics, and showed only marginally higher test scores for students whose teachers had taken more than 40 credits of science. For example, among teachers with courses in science but not in science education, students received a mean standardized score of 51.3 for teachers with more than 40 credits and 50.7 for teachers with 40 credits or fewer. Similarly, among teachers with courses in both science and science education, students received a mean of 50.6 if teachers had more than 40 credits, and 50.2 if teachers had 40 credits or fewer. No improvement was found in test scores based on teachers' coursework in science education. Again, teachers' GPAs could be related to differences in student outcomes: students whose teachers had science GPAs above 3.0 received a mean standardized score of 51.6, while students whose teachers had GPAs of 2.5 or lower received a mean of 49.3.

Besides overall numeric scores, NELS also provided for grading students based on three proficiency levels in mathematics: able to perform simple arithmetic operations on whole numbers; able to perform simple arithmetic operations with decimals, fractions, and roots; and able to perform simple problem solving, requiring conceptual understanding and/or the development of a solution strategy. Each of the proficiency levels was associated with four questions from the larger mathematics test, and to establish proficiency at a level, students had to answer at least three of the four questions correctly for that level as well as showing proficiency at all lower levels.

Figure 3 displays the relationship between teachers' academic backgrounds and student proficiency levels in mathematics. Teachers who had taken advanced courses in mathematics had a greater percentage of students at the highest proficiency level (22 percent) than teachers who had taken courses only at the calculus level or below (13-17 percent). No additional improvement was found in students' proficiency levels if their teachers had also taken courses in mathematics education. There also was a relationship between teachers' grade point averages and students' proficiency levels: students whose teachers had mathematics GPAs above 3.0 were more likely to be in the top proficiency level (23 percent) than those with teachers with GPAs of 2.5 or lower (17 percent).

Inequalities in Teacher Assignments and Student Outcomes

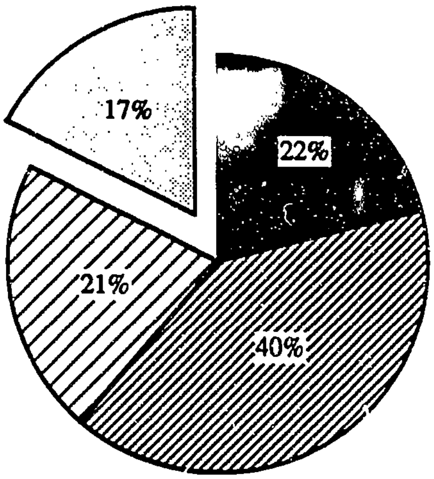
Despite the above findings of a relationship between teachers' academic preparation and student outcomes, it is possible that differences in student outcomes might be explained less by differences among teachers than by some other factor that also happens to be related to teachers' backgrounds. For example, the differences may be due to inequalities in teacher assignments. If the "best" teachers (in terms of academic preparation) were assigned to the "best" students, the apparent relationship between teacher qualifications and student outcomes might be a result of that teacher assignment process, rather than because those teachers are more effective in improving students' academic proficiency.

Figure 3. Proficiency of eighth-grade mathematics students, by teachers' backgrounds in mathematics: United States

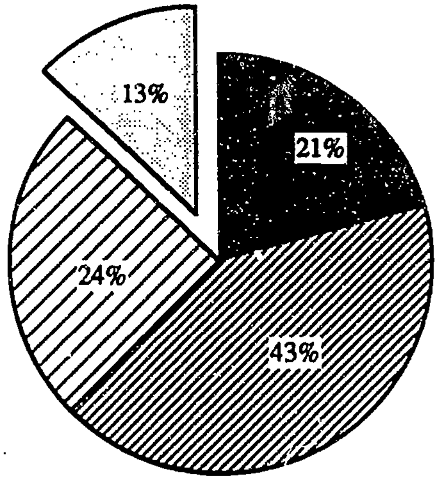
- Below level 1: Unable to perform simple arithmetic operations on whole numbers
- Level 1: Able to perform simple arithmetic operations on whole numbers
- Level 2: Able to perform simple arithmetic operations with decimals, fractions, and roots
- Level 3: Able to perform simple problem solving

Teacher took mathematics courses only at the calculus level or below

Courses in mathematics,
but not in mathematics education
(7% of students)

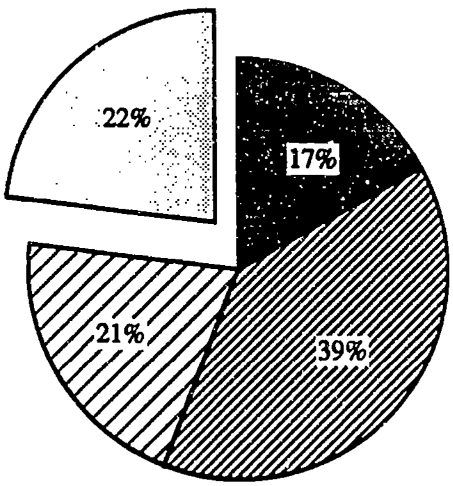


Courses in both mathematics and
mathematics education
(16% of students)

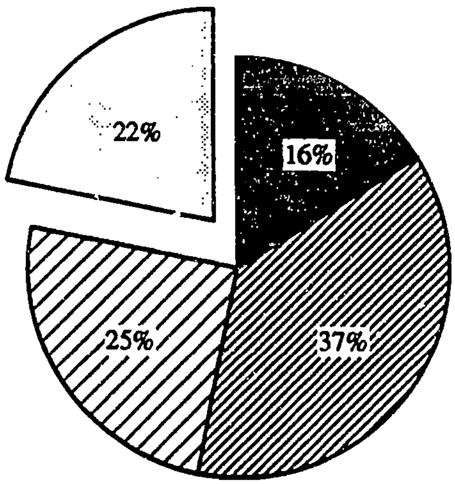


Teacher took at least some advanced mathematics courses

Courses in mathematics,
but not in mathematics education
(17% of students)



Courses in both mathematics and
mathematics education
(52% of students)



NOTE: Percentages may not add to 100 due to rounding.

There are many reasons why inequalities may have appeared in teacher assignments. Some inequalities might be due to teacher self-selection or teacher availability, so that, for example, the characteristics of teachers available to urban schools may have been different from those of teachers available to suburban or rural schools. Other inequalities may have resulted from student or parent choices, if some students or their parents sought schools or classes with particular characteristics. Schools also may have had policies such as placing high-achieving students together, and perhaps assigning the best teachers to those classes. Such policies are controversial, because they create the risk that some groups of students are doubly disadvantaged, in that they not only start out at lower levels of academic proficiency but they may be given fewer or less adequate resources for overcoming this disadvantage.

Table 7 provides a confirmation that some inequalities appeared in teacher assignments. For those teachers who had the least preparation in mathematics -- mathematics education only at the calculus level or below, with no courses in mathematics education -- students were disproportionately likely to be attending schools where more than 60 percent were minorities (38 percent versus 11-12 percent among the other three groups), to be attending urban schools (39 percent versus 17-20 percent), and to be black or Hispanic (32 percent versus 19-21 percent). By contrast, those teachers whose backgrounds were the strongest (with both advanced mathematics courses and mathematics education) were disproportionately likely to describe the overall achievement levels of the sampled classes as higher than for the average eighth grade student in their schools (31 percent of their students versus 19-24 percent for other teachers). Similarly, teachers with grade point averages above 3.0 had a greater concentration of students in such classes (33 percent) than other teachers (21-24 percent).

In science, the differences were not as large or as consistent in terms of the types and number of courses that teachers had taken. More substantial differences sometimes appeared based upon teachers' grade point averages. Students whose teachers had GPAs above 3.0 were more likely than students whose teachers had GPAs of 2.5 or lower to be in urban (26 versus 19 percent) or rural (41 versus 34 percent) schools, and less likely to be at schools with more than 60 percent being minorities (7 percent versus 15 percent) or in classes with average achievement levels (31 percent versus 41 percent).

These differences in teacher assignment were not sufficient to explain the relationship between teachers academic background and student outcomes. If one controls for the student-related characteristics, teachers' backgrounds still were related to student outcomes, with students performing better (on average) when their teachers had stronger backgrounds (Table 8). For example, the mean standardized score for students whose teachers had taken both advanced mathematics courses and courses in mathematics education was 59.5. Among students whose teachers had taken advanced courses in mathematics but no courses in mathematics education, the mean was 58.8, and among students whose teachers had not taken advanced courses in mathematics, it ranged from 57.0 to 57.2. Similarly, teachers' grade point averages could generally be related to differences in student outcomes within these subgroups, and sometimes to a larger degree than reported in Table 6. For example, the mean standardized score for all students ranged from 49.3 among students whose teachers had GPAs of 2.5 or lower to 51.6 among students whose teachers had GPAs higher than 3.0, but for students at schools where more than half of the students received free lunches, the range was from 43.7 to 52.6.

Summary

Teachers' postsecondary transcripts provide a valuable source of information on teacher quality. Both measures based on the types and numbers of courses taken, and measures based on teachers' grade point averages were used successfully; the measures based on grade point averages were the most consistently useful, while measures based on the types and numbers of courses were generally more useful for mathematics than for science. Possibly, this latter difference was due to the ability to also categorize mathematics courses in terms of the level of difficulty, which was less possible with the coding scheme used for science courses. The success of transcript-based measures of teacher quality suggests that they might be used as one tool for making decisions on hiring teachers and assigning them to classes, and that transcript-based studies could be used to evaluate the effectiveness of the teacher education curriculum and certification requirements.

Some of the ways in which teachers' backgrounds appeared related to teachers' approaches within the classroom were in: their use of instructional materials other than textbooks, other reading materials, and audio-visual materials; the degree of emphasis given to algebra, fractions, geometry, chemistry, and atomic theory; the amount of time devoted to whole class instruction, individual instruction, and lab periods; and teachers' feelings of preparedness.

Teachers' academic backgrounds could also be related to student outcomes. One interesting finding was the importance of teachers having taken advanced mathematics courses; training in mathematics pedagogy only provided an extra benefit if the background in advanced mathematics had also been obtained. In science, the greatest differences among teachers were based on grade point averages; there also were small differences based on the number of courses taken, but no difference based upon courses in science education.

Though there was evidence that certain categories of students were the most likely to have teachers with strong academic backgrounds, the relationship between teachers' backgrounds and student outcomes persisted even after controlling for these factors.

Table 1. Percentage of students in eighth-grade mathematics and science classes where various instructional materials were used frequently, by teachers' educational background: United States

Teachers' background	Instructional materials			
	Textbooks	Other reading materials	Audio-visual materials	Other instructional materials
Mathematics				
Types of courses taken				
Total	95	6	13	9
No courses in mathematics*	97	7	2	12
Courses in mathematics education only*	89	9	23	23
Courses in mathematics but not in mathematics education				
Calculus level or below	94	9	13	11
Some advanced courses	98	4	15	7
Courses in both mathematics and mathematics education				
Calculus level or below	95	5	16	7
Some advanced courses	95	6	12	8
Grade point average in mathematics				
2.5 or lower	93	7	14	13
2.5001 - 3.0	97	5	15	4
Higher than 3.0	95	6	12	7
Science				
Types of courses taken				
Total	87	12	21	14
No science courses, or science education only*	55	31	3	35
Science courses only				
40 credits or less	90	9	19	14
More than 40 credits	82	16	20	21
Both science courses and science education				
40 credits or less	92	10	24	11
More than 40 credits	84	13	21	12
Grade point average in science				
2.5 or lower	88	10	21	11
2.5001 - 3.0	90	10	23	8
Higher than 3.0	84	14	21	21

*Estimates in these categories are unstable because of the small numbers of teachers with no courses in mathematics or science.

NOTE: Percentages do not add to 100 because teachers may use more than one type of instructional method frequently.

SOURCE: NSF/NELS:88 Teacher Transcript Analysis

Table 2. Percentage of students in eighth-grade mathematics classes where various areas within mathematics were treated as major topics, by teachers' educational background: United States

Teachers' background	Major topic in mathematics classes									
	Common fractions	Decimal fractions	Ratios and proportions	Percentages	Measurement	Geometry	Algebra	Integers	Probability/ statistics	Problem solving
Total	61	58	63	75	35	51	64	72	18	74
Types of courses taken										
No courses in mathematics*	69	60	77	82	27	60	59	73	25	60
Courses in mathematics education only*	58	49	59	70	35	57	59	71	25	75
Courses in mathematics but not in mathematics education										
Calculus level or below	57	63	67	76	35	41	54	64	10	70
Some advanced courses	67	62	64	73	37	46	68	70	24	70
Courses in both mathematics and mathematics education										
Calculus level or below	64	63	65	83	42	52	63	74	24	73
Some advanced courses	58	56	61	73	33	52	66	74	13	78
Grade point average in mathematics										
2.5 or lower	64	63	61	76	38	45	59	73	16	75
2.5001 - 3.0	61	59	60	78	31	48	66	71	16	73
Higher than 3.0	58	56	66	73	37	56	70	74	19	76

*Estimates in these categories are unstable because of the small numbers of teachers with no courses in mathematics.

SOURCE: NSF/NELS:88 Teacher Transcript Analysis

Table 3. Percentage of students in eighth-grade science classes where various areas within science were treated as major topics, by teachers' educational background: United States

Major topic in science classes	Total	Types of courses taken					Grade point average in science		
		No courses in science, or science education only	Science courses only		Both science courses and science education				
			40 credits or less	More than 40 credits	40 credits or less	More than 40 credits	2.5 or lower	2.5001-3.0	Higher than 3.0
Plants	12	0	13	4	6	16	14	13	8
Animals	15	16	18	8	12	17	20	15	10
Human biology	19	29	22	17	18	16	24	15	16
Genetics	8	0	9	4	7	10	8	7	10
Personal health	10	23	9	3	16	9	9	12	10
Earth science	57	80	54	57	63	55	57	53	60
Weather	43	45	40	52	47	40	46	37	43
Astronomy	48	16	48	49	57	44	52	42	50
Electricity	29	53	26	28	26	32	30	25	29
Mechanics	22	20	19	25	21	25	22	24	22
Heat	28	16	27	26	26	30	28	28	27
Optics	17	13	16	22	13	19	16	17	20
Chemistry	42	49	37	45	42	45	38	40	49
Atomic theory	39	42	32	42	37	43	34	38	45
Environmental science	30	48	28	28	31	32	36	28	26
Oceanography	32	16	32	45	37	27	36	29	31
Science/society	19	31	17	18	24	18	20	14	32

*Estimates in this category are unstable because of the small number of teachers with no courses in science.

SOURCE: NSF/NELS:88 Teacher Transcript Analysis

Table 4. Percentage of students in eighth-grade mathematics and science classes where teachers spent 2 or more hours per week in various activities by teachers' educational background: United States

Teachers' background	Two or more hours of instruction devoted to						
	Whole class	Small groups	Individual instruction	Maintaining order/ discipline	Administering test and quizzes	Administrative tasks	Conducting lab periods
Mathematics							
Total	81	10	18	5	3	0	1
Types of courses taken							
No courses in mathematics*	80	13	22	6	10	1	1
Courses in mathematics education only*	83	22	19	5	4	2	5
Courses in mathematics but not in mathematics education							
Calculus level or below	80	7	12	5	0	2	0
Some advanced courses	80	10	14	5	2	0	2
Courses in both mathematics and mathematics education							
Calculus level or below	80	14	30	2	2	1	3
Some advanced courses	82	7	15	5	2	0	1
Grade point average in mathematics							
2.5 or lower	76	12	22	7	5	1	1
2.5001-3.0	84	7	18	4	3	0	1
Higher than 3.0	83	9	15	3	1	0	2
Science							
Total	75	9	8	5	3	1	21
Types of courses taken							
No science courses, or science education only*	46	10	5	0	10	0	16
Science courses only							
40 credits or less	82	7	8	6	6	1	15
More than 40 credits	69	4	4	4	2	0	32
Both science courses and science education							
40 credits or less	77	12	8	7	4	1	27
More than 40 credits	71	9	8	4	1	0	19
Grade point average in science							
2.5 or lower	73	10	10	7	5	1	22
2.5001 - 3.0	77	8	5	5	3	0	23
Higher than 3.0	75	8	7	3	1	0	16

*Estimates in these categories are unstable because of the small numbers of teachers with no courses in mathematics or science

SOURCE: NSF/NELS:88 Teacher Transcript Analysis

Table 5. Percentage of eighth-grade students in mathematics and science classes whose teachers felt well prepared to teach the courses, by teachers' educational background: United States

Teachers' background	Teachers' feelings of preparedness				
	Very well prepared	Well prepared	Adequately prepared	Somewhat prepared	Totally unprepared
Mathematics					
Total	83	13	3	0	0
Types of courses taken					
No courses in mathematics*	60	31	9	1	0
Courses in mathematics education only*	67	27	4	2	1
Courses in mathematics but not in mathematics education					
Calculus level or below	77	17	2	4	0
Some advanced courses	78	17	5	0	0
Courses in both mathematics and mathematics education					
Calculus level or below	76	18	5	0	0
Some advanced courses	91	7	1	0	0
Grade point average in mathematics					
2.5 or lower	84	12	3	1	0
2.5001 - 3.0	87	11	1	0	0
Higher than 3.0	85	11	3	0	0
Science					
Total	52	30	14	4	0
Types of courses taken					
No science courses, or science education only*	49	16	0	35	0
Science courses only					
40 credits or less	37	34	22	6	1
More than 40 credits	67	17	12	4	0
Both science courses and science education					
40 credits or less	36	47	13	4	0
More than 40 credits	68	24	8	1	0
Grade point average in science					
2.5 or lower	46	29	19	5	1
2.5001 - 3.0	48	31	8	3	0
Higher than 3.0	53	31	13	3	0

*Estimates in these categories are unstable because of the small numbers of teachers with no courses in mathematics or science.

NOTE: Percentages may not add to 100 due to rounding.

SOURCE: NSF/NELS:88 Teacher Transcript Analysis

Table 6. Mean scores per student in science and mathematics eighth-grade proficiency exams, by teachers' educational background: United States

Teachers' background	Number right	Number wrong	Number not attempted	Formula score	Standardized score	Item response theory: Estimated number right	Item response theory: Formula score	Quartile[1]
Mathematics								
Total	21.9	17.2	0.8	16.4	50.4	22.1	16.4	2.5
Types of courses taken								
No courses in mathematics[2]	18.8	19.6	1.6	12.5	46.9	19.2	12.5	2.2
Courses in mathematics education only[2]	21.0	18.4	0.6	15.1	49.2	21.2	15.2	2.4
Courses in mathematics but not in mathematics education								
Calculus level or below	20.4	18.8	0.8	14.3	48.5	20.5	14.2	2.3
Some advanced courses	22.3	17.0	0.7	16.8	50.7	22.4	16.8	2.6
Courses in both mathematics and mathematics education								
Calculus level or below	20.4	18.6	1.0	14.4	48.6	20.7	14.4	2.4
Some advanced courses	22.8	16.4	0.8	17.6	51.4	23.0	17.6	2.6
Grade point average in mathematics								
2.5 or lower	21.2	17.9	0.9	15.4	49.5	21.4	15.4	2.4
2.5001 - 3.0	21.6	17.5	0.9	16.0	50.0	21.8	15.9	2.5
Higher than 3.0	23.2	16.1	0.7	18.0	51.8	23.3	18.0	2.7
Science								
Total	13.6	11.0	0.4	10.2	50.6	13.7	10.2	2.6
Types of courses taken								
No science courses, or science education only[2]	12.7	12.1	0.2	9.0	48.5	12.9	9.1	2.4
Science courses only								
40 credits or less	13.6	11.0	0.4	10.2	50.7	13.8	10.3	2.6
More than 40 credits	13.9	10.6	0.5	10.6	51.3	14.1	10.7	2.6
Both science courses and science education								
40 credits or less	13.4	11.2	0.4	10.0	50.2	13.5	10.0	2.5
More than 40 credits	13.6	11.0	0.5	10.2	50.6	13.7	10.2	2.6
Grade point average in science								
2.5 or lower	13.0	11.6	0.4	9.5	49.3	13.2	9.6	2.4
2.5001 - 3.0	13.8	10.8	0.4	10.5	51.1	13.9	10.5	2.6
Higher than 3.0	14.1	10.5	0.4	10.8	51.6	14.1	10.8	2.7

[1]Quartile ranges from 1 (lowest quartile) to 4 (highest quartile).

[2]Estimates in these categories are unstable because of the small numbers of teachers with no courses in mathematics or science.

SOURCE: NSF/NELS:88 Teacher Transcript Analysis

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Table 7. The percentage of eighth-grade science and mathematics students with various characteristics, by quality of teacher's academic preparation in the subject area: United States

Teacher's academic background	School characteristics					Class achievement levels				Student characteristics			
	More than 60% are minorities	More than half receive free lunch	Urbanicity										
			Urban	Suburban	Rural	High	Average	Low	Widely differing	Black or Hispanic	Low SES quartile	Female	5.5 hours or more of homework per week
Mathematics teachers, total	13	12	23	43	34	26	38	20	16	22	25	50	33
Types of courses taken													
No mathematics courses*	38	21	32	50	18	20	40	25	14	42	28	51	31
Mathematics education only*	14	18	42	38	21	20	27	26	28	26	27	47	30
Mathematics only													
Calculus level or below	21	16	39	31	29	20	38	24	18	32	21	51	35
Some advanced courses	12	11	20	52	27	24	41	23	11	21	23	49	33
Both mathematics and mathematics education													
Calculus level or below	11	13	17	41	42	19	41	23	17	21	29	49	33
Some advanced courses	12	11	20	42	38	31	37	17	15	19	24	50	33
Grade point average in mathematics													
2.5 or lower	14	11	25	42	33	24	33	22	21	23	26	48	32
2.5001-3.0	13	14	18	36	46	21	41	20	18	20	28	49	32
Higher than 3.0	11	12	22	48	31	33	41	17	9	21	21	52	34
Science teachers, total	11	13	22	45	33	24	37	15	24	18	23	51	33
Types of courses taken													
No science courses, or science education only*	29	0	3	45	51	53	19	12	16	39	24	58	41
Science only													
40 credits or less	13	15	19	38	42	26	36	13	26	18	26	50	33
More than 40 credits	13	9	28	52	20	22	28	18	33	24	22	49	38
Both science and science education													
40 credits or less	10	15	22	50	28	26	36	19	18	20	23	53	34
More than 40 credits	9	12	22	45	33	20	41	15	24	15	22	51	31
Grade point average in mathematics													
2.5 or lower	15	16	19	47	34	22	41	17	20	23	26	50	31
2.5001-3.0	10	11	21	55	24	22	38	15	25	18	23	50	[illegible]
Higher than 3.0	7	11	26	33	41	27	31	14	28	14	20	52	36

*Estimates in these categories are unstable because of the small numbers of teachers with no courses in mathematics or science.

SOURCE: NSF/NELS:88 Teacher Transcript Analysis

Table 8. Mean scores per student in science and mathematics eighth-grade proficiency exams, by teachers' educational background and student-related characteristics: United States

Teacher's academic background	School characteristics					Class achievement levels				Student characteristics			
	More than 60% are minorities	More than half receive free lunch	Urbanicity: Urban	Urbanicity: Suburban	Urbanicity: Rural	High	Average	Low	Widely differing	Black or Hispanic	Low SES quartile	Female	5.5 hours or more of homework per week
Mathematics teachers, total	44.6	44.5	48.8	51.2	50.3	58.7	49.4	43.0	48.0	44.7	45.0	50.1	53.4
Types of courses taken													
No mathematics courses*	43.5	41.5	43.3	47.6	48.9	52.4	47.0	39.9	48.4	43.1	41.9	45.8	49.2
Mathematics education only*	46.4	43.9	49.6	49.5	47.8	58.2	49.5	42.7	48.5	45.4	43.5	49.1	51.8
Mathematics only													
Calculus level or below	43.4	41.8	46.4	49.4	50.6	57.2	47.5	41.2	50.0	44.6	43.8	48.1	50.8
Some advanced courses	45.4	46.5	48.8	51.0	51.5	58.8	50.2	44.0	48.6	45.2	45.7	50.5	54.0
Both mathematics and mathematics education													
Calculus level or below	43.7	45.4	51.4	48.6	47.5	57.0	48.9	43.1	46.3	44.1	44.0	48.0	51.0
Some advanced courses	45.0	44.8	49.2	52.7	51.2	59.5	49.8	43.3	48.0	45.0	45.7	51.3	54.7
Grade point average in mathematics													
2.5 or lower	43.4	42.9	47.5	50.2	50.1	58.0	49.1	43.0	47.3	43.9	45.0	49.2	52.8
2.5001-3.0	43.4	44.4	47.3	51.5	49.8	59.2	49.6	42.8	47.7	44.5	44.7	50.2	52.8
Higher than 3.0	46.6	46.3	51.2	52.2	51.5	59.2	49.9	43.5	49.2	45.8	46.0	51.3	54.7
Science teachers, total	44.9	46.4	49.5	51.3	50.3	55.5	49.8	45.3	50.2	45.2	45.2	50.0	53.1
Types of courses taken													
No science courses, or science education only*	41.0	-	44.0	45.9	51.2	53.3	44.3	36.3	47.1	43.4	40.1	46.8	52.2
Science only													
40 credits or less	42.7	48.6	47.3	51.8	. .	55.3	50.0	44.7	49.7	44.4	46.0	50.3	53.3
More than 40 credits	45.9	44.2	50.5	52.2	.	55.5	49.7	48.7	51.1	45.6	42.8	50.9	53.8
Both science and science education													
40 credits or less	45.6	44.4	50.1	51.1	48.6	55.9	49.7	44.8	48.2	45.2	44.6	49.7	52.7
More than 40 credits	47.1	46.0	50.3	51.0	50.1	55.6	49.8	45.3	51.1	46.0	45.4	49.8	53.1
Grade point average in mathematics													
2.5 or lower	43.9	43.7	47.5	50.8	48.3	54.3	49.1	45.7	47.5	44.6	44.5	48.9	51.6
2.5001-3.0	46.2	44.3	49.2	51.5	51.8	55.8	49.8	45.7	51.7	45.7	44.9	50.3	53.9
Higher than 3.0	46.3	52.6	51.5	52.1	51.3	56.6	50.9	44.6	51.1	46.0	46.6	51.2	54.2

*Estimates in these categories are unstable because of the small numbers of teachers with no courses in mathematics or science.

- Not available.

SOURCE: NSF/NELS:88 Teacher Transcript Analysis

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