DOCUMENT RESUME

ED 353 131 SE 053 053

AUTHOR	Stecher, Brian M.
TITLE	Describing Secondary Curriculum in Mathematics and Science: Current Status and Future Indicators. A RAND Note.
INSTITUTION	Rand Corp., Santa Monica, Calif.
SPONS AGENCY	National Science Foundation, Washington, D.C.
REPORT NO	RAND-N-3406-NSF
PUB DATE	92
CONTRACT	NSF-SPA-8850377
NOTE	137p.
AVAILABLE FROM	RAND, 1700 Main Street, P.O. Box 2138, Santa Monica, CA 90407-2138.
PUB TYPE	Reports - Research/Technical (143)
EDRS PRICE	MF01/PC06 Plus Postage.
DESCRIPTORS	*Course Content; Curriculum; Curriculum Development; Curriculum Research; *Data Collection; *Educational Trends; Enrollment Rate; *Graduation Requirements; *Mathematics Curriculum; Mathematics Education; Measurement Techniques; *Science Curriculum; Science Education; Secondary Education; Secondary School Mathematics; Secondary School Science; Surveys
IDENTIFIERS	*Educational Indicators; National Assessment of Educational Progress

ABSTRACT

The quality of mathematics and science education in the United States and the goal of becoming first in the world in those two disciplines are topics of concern. This study attempts to describe the current condition of mathematics and science education and to evaluate the adequacy of existing national data to provide such a description. The report is presented in six sections. An introduction defines curriculum, enumerates the research questions, and describes the organization of the report. Sections 2-5 present the current status, the availability and reliability of data, and the evaluation of the strengths and weaknesses of alternative indicators for the following areas: graduation requirements; course availability; course completion; and course content. Section 6 presents conclusions and recommendations of the study. The study concluded that the existing data sources were inadequate to construct a system of curriculum indicators. The indicator patchwork pieced together did not cover all aspects of curriculum, was temporally uneven, relied on sources of uneven quality, contained measures that were not always congruent, and in sum, was inadequate for effective policymaking. The following recommendations were made to fill in data gaps and build a comprehensive curriculum indicator system: (1) ensure the continued and extended availability of graduation standards, course availability, and course completion data; (2) develop, validate, and incorporate measures of course content into ongoing data-collection efforts; (3) support research to validate and extend the information provided by ongoing data sources; and (4) develop sources for information to describe the mathematics and science curriculum at the elementary and middle school levels. Supplemental sections provide a summary, lists of tables and figures, principal data sources for building the curriculum indicator patchwork, NAEP (National Assessment of Educational Progress) variables with high rates of missing values in 1985-1986, additional tables and figures, and a list of 59 references. (MDH)

A RAND NOTE

Describing Secondary Curriculum in Mathematics and Science: Current Status and Future Indicators

Brian M. Stecher

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The research described in this report was supported by the National Science Foundation under Grant No. SPA-8850377.

Published 1992 by RAND
1700 Main Street, P.O. Box 2138, Santa Monica, CA 90407-2138

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Supported by the
National Science Foundation

RAND

PREFACE

How good are mathematics and science education in the United States? How adequately do available data describe the quality of mathematics and science education? The current widespread concern about weaknesses in the performance of American students and the adoption of a national goal of becoming first in the world in mathematics and science achievement highlight the importance of answering the first question. Recent efforts to build a system of indicators capable of monitoring progress toward this goal underscore the importance of the second question.

These two questions motivated the current study, funded by the National Science Foundation, which attempts to describe the conditions of mathematics and science education and to evaluate the adequacy of existing national data to provide such a description. This work builds upon earlier efforts by RAND to develop models of indicator systems in mathematics and science (Shavelson et al., 1987), to examine access to mathematics and science curriculum (Oakes et al., 1990), and to develop methods of extending existing curriculum descriptions (McDonnell et al., 1990). This Note explores the mathematics and science curriculum at the secondary level; a companion Note being prepared by Koretz examines student achievement in mathematics and science. A third Note (Koretz, 1992) establishes a theoretical and procedural framework for evaluating indicators, and a final Report will discuss options for improving the monitoring of mathematics and science education.

SUMMARY

There is growing concern in the United States about the quality of mathematics and science education. If this concern is to be translated into educational improvement, then information about curriculum is essential. The present study seeks to describe the condition of mathematics and science curriculum at the secondary level (including changes in curriculum during the 1980s), to evaluate the quality of that description, and to evaluate the quality of secondary-level curriculum indicators that could be produced from existing data sources. We did not attempt to establish curriculum standards or to judge the quality of the curriculum itself; rather we focused on developing indicators that would support such endeavors.

DEFINITION OF CURRICULUM

For the purposes of this Note, curriculum is defined as the mathematics-specific and science-specific features of the educational environment that determine students' opportunities to learn. Some features are defined at the classroom level, reflecting the actual content and style of instruction; other features are defined at the school, district or state levels and are more distant from instruction. The curriculum elements that will be analyzed in this Note span this range. They include: graduation requirements, course availability, course completion, and course content, including topic coverage, curriculum-specific instructional strategies, and instructional equipment and materials.

DATA AVAILABILITY AND QUALITY

The amount of data available to describe secondary-level mathematics and science curriculum is limited, and information becomes more scarce as one moves from state- or district-level features to classroom-level features, i.e., as one moves "closer" to actual instruction. In fact, without the addition of data from nonrepresentative studies, it would be almost impossible to provide any description of curriculum at the classroom level. Furthermore, it is difficult to describe curriculum trends because few of the relevant data are collected on a regular basis.

The data sources that were used in the study are listed in Table S.1. Table S.2 summarizes the completeness of the curriculum description that can be fashioned from these data.

Table S.1

Sources of Data to Describe Curriculum Features

Curriculum Feature	Ongoing Nationally Representative Data	Nationally Representative Data	Nonrepresentative Data
Graduation requirements	CCSSO, ECS, NAEP, SASS	ATS	
Course availability	NAEP	NSSME	
Course completion	NAEP	HTS	SRA
Course content Topic coverage		NELS	SIMS, SISS, SRA
Course content Instructional strategies		NAEP-86, NELS, NSSME	SIMS, SISS, SRA
Course content Equipment & materials		NAEP-86, NELS, NSSME	SIMS, SISS

Key to Abbreviations:

ATS	Administrator and Teacher Survey—High School and Beyond (1984)
CCSSO	State Educational Indicators compiled under the auspices of the Council of Chief State School Officers (annual)
ECS	Education Commission of the States survey of minimum high school graduation requirements and advanced diploma standards (periodic)
HTS	1987 High School Transcript Study
IAEP	International Assessment of Educational Practice (mathematics and science) (1989)
NAEP	National Assessment of Educational Progress (biennial)
NAEP-86	The 1985-1986 NAEP included special sections on math and science
NELS	National Education Longitudinal Study (1988 eighth grade cohort)
NSSME	National Survey of Science and Mathematics Education (1986)
SASS	School and Staffing Survey (biennial)
SIMS	Second International Mathematics Study (1982)
SISS	Second IEA Science Study (1982)
SRA	School Reform Assessment project (1989)

Table S.2

Completeness of Curriculum Description Developed from Available Data*

Curriculum Feature	Ongoing Nationally Representative Data	Nationally Representative Data	Nonrepresentative Data
Graduation requirements	HIGH	MODERATE	
Course availability	MODERATE	HIGH	
Course completion	LOW	HIGH	LOW
Course content Topic coverage		LOW	MODERATE+
Course content Instructional strategies		LOW	MODERATE+
Course content Equipment & materials		MODERATE	LOW

*HIGH indicates that the curriculum feature can be described thoroughly; MODERATE indicates that some, but not most, aspects can be described; LOW indicates that only a few aspects can be described.

+For grade eight mathematics and precalculus/calculus only.

RESULTS

Study findings relating to graduation requirements, course availability, course completion, and course content are summarized in the following sections. Recommendations regarding the selection of indicators and potential data sources are summarized in Table S.3.

Graduation Requirements

Regular state-level high school graduation requirements in mathematics and science increased markedly between 1980 and 1985 to approximately two years of coursework in each subject; these requirements have remained relatively stable since then. On the other hand, an increasing number of states (16 as of 1989) have advanced graduation standards for voluntary academically enriched diplomas, which require approximately one additional year of coursework each in mathematics and science.

Table S.3

Recommended Indicator Types and Potential Data Sources

Curriculum Feature	Types of Indicators Recommended	Potential Data Sources*
Graduation requirements	Years of math and science required for regular diploma. Years of math and science required for advanced diploma.	ECS
Course availability	Percent of schools offering individual math and science courses. Percent of schools offering combinations of college-preparatory courses.	NAEP (expanded)
Course completion	Percent of students completing individual math and science courses. Percent of students completing combinations of college-preparatory courses.	New transcript studies; NAEP (expanded and validated)
Course content Topic coverage	Research necessary to develop and validate indicators.	New data sources
Course Content Instructional strategies	Research necessary to develop and validate indicators.	New data sources
Course Content Equipment & materials	Research necessary to develop and validate measures reflecting the existence of, quality of, access to, or use of instructional resources.	NAEP (expanded); new data sources

*Data collection must be designed to permit comparisons of curriculum opportunities between groups of students and schools.

Key to Abbreviations:

ECS Education Commission of the States survey of minimum high school graduation requirements and advanced diploma standards (periodic)

NAEP National Assessment of Educational Progress (biennial)

The growing use of alternative graduation standards means that at least two indicators of graduation requirements should be included in a comprehensive indicator system: one focusing on regular coursework requirements in mathematics and science, the other on standards for voluntary advanced diplomas. Two such measures would provide a reasonably valid indication of the status of state standards as presently constituted; neither is likely to be corrupted if included in a national indicator system. However, it would be a mistake to place too much emphasis on measures of graduation requirements as key indicators of curriculum; they describe only minimum conditions and do so in only the most general terms. They do not portray the distribution of courses or course taking across schools and students, nor do they differentiate between courses based on title, level or rigor.

Course Availability

With minor exceptions, course availability has changed little over the past decade. Basic and intermediate college-preparatory mathematics and science courses are available in over 90 percent of all high schools, as is at least one course in computer literacy or computer science. On the other hand, advanced courses, particularly advanced mathematics courses, are unavailable to large numbers of students. Physics, the most common advanced science course, is unavailable in 20 percent of all high schools, while advanced mathematics courses (such as calculus) are not available in 25 percent of all high schools. Life science, earth science, physical science, and statistics are the exceptions to the trend of stable course availability; each of these courses is available currently in one and one-half to two times as many high schools as a decade ago.

Although all schools are likely to offer at least one section of basic and intermediate mathematics and science courses, there are substantial differences between schools in the availability of advanced mathematics and science courses. Students attending urban schools with the lowest parent-occupation profiles (i.e., a small percentage of parents employed in professional or managerial jobs and a large percentage of parents unemployed or on welfare) are up to five times less likely than students attending urban schools with the highest parent-occupation profiles (i.e., a large percentage of parents employed in professional or managerial jobs and a small percentage unemployed or on welfare) to be offered advanced mathematics and science courses. Similarly, students attending small schools are two to three times less likely than students attending large schools to be offered such courses, and students in schools with a high percentage of minority students are one and one-half times less likely to be offered advanced courses than students in schools with a low percentage of minority students. Furthermore, these between-school differences in course availability increase as the level of the course increases, with the greatest differences occurring in college-equivalent courses, such as Advanced Placement courses.

In order to adequately describe course availability, at least two indicators are recommended, one focusing on the availability of individual mathematics and science courses, the other on the availability of combinations of college-equivalent courses in mathematics and science (e.g., geometry *and* trigonometry; biology, chemistry *and* physics; etc.). In each case it is important to be able to analyze the data by school and student characteristics to highlight differential access to courses.

Unfortunately, current data sources will have to be modified to support such indicators. Moreover, additional research on the validity of course availability indicators is needed. For example, there is evidence that courses with the same title can differ markedly in content. There also is some concern that measures of course availability will be corrupted in a high-stakes indicator environment, e.g., if schools offer advanced courses of lower quality in an attempt to improve their standing with respect to this indicator.

Course Completion

The majority of high school graduates complete a core of basic and intermediate mathematics and science courses. In contrast, fewer than one-quarter of high school graduates complete advanced mathematics and science courses, although advanced courses are available in the majority of schools.

Course completion rates have been increasing for almost all mathematics and science courses, and the increases are proportionally greatest for intermediate and advanced courses. For example, the percent of graduates who completed trigonometry, analysis/precalculus, chemistry, or physics increased roughly 50 percent between 1982 and 1987. Some of the increase in course completion rates may be due to the marked increase in graduation requirements between 1982 and 1987. Another factor may be the growing emphasis on mathematics and science as critical tools in an increasingly technological world.

Unfortunately, differences in course completion rates among population groups are large and have been growing. Asian and white students complete intermediate mathematics and science courses at a rate two to three times greater than black and Hispanic students, and the differences increase as the level of the course increases. Differences are greatest in mathematics, where course completion rates have been growing 50 percent to 100 percent faster for white students than for Hispanic or black students, and 100 percent to 400 percent faster for Asian students than for Hispanic or black students. The same differences in completion rates between population groups are found in science, but changes over time have been somewhat more uniform. The only completion rate difference that is increasing is the gap between Asian students and all others.

In contrast, males and females complete most math and science courses in equal ratios. The only gender-related differences in course completion occur in advanced science courses: approximately 50 percent more males than females complete three years of science, including physics.

There also are associations between course taking (self-reported by students in 11th grade) and school characteristics. For example, 11th grade students who attend urban schools with the highest parent-occupation profiles and schools with few students receiving subsidized lunches are two to three times more likely than their counterparts in schools with the opposite characteristics to complete intermediate mathematics and science courses. Similarly, 11th grade students in larger schools, in low-minority schools, and in Catholic and private schools are somewhat more likely to complete intermediate mathematics and science courses than students in small schools, high-minority schools and public schools. Moreover, these differences in course taking are larger than the corresponding differences in course availability, and therefore cannot be explained completely by them. In general, the relationships between course taking and school characteristics are stronger in mathematics than in science.

Two indicators of course completion are recommended, one focusing on completion of individual mathematics and science courses and one on completion of combinations of courses that characterize the college-preparatory sequence (e.g., geometry *and* trigonometry; biology, chemistry *and* physics, etc.). In each case it is important to be able to analyze the data by school and student characteristics to highlight differential course completion patterns.

The same concerns raised regarding the validity of course availability indicators apply to indicators of course completion. In particular, measures of course taking based on student self-reports may be subject to corruption if used as elements of a national indicator system; transcript-based indicators would be more robust.

Course Content

Very few aspects of course content can be described adequately using existing data. Most importantly, little is known about the actual topics that are covered or the manner in which they are presented.

The only aspects of course content that can be described even marginally adequately are the availability and use of instructional resources, such as textbooks, laboratory facilities, computers, and calculators. For example, a small number of different textbooks are used almost universally in mathematics and science classes. However, this commonality of textbooks does not translate into a uniformity of content, because teachers do not cover the same proportion of the textbooks.

Computers or computer terminals are available in almost all schools, and the number of computers grew rapidly during the preceding decade. However, the ratio of computers to students is still low (approximately 1 to 30 in 1986). Only slightly more than half of all schools have enough computers in one location for a full classroom to use them, and fewer than 30 percent of mathematics and science teachers have computers that are readily accessible to them. Finally, less than 10 percent of student computer use is for the study of mathematics or science.

Similarly, although most schools have calculators (the percentage of schools with calculators has grown from 77 percent to 94 percent in the past decade), a minority of students actually use calculators in mathematics or science classes.

Instructional resources are not evenly distributed across schools and classrooms. For example, laboratory facilities of one type or another are available in almost three-quarters of all high schools; however, specialized science laboratories of the type associated with advanced science courses are found twice as often in larger schools than in smaller ones and in urban schools with high parent-occupation profiles than in urban schools with low parent-occupation profiles. Similarly, schools with relatively high parent-occupation profiles, low-minority schools, and non-inner city schools have more computers, calculators, and other instructional resources available than other schools.

At least one indicator of instructional materials should be included in a comprehensive curriculum indicator system. Such an indicator might be defined on the basis of the existence of selected resources, the quality of the resources, the ease of access to these resources for teachers or students (whoever is the predominate user of the resources), or the actual use of the resources. Additional research is needed to explore the role of such equipment in instruction and the validity of alternative measures before a specific indicator can be recommended.

In contrast, there are no ongoing, nationally representative sources of information about topic coverage or instructional strategies. Considerable research would be necessary to define and validate appropriate measures of these aspects of course content and to decide which measures to incorporate into an indicator system. Furthermore, course content measures (which often are based on self-reports) are particularly susceptible to corruption in a high-stakes environment. Caution must be exercised to ensure that such measures are defined and collected in ways that accurately depict the construct of interest rather than merely influence reports about it.

CONCLUSIONS

Unfortunately, it is not possible to construct an adequate system of curriculum indicators based on existing data sources. The indicator patchwork pieced together from existing sources is incomplete or uneven in four important ways. First, the patchwork does not cover many important aspects of curriculum; i.e., there are significant gaps in our ability to describe opportunities to learn mathematics and science. Second, the patchwork is temporally uneven. Some data are current, others are almost a decade old; some are updated biennially, some quadrennially, and others are unlikely to be updated for a decade. Third, the patchwork is of uneven quality. To fill in some gaps it is necessary to rely on data from less well-implemented or less rigorous surveys; other gaps cannot be filled at all. Fourth, measures drawn from different data sources are not always congruent, so it may not be possible to draw desired comparisons.

As a result, our knowledge of the status of mathematics and science curriculum in U.S. secondary schools is inadequate for effective policy making. The greatest gaps in our knowledge of curriculum occur at the classroom level: little is known about the actual content of courses or the manner in which content is presented. At the present time, a patchwork indicator system can provide a picture of curriculum that is adequate only if we are willing to ignore such classroom-level variation.

The lack of information about course content is a serious deficiency. Measures of course completion do not adequately reflect students' exposure to specific mathematical and scientific knowledge and patterns of thought, nor do they reveal the full extent of differences in curriculum opportunities. This limits the value of these measures as a monitoring tool. Furthermore, current reform efforts focus on the content and process of mathematics and science education. The curriculum patchwork that can be assembled from existing data is insensitive to changes likely to be engendered by such reforms, so the patchwork is of limited value for monitoring the effects of these efforts.

The partial picture that can be portrayed from existing data reveals that some students have access to broader curriculum opportunities than others, and these differences are not random variations but systematic differences associated with identifiable conditions. It is critical that such differences be more closely monitored through a mechanism such as an indicator system so that problems can be identified, addressed, and, hopefully, alleviated.

RECOMMENDATIONS

Although this analysis revealed serious deficiencies in our ability to describe mathematics and science curriculum and to monitor curriculum changes, most of these deficiencies can be remedied through additional research and data collection. There are four broad areas of action the National Science Foundation (NSF) might consider to fill the gaps in the existing data network and to build a comprehensive curriculum indicator system.

First, although existing sources provide basic data about graduation standards, course availability, and course completion, there are no assurances that these data will continue to be available on a regular basis in the future. It is likely that data on the first two of these features—graduation requirements and course availability—will continue to be collected (by the National Assessment of Educational Progress (NAEP), the Education Commission of the States (ECS), the Council of Chief State School Officers (CCSSO), or other agencies), but this is not a certainty. Neither the National Assessment Governing Board nor the leadership of the Education Commission of the States has specific reasons to collect these data in a style and format appropriate for curriculum indicators. It might be prudent to act to ensure the continued availability of these two types of core data in an appropriate format.

Course completion measures pose a greater problem because complete data are not collected in any ongoing surveys. Only incomplete self-reported measures of course taking are available through NAEP. There are two ways this deficiency might be remedied—new transcript studies or modifications to NAEP. The most reliable course completion data come from transcript studies, and the most satisfactory solution would be to take actions to ensure that regular transcript studies were conducted. As an alternative, NAEP course-taking measures could be expanded to provide a basis for course completion indicators. This would require extending the range of courses on which students were asked to report. It also would require supplemental research to validate these self-reported data against transcript-based results, because it would be unwise to rely on modified NAEP course-taking measures without such validation research.

Second, the greatest gap in current curriculum data concerns course content. A comprehensive curriculum indicator system should be able to describe the content of mathematics and science courses and how this content is presented to students. To accomplish this, measures of course content would have to be developed, validated, and incorporated into ongoing data-collection efforts. NSF already has funded promising research to investigate alternative coursework indicators at the eighth grade level, but much more research is needed to complete this developmental work and to broaden the scope to include subject matter content and instructional strategies at multiple grades.

Third, an indicator system requires ongoing maintenance; it is not enough merely to collect data and compute indicators. Supplemental research is needed to validate and extend the information provided by ongoing data sources. Such research would include validation of specific indicator alternatives, examination of the relationship between curriculum measures and other student outcomes, and targeted studies of specific topics of interest within and across mathematics and science curriculum domains. The maintenance of an indicator system requires an ongoing commitment of resources for such supplemental development and validation research.

Finally, more information is needed to describe the mathematics and science curriculum at the elementary and middle school levels. It is clear from the Second International Mathematics Study (SIMS) and the National Education Longitudinal Study (NELS) that curriculum differentiation has begun already by the eighth grade; it would be valuable to understand much more about the presentation of mathematics and science prior to that grade level. Few sources exist to describe elementary mathematics and science curriculum, so much work would have to be done to fill this gap. It would be necessary to develop surveys to gather relevant data and to define and validate curriculum indicators based on these data.

The National Science Foundation has a number of options regarding curriculum indicators, from fully funding all four of the efforts described above to taking no actions at all. While all four components would be necessary to have an ongoing, comprehensive, and valid mathematics and science curriculum indicator system, they are not equally important. Moreover, the actions suggested above do not have equal priorities for NSF.

It is likely that most of the desired information about graduation standards and course availability will continue to be collected by other organizations. These are the two areas of curriculum where the potential to build a valid indicator patchwork is the greatest. However, small changes and modifications to the work of ECS, NAEP, and CCSSO would increase the value of these data for use in an indicator system. NSF might try to influence or coordinate the design of these surveys so they better meet the needs of an indicator system.

Producing appropriate course completion data may require a somewhat larger effort on the part of NSF. Although an expansion of NAEP course-taking measures conceivably could be accomplished at little cost, it would have to be accompanied by validation research. Transcript studies are the preferred alternative, but such studies are expensive. However, since transcript studies provide data of value to many educational constituencies, it might be possible to develop a collaborative arrangement among educational agencies to share the costs of regular studies of this type.

The most significant gap in our ability to describe mathematics and science curriculum involves course content. NSF has already recognized the importance of this problem, and it has sponsored research to explore the development of coursework measures. These efforts satisfy a need that is largely unmet through other sources, and the agency should consider continuing or even expanding this work until the potential for such indicators is better understood.

Another area in which NSF's efforts may yield significant returns is the ongoing enhancement and validation of the basic curriculum indicators derived from other surveys. No other group is actively supporting this important work. Such research is necessary to maintain the quality of the existing incomplete patchwork, to validate additional secondary-level curriculum indicators, and to provide information about other issues of interest within and across mathematics and science curriculum domains.

Once a broad secondary-level curriculum indicator system is operational, attention should turn to curriculum opportunities in earlier grades. Existing data suggest that it is important to monitor students' exposure to mathematics and science at the elementary and middle school levels. However, by postponing development of elementary indicators for a time, future work on this topic can benefit from the research done at the secondary level. Resources might be used more efficiently as a result. A study to investigate the costs and feasibility of developing elementary and middle school curriculum indicators in mathematics and science might be a reasonable first step toward a more complete set of elementary and middle school curriculum indicators.

ACKNOWLEDGMENTS

Acknowledgments are due to many people for the contributions they made to this study. Richard Berry and others at the National Science Foundation were helpful and patient. My colleagues at RAND and UCLA provided valuable assistance throughout the study: Daniel M. Koretz, Leigh Burstein, and Jeannie Oakes helped to conceptualize and organize the study; Tor Ormseth, Patricia Camp, Carol Edwards, and Kathy Rosenblatt assisted with data analysis and reporting; Gary Bjork helped to refine my prose; and Melinda Phelps and Valeria Wright were patient and efficient in the production of tables and text. Careful review and insightful suggestions from Senta Raizen of the National Center for Improving Science Education greatly enhanced the quality of this Note.

CONTENTS

FIGURES.

TABLES

1. INTRODUCTION

Why should anyone be interested in educational indicators, particularly indicators of curriculum in mathematics and science? The short answer is that the ability to describe the status of the educational system is a critical element in efforts to improve it, and that the opportunity to learn mathematics and science, i.e., the curriculum, is one of the most important determinants of student achievement in these subjects. The long answer, which fills the next page or two, supplements this explanation with a description of why this issue is important at the present time and how this study relates to other attempts to describe the educational system.

Over the past few years, there has been growing concern about the effectiveness of the educational system in the United States. Educators are questioning the effectiveness of a system that has been marked by declining or static scores on college entrance examinations, increasing numbers of drop-outs from high school, and increasing doubts about the qualifications of teachers. Policymakers are questioning whether schools are producing the skilled work force necessary to be competitive in the 21st century.

Amid this climate of concern, the president and state governors held an educational summit in 1989 and established national goals for education for the year 2000. Reminiscent of the post-Sputnik goal of being the first to the moon, the assembled politicians declared that students in the United States should be first in the world in mathematics and science achievement by the year 2000. With these lofty aspirations in place, educators and policymakers now are confronted with the daunting task of achieving them.

How can educational indicators contribute to this process? The chief function indicators can perform is to monitor our progress toward achieving these goals. Modern engines are built with internal sensors to monitor the status of critical components, and mechanics interpret the information provided by these sensors to tune engines to achieve maximum performance. It is hoped that educational indicators can be developed to serve a similar function, i.e., to describe the performance of students, teachers, and schools, in a manner that is accurate and of value to policymakers.

If there had not already been an effort under way to develop national indicators of education, then the ratification of the president's goals would certainly have sparked such development. Fortunately, people have been concerned about measuring the performance of the educational system for over a decade (Harnischfeger and Wiley, 1975; Breland, 1976;

Koretz, 1986; Mullis and Jenkins, 1990), and much work has already been done to describe important aspects of schooling, particularly student achievement.

Unfortunately, measures of student performance such as standardized achievement tests, the SAT and ACT examinations, and the National Assessment of Educational Progress (NAEP) offer little guidance for educational improvement. To use a metaphor from athletics, achievement data do a reasonable job of telling the score (we were falling behind throughout the 1970s and early 1980s but began to stabilize and even improve in the latter part of the 1980s), but they tell us nothing about how to improve it.[1] Policymakers need information similar to that contained in playbooks and game highlight films, e.g., descriptions of strategies and successful performances that show how more points can be scored.

Over the past five years, there have been a number of efforts (including some sponsored by the National Science Foundation [NSF]) to develop methods for monitoring the status of the educational system as a whole (Raizen and Jones, 1985; Blank, 1986; Gilford, 1987). Most of these activities focused on the development of a small set of indicators that could be used to track key features of education (Kaagan and Coley, 1989; Murnane and Raizen, 1988; the Council of Chief State School Officers [CCSSO] 1987). The most comprehensive efforts used explicit models of schooling as the basis for selecting critical elements for inclusion in the monitoring system (Shavelson et al., 1987). This approach increases the likelihood that the information provided by the indicators will be relevant to school improvement.[2]

Measures of curriculum were essential elements in many of these models (Murnane and Raizen, 1988; Oakes, 1989; McDonnell et al., 1990) because curriculum is a key element of schooling and one of the chief determinants of student outcomes. Furthermore, the distribution of curriculum is an important measure of educational equity (Oakes et al., 1990). A reasonable portrayal of the educational process requires some attention to the curriculum.

DEFINING CURRICULUM

What do we mean by curriculum? For the purposes of this Note, curriculum refers to the mathematics-specific and science-specific features of the educational environment that determine students' opportunities to learn. Some of these features are determined at the district or state level, including minimum graduation standards and other requirements that guide students' choices of courses.

[1]For additional analysis of the appropriateness of achievement scores for "telling the score," see Koretz, 1992.

[2]One of the challenges in developing an indicator system is to balance comprehensiveness with practicality, i.e., to identify a small set of statistics that describe important educational constructs.

Other features are determined at the school level. These include the syllabi and textbooks that help to define the content of instruction. Also included are other enabling conditions that affect students' opportunity to learn mathematics and science, such as the courses that are offered and the instructional resources that are made available.

Finally, many aspects of curriculum are determined at the classroom level. Classroom features include the traditional notion of curriculum as the substance of instruction, i.e., *what* is taught. This means the specific topics in the domains of mathematics and science that are presented to students. The classroom-level features also include certain content-specific aspects of *how* material is presented, such as the teacher's choice of representations to use to operationalize particular concepts, the teacher's goals for student learning in mathematics and science, the materials or equipment used to illuminate information, etc. We consider these instructional variables to be elements of curriculum because they directly affect students' opportunity to learn specific content. (Excluded from this definition are more general pedagogical variables, such as pacing, management style, etc.) Together these classroom-level features can be thought of as defining course content.

In combination these state-, district-, school-, and classroom-level features interact to create the mathematics- and science-specific environment in which student learning takes place. This environment includes: what's required, what's available, what's elected, what's presented, how it's presented, and how it's supported. One may think of it as a continuum of curriculum influences, ranging from those "close to" classroom instruction to those that affect student opportunities only at a "distance," and we will use this metaphor as a way of organizing the presentation of data about curriculum in subsequent chapters.

It also is helpful when talking about curriculum to distinguish between official policy, actual practice, and the impact of curriculum on students. Crosswhite et al. (1986) differentiated between the intended curriculum (defined at the system level by course offerings, course outlines, syllabi, and textbooks), the implemented curriculum (defined at the school and classroom levels by the courses elected by students, the equipment and materials available, and the specific topics and approaches chosen by teachers), and the attained curriculum (defined at the student level by the body of knowledge and attitudes imparted to students). This Note is concerned with the first two aspects: curriculum policy and curriculum practice. Koretz is preparing a companion Note that explores the effects of schooling on student achievement.

Due to the limitations of the available data, we are not able to explore all of the aspects of curriculum others have identified as important. For example, there is little or no information about the scientific and mathematical accuracy of the curriculum or its pedagogical quality (Murnane and Raizen, 1988). Similarly, it is not possible to conduct a thorough examination of the depth of the curriculum or the sequence of presentation (Oakes and Carey, 1989). Finally, existing data provide no basis for monitoring broader elements of the school context, such as press for achievement, that affect students' coursework choices and performance (Oakes, 1989).

We use available data to describe four distinct aspects of mathematics and science curriculum. These elements range from broad state-level policies (such as minimum graduation standards) to specific classroom-level features that define course content (such as topic coverage, instructional strategies, and materials). Four important curriculum elements will be explored in subsequent chapters:

- Graduation requirements
- Course availability
- Course completion
- Course content, including
  - Topic coverage
  - Curriculum-specific instructional strategies (e.g., mathematical or scientific goals, choice of representation, etc.)
  - Instructional equipment and materials

RESEARCH QUESTIONS

The specific goals of this study were to describe the current conditions of mathematics and science curriculum at the secondary level and to evaluate the quality of that description. First, a patchwork of curriculum statistics was drawn from existing data sources to portray the current status of secondary mathematics and science curriculum (Shavelson et al., 1987). Second, the soundness of the data was evaluated, the major gaps in the description of secondary curriculum drawn from the data sources were identified, and recommendations were made for changes in data collection. Third, alternative indicators of secondary curriculum were evaluated, and recommendations were made for adopting a small number of indicators and for conducting additional research on indicator development. We did not attempt to judge the quality of the curriculum nor to establish curriculum standards; rather, we focused on constructing a database that would support these endeavors and others.

This study addressed the following specific research questions regarding mathematics and science curriculum at the secondary level:

- What is the status of the curriculum? Specifically, how has curriculum changed over time; how evenly is the curriculum distributed across schools and students?
- Are reliable, representative data available on a regular basis to describe the curriculum?
- What are the strengths and weaknesses of alternative curriculum indicators? Are they valid for the intended purposes and resistant to corruption?

The Current Status of Secondary Mathematics and Science Curriculum

At the broadest level, a system of curriculum indicators should answer the following questions: What is the nature of the educational opportunities offered to students in mathematics and science? What mathematical and scientific content (knowledge, skills, and experiences) is presented to students and how is it presented? For the purposes of this presentation, these general questions have been translated into two specific research questions, one focusing on curriculum trends, the other focusing on the distribution of curriculum across policy-relevant groups of schools or students. For each curriculum construct presented in subsequent chapters, information will be presented to answer these questions.

Whenever possible, the answers to these questions will be based on current, reliable, nationally representative data. When such information does not exist, results from exploratory studies may be used to suggest the current status of that particular aspect of curriculum.

Data Limitations

Unfortunately, there are both practical and theoretical constraints on the description of secondary mathematics and science curriculum. On the practical level, existing data sources simply do not provide a complete picture of the curriculum. The amount of information declines as the focus changes from the curriculum as intended (in the form of graduation requirements and course titles) to the curriculum as implemented (in the form of topic coverage, instructional strategies, and materials).[3] Moreover, the data that are available to describe curriculum are of uneven quality; some are quite reliable, valid for use in the manner intended, and resistant to corruption; others are less so. On the theoretical level, there is no widely accepted framework for describing some aspects of the secondary

[3]The problem was worse at the elementary and middle school level. So few data were available that it was impossible to include elementary and middle school curriculum in this study.

mathematics and science curriculum, notably course content. (This may account, in part, for the paucity of data on course content.)

As a result, the indicator patchwork that can be assembled provides an incomplete and inconsistent answer to basic questions about curriculum. One of the purposes of this study was to examine how adequate existing data are to support an indicator system.

Primary Data Sources

The number of nationally representative studies that assess aspects of secondary-level mathematics and science curriculum is quite small (and the number of ongoing studies that provide regular updates is even smaller). In fact, it is not possible to build an adequate picture of curriculum without drawing upon results from nonrepresentative studies. Even with the inclusion of large-scale nonrepresentative studies, the number of independent sources of information regarding curriculum is small; only a dozen data sources were used to generate the vast majority of the results reported in this Note. Table 1.1 lists each of these studies and classifies them with respect to curriculum features, representativeness and regularity. The studies are described in detail in Appendix A. Table 1.2 summarizes the completeness of the curriculum description that can be produced using these data.

Evaluating Indicators

Another of the major tasks of this research was to evaluate potential indicators of secondary mathematics and science curriculum. Traditionally, educational measures (tests, inventories, etc.), are evaluated in terms of reliability and validity, and these criteria are appropriate for evaluating indicators as well. Reliability is the degree to which a measure is free from random measurement error. A measure is reliable if it produces a consistent result—either internal consistency (one part with another) or consistency across scorers, administrations, or other conditions of measurement. Reliability can be established by determining the invariance of measures across different conditions of measurement.

Validity is the degree to which a measure supports the inferences being drawn from it. Measures are not valid in and of themselves; they are only valid with respect to a particular inference. Depending upon the inference being made, validity might be established, like reliability, by examining the consistency of results. It might also be established by comparing the content of the measure with the content of the domain it purports to represent, comparing the pattern of results among measures of similar and dissimilar constructs, and/or comparing results of the measure with results of some external criterion whose validity is not in question. In the present context, a useful indicator of validity is the invariance of results across alternative measures and alternative conditions of measurement.

Table 1.1

Sources of Data to Describe Curriculum Features

Curriculum Feature	Ongoing Nationally Representative Data	Nationally Representative Data	Nonrepresentative Data
Graduation requirements	CCSSO, ECS, NAEP, SASS	ATS	
Course availability	NAEP	NSSME	
Course completion	NAEP	HTS	SRA
Course content Topic coverage		NELS	SIMS, SISS, SRA
Course content Instructional strategies		NAEP-86, NELS, NSSME	SIMS, SISS, SRA
Course content Equipment & materials		NAEP-86, NELS, NSSME	SIMS, SISS

Key to Abbreviations:

ATS	Administrator and Teacher Survey—High School and Beyond (1984)
CCSSO	State Educational Indicators compiled under the auspices of the Council of Chief State School Officers (annual)
ECS	Education Commission of the States survey of minimum high school graduation requirements and advanced diploma standards (periodic)
HTS	1987 High School Transcript Study
IAEP	International Assessment of Educational Practice (mathematics and science) (1989)
NAEP	National Assessment of Educational Progress (biennial)
NAEP-86	The 1985–1986 NAEP included special sections on math and science
NELS	National Education Longitudinal Study (1988 eighth grade cohort)
NSSME	National Survey of Science and Mathematics Education (1986)
SASS	School and Staffing Survey (biennial)
SIMS	Second International Mathematics Study (1982)
SISS	Second IEA Science Study (1982)
SRA	School Reform Assessment project (1989)

Table 1.2

Completeness of Curriculum Description Developed from Available Data*

Curriculum Feature	Ongoing Nationally Representative Data	Nationally Representative Data	Nonrepresentative Data
Graduation requirements	HIGH	MODERATE	
Course availability	MODERATE	HIGH	
Course completion	LOW	HIGH	LOW
Course content Topic coverage		LOW	MODERATE+
Course content Instructional strategies		LOW	MODERATE+
Course content Equipment & materials		MODERATE	LOW

*HIGH indicates that the curriculum feature can be described thoroughly; MODERATE indicates that some, but not most, aspects can be described; LOW indicates that only a few aspects can be described.

+For grade eight mathematics and precalculus/calculus only.

Koretz (1992) reviews likely threats to reliability and validity of indicators and concludes that testing the robustness of the results is a key element in assessing both criteria. This includes asking whether the results are consistent across data sources (e.g., NAEP versus National Survey of Science and Mathematics Education [NSSME]) and alternative measures (courses available versus courses selected). It also relates to the question of corruptibility, i.e., whether measures continue to support the same inferences in different contexts (e.g., whether scores improve in a high-stakes environment, such as a national indicator system, even though the underlying constructs may not have improved).

We used these general criteria as bases for evaluating alternative formulations of indicators. Particular attention was paid to the potential validity of measures (including their resistance to corruption) in an indicator environment.

ORGANIZATION OF THIS NOTE

Each of the four major aspects of curriculum is addressed in a separate chapter, beginning with graduation requirements. The sequence of chapters is arranged in a "top down" order, from more distal state- and district-level features of curriculum to more proximal school- and classroom-level features. Each chapter describes the current status of one aspect of the secondary curriculum, provides a more detailed analysis of the availability and quality of data to support indicators of that aspect of the curriculum, and evaluates alternative formulations for indicators. Particular attention is paid to the likelihood that alternative indicators would be corrupted in a high-stakes context. The final chapter summarizes the results of the study and offers recommendations regarding the development of an effective curriculum indicator system.

This Note is part of a larger effort to assess the status of precollege mathematics and science education and evaluate the efficacy of a patchwork indicator system. The other parts of the study address the status of student achievement in mathematics and science and appropriate measures of reliability and validity in the context of educational indicators (Koretz, 1992). The final report of the project will examine the overall condition of mathematics and science education across these three areas and evaluate indicator options.

2. GRADUATION REQUIREMENTS

This chapter addresses three issues: the current status of graduation requirements in mathematics and science, the availability and quality of data to describe these requirements, and the strengths and weaknesses of alternative graduation requirement indicators. Each section begins with a statement of the fundamental question that guided the investigation followed by a detailed presentation of relevant information.

CURRENT STATUS

What course requirements in mathematics and science must students complete to earn a high school diploma, and how have these requirements changed over time?[1]

Two types of graduation requirements have been adopted by state and local boards of education: standard requirements that apply to all students, and supplemental or advanced requirements that apply to a subset of students who elect to pursue advanced study. These requirements are described in the following sections.

Regular Graduation Requirements

At least 45 states establish specific minimum requirements for high school graduation. In the remainder of the states, the authority for setting graduation standards has been delegated to local boards of education (or it resides with them constitutionally). With the exception of these five states, state-level standards define the minimum educational requirements for a regular high school diploma. In all cases, the basic requirements describe conditions that must be met during a student's last four years of schooling, grades 9 through 12.

Table 2.1 shows the student-level average number of years of mathematics and science courses required for graduation. These values rose substantially between 1974 and 1985 and have remained essentially unchanged since then.

State requirements, although they are the most prominent, are not the only graduation standards that apply to students. In many instances, state standards are supplemented by district and/or school requirements, increasing the cumulative graduation standards that must be met by students. In theory, one should be able to determine graduation requirements enacted at any administrative level: state-level, district-level,

[1]Graduation requirements apply equally to all students within a jurisdiction, so there is no need to examine the distribution across different groups of students.

Table 2.1

State-Imposed Regular Graduation Requirements in Mathematics and Science

	Mean Number of Years Required by Typical Student*						
Subject	1974	1980	1983	1985	1987	1989	1990
Mathematics	.74	87	1.6	2.0	2.1	2.1	2.1
Science	.81	.84	1.4	1.7	1.8	1.8	1.8

* Based upon total K-12 enrollments reported in 1976, 1981, 1986 and 1989.

SOURCES: National Association of Secondary School Principals, 1975 & 1980; Education Commission of the States, 1983 & 1990; Council of Chief State School Officers, 1987 & 1990; Center for Education Statistics, 1987; National Center for Education Statistics, 1989; Clune, 1989.

school-level or cumulative. In practice, the only data that are available from existing sources are those that reflect cumulative requirements across all levels.

Graduation requirements established by local boards and schools in the absence of (or as a supplement to) state requirements exceed somewhat those promulgated by states. Table 2.2 shows the school-level (in some cases district-level) average number of years of mathematics and science required to meet all state and local graduation requirements. These values have been increasing gradually over time, although changes in the level at which the data were collected may account for some of these differences.

Advanced Graduation Standards

A number of states have established standards for advanced diplomas in addition to their regular graduation standards. There are various designations for these programs, including "advanced studies," "academic scholars," "college-preparatory studies," etc. The advanced standards differ from the regular ones in many ways, including the number of required courses in particular subjects, the type and level of required courses, the number of

Table 2.2

Cumulative Regular Graduation Requirements in Mathematics and Science (As Reported by Schools and Districts)

	Mean Number of Years Required by Schools				
Subject	1982	1984	1986	1987*	1988*
Mathematics	1.7	1.9	1.6	2.3	2.4
Science	1.5	1.6	1.4	2.0	2.1

*Mean number of years required by districts.

SOURCES: RAND tabulations of data from the 1985–1986 National Assessment of Educational Progress, RAND tabulations of data from the 1987–1988 School And Staffing Survey.

electives, the establishment of minimum grade point averages, and the use of qualifying examinations. The number of states enacting such standards grew from 6 to 16 between 1985 and 1990. Furthermore, in 14 of the 16 states, the new requirements included additional coursework or examinations in mathematics or science. The average (across 14 states) number of years of mathematics and science courses required for advanced graduation is displayed in Table 2.3, and the mean difference (across 14 states) between advanced and regular graduation standards over time is shown in Table 2.4.

AVAILABILITY AND RELIABILITY OF DATA

Are reliable, representative data available on a regular basis to describe high school graduation requirements?

Data Availability

Until recently, there was no ongoing national survey of state graduation requirements. Data for the analysis of regular graduation requirements were drawn from a number of

Table 2.3

State-Imposed Advanced Graduation Requirements in Mathematics and Science

	Mean Number of Years Required					
Subject	1974 (3 states)	1980 (2 states)	1983 (2 states)	1985 (6 states)	1987 (13 states)	1990 (14 states)
Mathematics	1.7	1.5	2.0	2.8	3.1	3.1
Science	1.3	1.5	1.5	2.5	2.9	2.9

SOURCES: RAND tabulations of data from the Center for Education Statistics, 1987; National Center for Education Statistics, 1989; the National Association of Secondary School Principals, 1975 & 1980; and the Education Commission of the States, 1983 & 1990.

Table 2.4

Difference Between State-Imposed Regular and Advanced Graduation Requirements in Mathematics and Science

	Mean Number of Years Required					
Subject	1974 (3 states)	1980 (2 states)	1983 (2 states)	1985 (6 states)	1987 (13 states)	1990 (14 states)
Mathematics	1.0	0.5	1.0	0.7	0.9	0.9
Science	0.3	0.5	0.5	0.5	0.9	0.8

SOURCES: RAND tabulations of data from the Center for Education Statistics, 1987; National Center for Education Statistics, 1989; the National Association of Secondary School Principals, 1975 & 1980; and the Education Commission of the States, 1983 & 1990.

different sources,[2] and data regarding advanced diploma standards came from CCSSO (1990) and the Education Commission of the States (ECS, 1990).

The irregular and uncoordinated nature of the data collection efforts raised questions about the availability of information in the future. An unofficial, catch-as-catch-can approach does not provide the ongoing flow of data needed to support an indicator system. Fortunately, it appears that one organization, the ECS, has assumed the responsibility for collecting and updating these data on a periodic basis.[3] (In recent years, data on advanced state diploma standards also have been included in the database.) This provides some of the continuity that was lacking when no one group took responsibility for collecting information regarding state graduation requirements. However, since no federal funds are provided to support the collection of these data, their continued availability depends upon the interests and resources of an independent organization. Furthermore, it will continue to be difficult to assess data quality without direct monitoring of data collection and analysis or independent verification of results.

Data for generating estimates of cumulative regular graduation requirements (state-, district- and school-level requirements combined) were collected by three national school-level surveys: the 1984 High School and Beyond Administrator and Teacher Survey (ATS), the 1985-1986 National Assessment of Educational Progress (NAEP), and the 1988 School and Staffing Survey (SASS). Unfortunately, as Table 2.2 revealed, the three sources do not paint a consistent picture of cumulative requirements; the 1986 NAEP results are inconsistent with the trend portrayed by the other sources (and with the trend in state-level requirements portrayed in Table 2.1). Furthermore, the 1987-1988 SASS results were collected at the district rather than the school level, which may in part account for differences between these data and the data from the other surveys. Taken together, the differences between the results raise some doubts about the reliability of the surveys, primarily the reliability of the data collected by NAEP.

Which data are likely to be available in the future? It is unlikely that ATS will be repeated. On the other hand, both NAEP and SASS are intended to be biennial surveys. Although the content of these surveys is not fixed, the surveys could include regular

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[2]The National Association of Secondary School Principals (1974 and 1980), the Education Commission of the States (1983 and 1990), the Center for Education Statistics (1987), the National Center for Education Statistics (NCES, 1989), The Council of Chief State School Officers (1987 and 1990) and Clune (1989). The Clune report, in turn, drew upon the previously cited work of ECS and NCES as well as Goertz (1988) and Belsches-Simmons et al. (1987, March).

[3]ECS data files on state graduation requirements are updated whenever changes are enacted. However, summary reports are issued only when a "substantial number of changes have occurred since the last report." (Personal communication.)

assessment of cumulative graduation requirements, if sufficient interest is shown in these results. (It should also be possible to improve the question formats to test our assumptions about the accuracy of the results.)

At the present time, neither NAEP nor SASS collects data on advanced graduation requirements. While it would be possible to include this topic in future surveys, the extra effort does not appear warranted. To our knowledge, advanced standards are almost exclusively a state-level phenomenon. (There is no information about the extent of locally defined advanced graduation standards.) Consequently, it seems to make sense to rely on state-level reports for this information.

Data Reliability

Because so many researchers collected data on state graduation requirements, there was ample opportunity to assess the consistency of results across data sources. Although there were a number of small discrepancies between concurrent results, most were procedural in nature (e.g., different operational definitions). The number of errors in data collection or reporting was small.

The number of procedural discrepancies in tabulating or analyzing regular requirements was slightly greater, but not great enough to cause alarm. Furthermore, most could be resolved easily. For example, some researchers included new requirements in the year they were enacted, and others included them in the year they became effective for graduating seniors. It should be fairly simple to standardize operational definitions in the future so changes in requirements are reported consistently. The discrepancies most difficult to resolve arose from differences in the way researchers treated the complex options or substitutions permitted in some state requirements. For example, if students were required to complete two years of mathematics, two years of science, and a fifth year of either subject, there was little consistency in how this was reported. Furthermore, as options grew more complex, there were greater differences in reporting. Requirements that include choices will continue to be a problem for data reporting, and they may continue to complicate or confound the computation of indicators.

There was a relatively greater proportion of discrepancies in the reporting of advanced standards than in the reporting of regular standards. It would appear that most differences were due to a lack of standardization in defining and labeling criteria, but this was harder to verify on the basis of the results themselves.

EVALUATION OF INDICATORS

What are the strengths and weaknesses of alternative indicators of high school graduation requirements? Are they valid for the intended purposes and resistant to corruption?

Regular State Graduation Requirements

The distribution of graduation requirements across states can be used to compute two different indicators: the average value across the 45 states portrays the requirements in effect in a typical state (regardless of the number of students enrolled in high school); the weighted average (based on the number of students in the state) portrays the minimum state standards that must be fulfilled by a typical student in the United States. In theory, these two averages could differ considerably if large states and small states had different graduation requirements. In fact, since 1983, they have differed by no more than five percentage points. This similarity occurred because there was no systematic relationship between total enrollment and state graduation requirements, and it is unlikely that this situation will change in the future. As a result, the two statistics should continue to describe the same trend, and either could serve as an adequate indicator of graduation requirements.

However, the two measures have different meanings. The choice of which to use as an indicator depends upon the intended use. The advantage of the across-student average is that it permits direct comparison with other measures of schooling that can be reported at the student level. For example, Tables 1.1 and 1.2 can be used to compare state requirements with cumulative requirements, which were available only at the student level. In a similar manner, one might look at average graduation rates, post-secondary educational enrollments, or achievement scores during the same period of time to see if relationships existed between these and graduation standards.

The cross-state average, in comparison, would be more meaningful if one were interested in educational variables occurring at the state level, such as teacher-licensing standards, and state support for education. We recommend the former definition (and we reported results in this format in the previous section) because the student-level perspective offered the greatest commonality across different aspects of curriculum.

Finally, there is a subtle problem of definition that plagues both indicators. The problem arises because not all states establish specific graduation standards. The absence of state requirements may mean different things, which might lead one to treat them differently in computing an overall average value. Some states set standards that are low (or even zero), while others do not set standards at all, but leave this responsibility for local boards of education. It is difficult to know whether to exclude a state when computing the mean (on the grounds that there are no state requirements), include it (on the grounds that the state sets requirements but its requirement in mathematics or science is zero) or impute a value (based on an estimate of the average). The choice should depend upon the intended use of the data.

Furthermore, some of the states that leave standard setting to local school boards strongly recommend minimum course requirements for the boards to adopt, which becomes the de facto state standard. In this report we have included all states in the computation; those that had no minimum requirements in mathematics or science (or only made recommendations) were counted as zero. The statistic produced in this manner reflects (more or less accurately) the actions of states (though it clearly underestimates the cumulative graduation requirements affecting students).

One consequence of including zero requirements in the calculation of the state-level average is that recent increases in the value of this statistic are, in part, artifacts of changes in the agency that sets graduation requirements, not the level at which they are set. The number of states with no state standards in mathematics and science declined from 14 in 1980 to 6 in 1989. Because of the way these states were treated in defining the indicator, the change from local to state requirements will increase the value of the indicator. Unfortunately, there is no information about the degree to which these new state requirements differed from existing local ones. As a result, it is impossible to determine what proportion of the change in the value of the indicator was due to the substitution of state standards for local ones of the same rigor and what proportion was due to an increase in the overall requirements faced by students.

Once a decision is made regarding the treatment of zero coursework requirements, both the cross-state and cross-student averages can be computed unambiguously, and both offer a number of strengths as indicators. First, either indicator is interpretable in everyday terms: students must take mathematics and science classes two of the four years they are in high school to satisfy regular state standards for graduation. Second, either indicator lends itself easily to longitudinal comparisons. For example, regular state graduation requirements in mathematics and science increased dramatically between 1980 and 1985 but have remained relatively stable since 1985. Third, the indicators are relatively stable, i.e., changes in the value of the indicator reflect real changes in state policy regarding graduation standards. (For the purpose of comparison, the distribution of regular state graduation standards in mathematics and science is shown in Tables C.1 and C.2 in Appendix C.)

On the other hand, both formulations have potential weaknesses. First, the mean of graduation requirements across states or across students is not sensitive to small changes in requirements that might be significant from a policy perspective. For example, a change in course requirements in one state from two years of mathematics or science to three years may reflect a hard-fought change in attitudes among policymakers, but it will have little or no impact on the value of the indicator. Neither the mean nor the standard deviation would be affected to a degree that would indicate the significance of the change in state curriculum practices. The full distribution of state requirements in mathematics and science would reflect such changes more accurately, although it would be unwieldy as an indicator.

Cumulative Regular Graduation Requirements

In many instances, state standards are supplemented by district and/or school requirements, increasing the cumulative graduation standards that must be met by students. An indicator could be defined in terms of cumulative standards, and (with the exception of 1986) it would depict a trend similar to that shown by an indicator based on state-level standards. (See Tables 2.1 and 2.2.)

We recommend against the use of a single indicator based on cumulative graduation requirements for three reasons. First, data to describe state-level requirements are available more readily. Second, these data appear to be more reliable than the data that describe cumulative requirements. Third, state-level requirements are more directly subject to policy intervention.

However, if the standard-setting context changes and local authorities assume greater responsibility for setting graduation requirements, an indicator based on state requirements will no longer provide a valid picture of minimum graduation standards. In these circumstances, an indicator based on cumulative requirements would be preferable. If adequate resources are available, it would be useful to track both sets of requirements and monitor the degree to which local authorities find it necessary to supplement state actions.

Advanced Graduation Standards

Some indication of the status of advanced diploma standards is important, because it may help explain trends that are observed in other features of schooling. For example, the rapid increase in the establishment of advanced standards in the mid-1980s may partially explain the stability in regular state graduation requirements during this time period: policymakers focused their attention on a different mechanism to enhance curriculum standards for a selected group of students, those intent on college.

What is the best measure to use to monitor the status of advanced graduation standards? A "head count" of the number of states adopting advanced graduation requirements that affect mathematics or science is one option. However, this approach reveals little about the nature of the requirements, which vary dramatically from state to state. For example, one state requires two additional years of coursework in both mathematics and science while another imposes no increase in coursework, but adds a comprehensive examination. A tally provides no insight into the rigor of the supplemental standards.

In contrast, the average number of years of mathematics and science coursework required by the states for an advanced diploma provides a more accurate picture of the intensity of these programs. Unfortunately, once the distribution of standards is known, an average can be computed in three different ways—based on the number of states, the total number of students in states, or the number of students who elect to pursue advanced diplomas. Furthermore, one could compute an average based on the absolute level of the standards or an average based on the difference between advanced and regular standards.

We recommend the state-level average for two practical reasons. First, no information is available at present about student participation rates, so the latter mean cannot be computed. Second, the fact that there are two different student-level averages is likely to create confusion about the meaning of either of these two indicators.

However, this definition has weaknesses. One of the drawbacks of an advanced-standards indicator defined as a state-level average is that it may be inappropriately compared to other noncomparable statistics, particularly indicators of regular standards. By necessity, the state-level average for advanced requirements is based on a subset of states (14 at present), while the state-level average for regular requirements is based on the entire country. As a result, it is incorrect to draw inferences about mean differences between regular and advanced standards based on the two averages, even though they are both defined at the state level.

For example, Table 2.3 shows that the typical state advanced graduation standard in 1990 was 3.1 years of mathematics and 2.9 years of science (based on 14 states). At the same time, the typical state regular graduation requirement was 2.1 years of mathematics and 1.8 years of science (based on 50 states).[4] However, it was not true that the increase in advanced standards over regular ones was the difference between these two statistics (1.0 years of

[4]These are the correct values of the state-level averages. They were not reported in Table 2.1 because they differed little from the student-level averages.

mathematics and 1.1 years of science). Similarly, it would be incorrect to use any two of the three values to compute the other value.

A different indicator would be needed to monitor differences between supplemental requirements and regular requirements. The natural way to define such an indicator would be the mean of the differences between advanced and regular standards in those states that have adopted both types of standards. In 1990, 14 states required 0.9 additional years of mathematics and 0.8 additional years of science, on average, to meet honors or college-preparatory studies requirements. (See Table 2.4.)

Although this indicator overcomes the problem of inexact comparisons, it suffers from shortcomings of its own. First, by providing only relative information, the indicator conveys nothing about the absolute level of the standards. An increase in mathematics requirements from one to two years would appear equivalent to an increase from two to three years. In some instances one might want to equate these two changes (they both might reflect similar tightening of state policies), while in other circumstances they should be differentiated (students with advanced diplomas in one state might be less well prepared than students with advanced diplomas in another).

Second, and more problematic, the value of the relative change indicator decreases as regular standards increase. This may convey the false impression that advanced standards are declining, when in fact they remain the same. For example, Rhode Island increased its regular requirements from one year each of mathematics and science courses to two years each without increasing its requirements for an advanced diploma. As a result, the difference between regular and advanced standards decreased.

Which statistic is more meaningful, the absolute level of advanced standards or the relative difference between advanced and regular standards? As the previous discussion illustrated, the two indicators are more meaningful in combination than either is alone. Both may be required to accurately track advanced graduation standards. However, if a single indicator must be chosen (for reasons of cost or simplicity) we would recommend an indicator based on absolute level rather than one based on relative differences.

Another important consideration is the degree to which the proposed indicators are corruptible in different political contexts. If the stakes associated with performance as measured by these indicators increased (i.e., if greater attention were paid to the number of years of mathematics and science courses students were required to complete to receive a high school diploma), states might feel pressure to raise absolute requirements. Whether this is a good policy is debatable. We know that increased state graduation requirements in the mid-1980s resulted almost exclusively in increases in the number of basic, general, or remedial courses offered (Clune, 1989). We can assume that a similar phenomenon would occur if additional pressure were put on states in terms of regular graduation requirements. However, it is not possible to improve one's standing with respect to this indicator without making a real change in standards. To this extent the indicators are not corruptible.

Would an indicator of cumulative requirements be equally resistant to corruption, i.e., would local respondents exaggerate graduation requirements in an effort to portray their program as more rigorous? Since data are collected at random, and results are not associated with individual respondents, this is highly unlikely.

On the other hand, there may be some negative consequences of using either indicator (average regular state graduation requirements or average cumulative graduation requirements) as an element of a national indicator system. The pressure to increase the total number of years required might work to the detriment of states, such as Oklahoma, that have made standards more rigorous in terms of curriculum and course level but have relaxed the absolute number of courses required. Greater attention to the number of courses required would run counter to this type of meaningful educational reform.

Further Limitations of Graduation-Standards Indicators

An additional shortcoming of all the graduation-standards indicators (and all indicators based on *years of coursework)* is that they equate all courses in a subject, (e.g., counting General Science the same as Advanced Placement Chemistry, Consumer Mathematics the same as Trigonometry). As a result, the indicators reveal little about the mathematics and science courses students actually take or the content to which students are exposed. For example, two students who graduate from high school having completed the same number of years of mathematics may have taken dramatically different courses. A vocational student might take courses that focused on applied computation and algebra while a college-preparatory student might take courses in statistics and calculus. Bo students could satisfy the graduation requirements with educational experiences that were completely dissimilar.

This insensitivity to differences in course level is not a deficiency in the definition of the indicator but a limitation in the way states have chosen to implement policies regarding graduation. For the most part, states have chosen to ignore differences in the level of courses when establishing graduation standards, opting instead to define requirements in terms of years of coursework with no reference to course content or difficulty.

While the indicators described here accurately reflect the nature of most state requirements, we still might wish for more refined information. Knowing that two students completed the same number of years of mathematics provides some information about their preparation, but it offers little insight into the more fundamental question, What level of mathematics and science instruction are students exposed to in high school? Course completion and course content data are much more revealing about the implemented curriculum than minimum requirements.

It is worth noting that at least one state has requirements that are sensitive to differences in the level or difficulty of courses. Oklahoma offers an advanced, college-preparatory diploma whose standards are both more rigorous and more flexible than those in place for a normal diploma. Rather than requiring a greater number of courses, the state substituted more demanding standards regarding the choice of courses. The result is that the number of courses required for the college-preparatory diploma (15) is less than the number required for regular graduation (20). In this instance, an indicator based solely on the number of years of coursework would be misleading, giving the impression that the college-preparatory program was less rigorous than the regular one.

As this example shows, the validity of an indicator based on average years of coursework would drop dramatically if more states adopted standards that focused on the content of the curriculum and the level of the course while relaxing requirements regarding the number of courses. An alternative indicator that distinguished between course requirements based on level or difficulty would be required to portray this situation accurately. Information about the level or difficulty of course requirements might be of great value to policymakers; however, most states do not express graduation requirements in these terms. The indicators of graduation requirements proposed here will not provide an indication of course level. Nevertheless, it appears that a coursework average will provide a valid picture of minimum graduation standards for the near future.

3. COURSE AVAILABILITY

Course availability refers to the opportunity schools present to students to enroll in (and as a result to master the content of) specific courses in mathematics and science. This chapter begins with information about the current availability of courses and the distribution of course offerings across schools. It continues with an analysis of the quality of the data that are available to describe course availability, and then concludes with an evaluation of alternative indicators relative to this topic.

CURRENT STATUS

How widely available are secondary-level mathematics and science courses and how has course availability changed over time?

Courses are the basic organizational units of curriculum in secondary schools. Subject-matter knowledge and skills are clustered into coherent sequences designed to be taught over a period of one semester or one school year. Courses are designated by titles, and mathematics and science titles are quite similar throughout the country (Weiss, 1987). This similarity makes it possible to develop various indicators of secondary mathematics and science curricula based on course titles.

There are limitations to the use of courses as the basic unit of analysis, which are discussed below in the section on the validity of course-availability indicators. However, because courses are the organizing unit of the secondary curriculum, it is difficult to conceive of an indicator system that does not include measures of course availability or course completion. Appropriate caution must be used in interpreting measures based on course titles.

Tables 3.1, 3.2, and 3.3 display the percent of high schools that offered common mathematics, science, and computer science courses. The tables confirm that almost all schools offered algebra and geometry, biology, and chemistry and some type of computer science course. Schools did not appear to differ in terms of course availability at the basic and intermediate levels, i.e., the courses were found in almost all schools. However, higher level courses were not universally available, and, as will be shown below, lack of availability was associated with specific school and student characteristics.

One set of courses of particular interest to those concerned about the production of future mathematicians and scientists are the highly advanced mathematics and science courses that cover curriculum comparable to that included in credit courses at four-year

Table 3.1

Mathematics Course Availability

Course Title	Percent of Schools Offering Course*
General mathematics, grade 9	64
General mathematics, grade 10	46
Business mathematics	49
Consumer mathematics	49
Remedial mathematics	29
Pre-algebra/introduction to algebra	63
Algebra, first year	99
Algebra, second year	92
Geometry	95
Trigonometry	59
Probability/statistics	14
Advanced sr. math, without calculus	36
Advanced sr. math, with calculus	34
Calculus	31
Advanced placement calculus	18
Any calculus or advanced mathematics	76

*All schools with grades 10 to 12.
SOURCE: Weiss, 1987.

Table 3.2

Science Course Availability

Course Title	Percent of Schools Offering Course*
Life science	46
Earth science	52
Physical science	68
General science, grade 9	31
General science, grades 10–12	18
Biology, first year	99
Chemistry, first year	91
Physics, first year	81
Biology, second year	53
Chemistry, second year	28
Physics, second year	11
Astronomy	8
Anatomy/physiology	32
Ecology, environmental science	15
Zoology	6

*All schools with grades 10 to 12.
SOURCE: Weiss, 1987.

colleges. This set, referred to as "college-equivalent courses," includes Advanced Placement courses in mathematics, science, and computer science; second-year courses in biology, chemistry, physics, and computer programming; and calculus courses. Table 3.4 shows that

Table 3.3

Computer Science Course Availability

Course Title	Percent of Schools Offering Course*
Computer awareness of literacy	62
Applications and implications of computers	24
Introductory computer programming	65
Advanced computer programming	38
Advanced placement computer science	13
Any computer science	91

*All schools with grades 10 to 12.
SOURCE: Weiss, 1987.

Table 3.4

College-Equivalent Course Availability*

Subject	Percent of Schools Offering Course
Mathematics	73
Biology	60
Chemistry	33
Physics	18
Computer science	46

*Advanced Placement or second year courses
SOURCE: RAND tabulations of data from the 1985–1986 National Assessment of Educational Progress.

the percentage of schools that offered college-equivalent courses ranged from 73 percent in mathematics to only 18 percent in physics.

What was the trend in course availability over the past decade? Table 3.5 shows only a modest increase (less than or equal to five percentage points) in the availability of common mathematics and science courses between 1977 and 1986. The lack of growth in the availability of basic and intermediate courses can be explained, in part, by the high percentage of schools that offered these courses. Geometry, algebra II, biology I, and chemistry I were offered in over 90 percent of all high schools, so little increase was possible. (It is disappointing to see that the percentage of schools offering geometry actually declined between 1977 and 1986.) On the other hand, the percentage of schools offering advanced courses, such as trigonometry, calculus, and physics I, also changed little between 1977 and 1986, despite the fact that there was ample room for improvement.

The greatest growth in course availability occurred in the sciences; a substantial percentage of schools began offering life science, earth science, and physical science for the

Table 3.5

Comparison of Common Mathematics and Science Course Availability: 1977 and 1986

Course Title	Percent of Schools* Offering Course	
	1977	1986
Mathematics		
General math, grade 9	59	64
General math, grades 10 to 12	42	46
Business mathematics	52	49
Geometry	97	95
Algebra II (advanced algebra)	87	92
Trigonometry	54	59
Probability/statistics	7	14
Calculus	31	31
Science		
Life science	18	46
Earth science	37	52
Physical science	40	68
General science, grade 9	46	31
General science, grades 10–12	11	18
Biology, first year	95	99
Chemistry, first year	89	91
Physics, first year	81	81

*All schools with grades 10 to 12.
SOURCES: Weiss, 1978; Weiss, 1987.

first time between 1977 and 1986. This appears to represent a change in the traditional science curriculum that should be monitored carefully in future surveys.

How evenly is course availability distributed across secondary schools and students? Nationwide course availability statistics, such as those presented in the previous section, provide an incomplete picture of the curriculum. They fail to portray between-school differences in course availability associated with certain characteristics of the schools and their students. An indicator system would be deficient if it did not provide information that could be used to monitor these differences.

Three benchmark courses from each field were selected to use as comparative measures:

Mathematics	Science	Computer Science
algebra II	physics	computer literacy
trigonometry	biology II	programming I
precalculus/calculus	Advanced Placement (AP) biology	programming II

These courses were selected for two reasons. First, little differentiation was likely to be found among introductory courses available in over 90 percent of all schools. Second, NAEP (which provided the best information on student and school characteristics) did not collect course availability data on introductory courses, focusing only on intermediate and advanced courses.

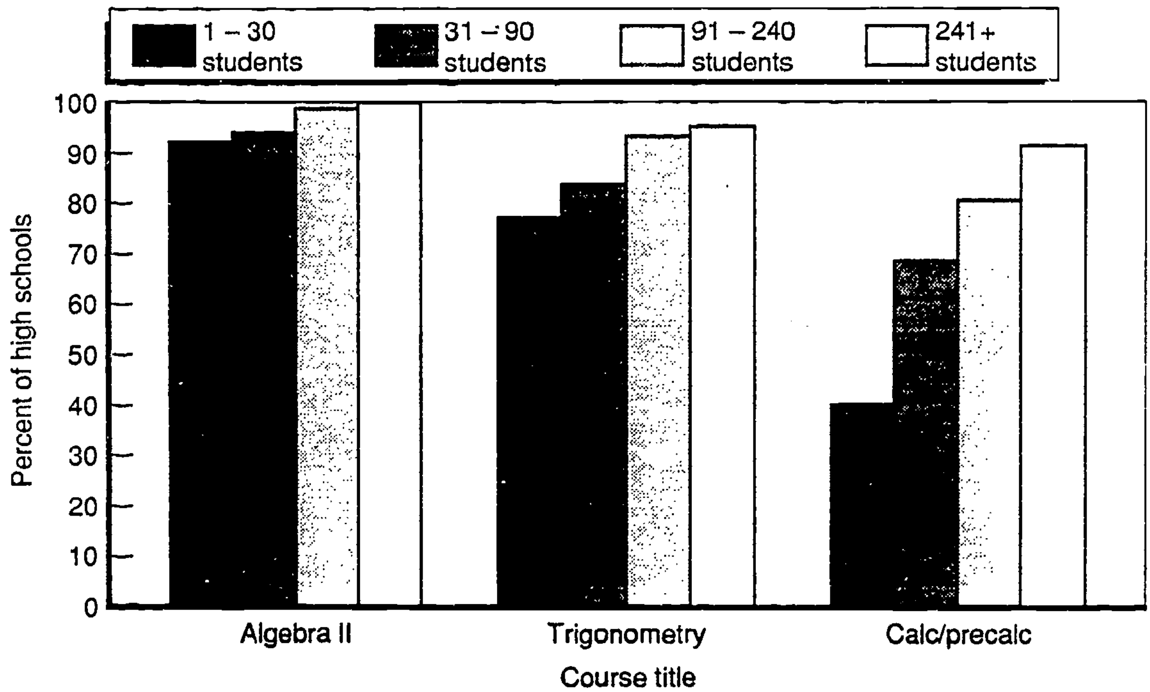
For these analyses, schools were compared on five dimensions: size (measured as the average enrollment per grade level), size and type of community (a variable constructed by NAEP to reflect a combination of location and parent occupation[1]), lunch participation (defined as the percent of students participating in the subsidized lunch or nutrition program), minority enrollment (defined as the percent of non-Asian minority students in the school), and type (public, private, or Catholic).

To analyze the distribution of course availability, we used a technique that focused on differences between groups of schools. Schools were clustered into groups based on the characteristic of interest, and within-group percentages of schools offering each course were computed. For example, schools were subdivided into quartiles based on total enrollment, and the percent of schools in each quartile group offering each course was computed. (See Figure 3.1.) As Figure 3.1 illustrates, the proportion of schools that offered selected mathematics courses increased as school size increased. (For comparable data regarding the relationship between course availability and school size in science and computer science courses, see Figs. C.1 and C.2 in Appendix C.)

By way of comparison, Figure 3.2 shows mathematics course availability by size and type of community. Here the greatest differences occurred between high metropolitan and low metropolitan schools, although the differences changed depending upon the level of the courses. High metropolitan and extremely rural schools offered intermediate courses in approximately equal percentages. However, high metropolitan schools were more than twice as likely as low metropolitan or extremely rural schools to offer advanced mathematics courses.

These group statistics can be used to calculate indicators of differentiation. We have chosen to use a comparison between the mean values of the largest and smallest schools as a measure of the severity of the differentiation of course availability associated with school size. In particular, the ratio of mean percentages in the extreme groups provides a numerical

[1]Three extreme subgroups were compared: High Metropolitan, defined as the top 10 percent of urban schools in terms of parent occupation; Low Metropolitan, defined as the bottom 10 percent of urban schools in terms of parent occupation; and Extreme Rural, defined as the bottom 10 percent of rural schools in terms of parent occupation.



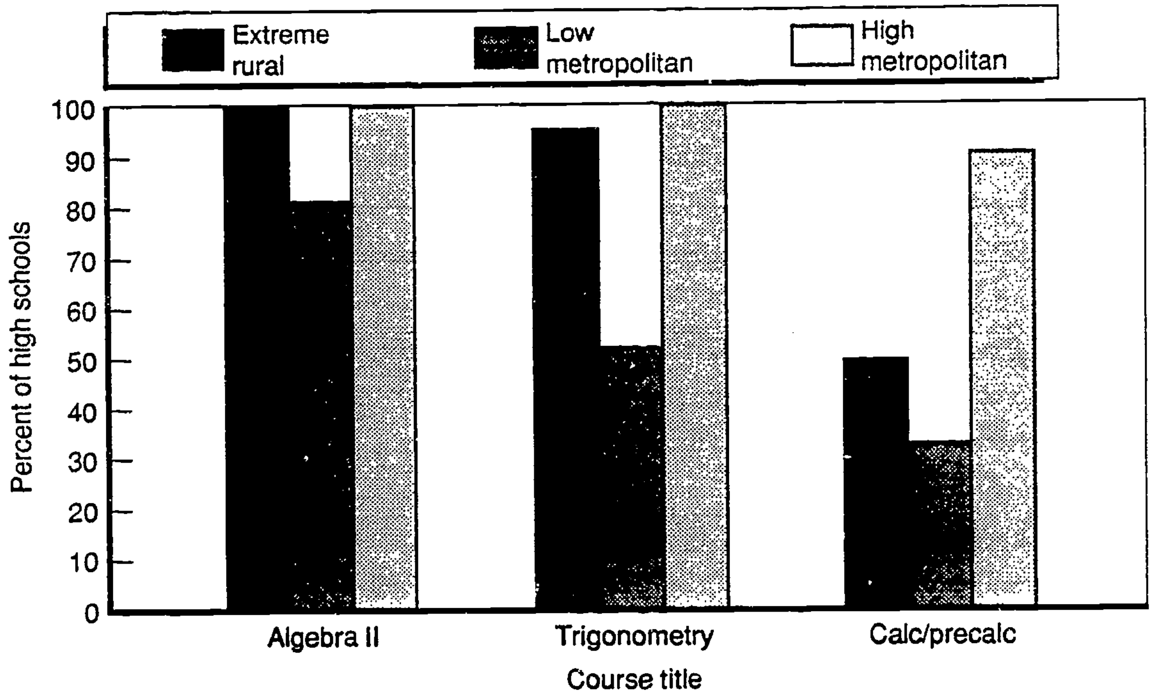
SOURCE: RAND tabulations of the 1985–1986 National Assessment of Educational Progress

Fig. 3.1—Mathematics Course Availability by Grade Level Enrollment

indication of the extent to which students in the largest and smallest schools have similar access to selected mathematics courses.

Table 3.6 contains course availability ratios (between extreme groups) for four factors: total enrollment, size and type of community, population groups, and subsidized lunch participation. The ratios in the first column of Table 3.6 reflect the degree of difference in access to courses based on school size. For example, the ratio of calculus availability for large schools versus small schools was 2.2, meaning that the percentage of large schools that offered calculus was more than twice as great as the percentage of small schools. This also is equivalent to an estimate of the relative probability that large and small schools will offer specific courses; e.g., the probability that a large school will offer precalculus/calculus was over twice the probability of a small school. (Figures depicting course availability in mathematics, science, and computer science for all four variables will be found in Appendix C, Figures C.3 through C.13.)

The results depicted in Table 3.6 confirm that curriculum (in the form of course availability) was distributed unevenly, based on school and student characteristics (Oakes et al., 1990). The table illustrates a number of relationships. First, schools were less likely to



SOURCE: RAND tabulations of the 1985–1986 National Assessment of Educational Progress

Fig. 3.2—Mathematics Course Availability by Size and Type of Community

Table 3.6

Course Availability Ratios

Course Title	Large/Small Schools*	High/Low Metropolitan+	Low/High Minority Enrollment**	Low/High Lunch Participation++
Mathematics				
Algebra II	1.1	1.2	1.1	1.1
Trigonometry	1.2	1.9	1.3	1.2
Precalculus/calculus	2.2	2.8	1.6	2.2
Science				
Physics I	1.4	1.6	1.2	1.3
Biology II	2.0	3.5	1.8	1.5
AP biology	2.6	5.2	1.4	2.5
Computer Science				
Computer literacy	1.0	1.1	1.1	1.2
Programming I	1.6	2.0	1.4	1.5
Programming II	3.6	4.6	2.3	6.2

*Ratio of first quartile mean percentage offering course to fourth quartile mean percentage offering course.
**Ratio of 0 to 25 percent non-Asian minority group mean percentage to 75 to 100 percent non-Asian minority group mean percentage.
+Ratio of high metropolitan school mean to low metropolitan school mean.
++Ratio of 0 to 19 percent subsidized lunch group mean to 40+ percent subsidized lunch group mean.
SOURCE: RAND tabulations of data from the 1985–1986 National Assessment of Educational Progress.

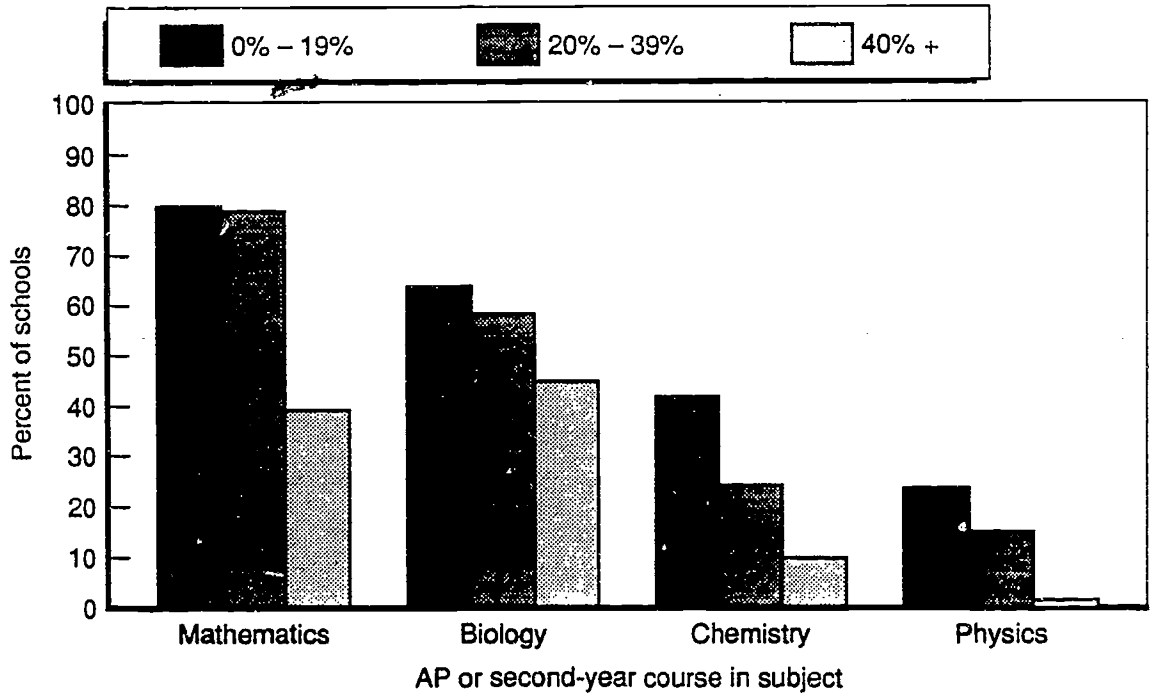
offer advanced courses if they were small rather than large, had a high rather than low percentage of non-Asian minority students, had a high rather than low percentage of students receiving subsidized lunch, or drew students from urban neighborhoods with low rather than high parent-occupation profiles.[2] Second, the degree of difference in course availability increased as the level of the course increased. Third, the pattern of differentiation was similar for mathematics, science, and computer science, and was most severe for computer science. Fourth, the ratios of differentiation were somewhat greater for size and type of community (STOC) than for the other factors, although this was due, at least in part, to the fact that the high and low categories of STOC were smaller in number and had less variation than the extreme categories of the other variables. School population groups affected course availability somewhat less than the other three characteristics.

School type (public, private, Catholic) did not affect course availability as strongly as the four factors mentioned above. The probability that a school offered selected mathematics, science and computer science courses was approximately the same regardless of whether the school was public or Catholic. However, the proportion of private schools offering selected courses, particularly computer science courses, was lower than the other two groups. (See Figures C.11 through C.13 in Appendix C.)

Do all students have equal access to the most advanced courses? The previous analysis showed that the answer is *no*. We found the patterns of differentiation even more striking in the case of college-equivalent courses. Students in small schools, urban and rural schools with low parent-occupation profiles, high-minority schools, and schools with a high percentage of students receiving subsidized lunches were less likely to have access to college-equivalent mathematics and science courses than students in large schools, urban schools with high occupational profiles, schools with few minority students, and schools with few students participating in the school lunch program. For example, schools in which a high percentage of students were receiving subsidized lunches were less than half as likely as schools in which a moderate percentage of students were receiving subsidized lunches to offer college-equivalent courses in mathematics, chemistry, or physics. (See Figure 3.3. For comparable information regarding the other school characteristics, see Figures C.14 through C.17 in Appendix C.)

Measures defined in terms of extreme groups focus on the worst instances of unequal access. For this reason, they may be an effective tool for encouraging policymakers to

[2]This pattern of relationships is not completely surprising, since the dimensions on which schools were compared were not independent. For example, urban schools with low parent-occupation profiles were generally characterized by high percentages of minority students and high percentages of students receiving subsidized lunch.



SOURCE: RAND tabulations of the 1985–1986 National Assessment of Educational Progress

Fig. 3.3—College-Equivalent Course Availability by Percent Receiving Subsidized Lunch

address inequities. Certainly, declines in these course availability ratios would represent genuine lessening of differentiation where it is most severe.

AVAILABILITY AND RELIABILITY OF DATA

Are reliable, representative data available on a regular basis to describe secondary-level course availability?

There are two recent nationally representative sources of data regarding course offerings in mathematics and science that can be used as the basis for computing an indicator of course availability. Both the National Assessment of Educational Progress (NAEP), which included mathematics and science in 1985-1986, and the 1985-1986 National Survey of Science and Mathematics Education (NSSME) offer information that is relevant to this construct. NAEP is an ongoing biennial survey; NSSME was designed to be a one-time update of the 1977 National Survey of Science, Mathematics, and Social Studies Education (Weiss, 1978). To our knowledge, there are no current plans to repeat the NSSME survey in the future, so these data cannot be relied upon to meet the needs of an indicator system.

This is unfortunate, for NSSME is, in many respects, the richer of the two databases for monitoring curriculum.

Because there were two concurrent sources of data regarding course availability in 1985-1986 (NAEP and NSSME), it was possible to test the consistency of the findings directly. Unfortunately, there were a few significant disagreements between the results that cast doubts on their reliability. Table 3.7 compares the percentage of schools offering mathematics, science, and computer science courses reported by NAEP and NSSME. The results in science were reasonably similar, differing by no more than three percentage points. However, the results in mathematics and computer science were vastly different.

Part of the discrepancy can be explained by the fact that the two surveys used different labels for some courses. For example, NAEP asked about "precalculus/calculus" while NSSME specified only "calculus." However, this does not explain the differences of 50 percent or more in the values reported for trigonometry, probability/statistics and computer literacy. These discrepancies call into question the reliability of the course availability data from both surveys. While NSSME appears to have been more conscientious in gathering

Table 3.7

Comparison of Mathematics and Science Course Availability from Two National Surveys

Course Title	Percent of All High Schools Offering Course: NAEP	Percent of All High Schools Offering Course: NSSME
Mathematics		
Algebra, second year	94	92
Trigonometry	84	59
Probability/statistics	23	14
Calculus	67*	31
AP calculus	38**	18
Science		
Physics, first year	83	81
Physics, second year	13	11
Biology, second year	56	53
Chemistry, second year	28	28
Computer science		
Computer literacy	89	62
Computer programming, first year	75	65+
Computer programming, second year	42	38++
AP computer science	18	13

*Precalculus/calculus.
**AP math.
+Computer programming, introductory.
++Computer programming, advanced.
SOURCES: Weiss, 1987; RAND tabulations of data from the 1985–1986 National Assessment of Educational Progress.

course-related data, there is no specific basis for discounting the NAEP results. Consequently, one must be somewhat dubious about the data on advanced mathematics course availability from both sources.

A direct comparison also points out another problem with NAEP as a source of course availability data. The designers of the survey chose to focus the school questionnaire on advanced courses, rather than courses at all levels. As a result, no information was gathered about the availability of algebra I, geometry, biology I, or chemistry I. This reduces NAEP's value as a basis for describing this aspect of the curriculum. Fortunately, it would be easy to modify future surveys to include these courses. In fact, the questions on course taking in the spiraled Student Questionnaire included a more extensive (although still incomplete) list of courses.

We also have concerns about the *quality* of the NAEP data, particularly the data on course availability, participation in the subsidized school lunch program, and size and type of community. Missing data were a serious problem in the cases of the course availability and school lunch participation variables. Between 10 percent and 20 percent of the schools failed to report data about course offerings and about the percent of students receiving subsidized lunches. (See Appendix A for a more complete list of NAEP variables with high rates of missing values.) We chose not to eliminate variables from our analysis solely on the basis of missing data. Instead, we examined the patterns of missing data and the correlations between related variables before making decisions about which variables to include and which to exclude from the analysis. For example, further analysis of the characteristics of schools that were missing course offering information did not support the hypothesis that these schools were less likely than the rest to offer specific courses. Consequently, we included this variable in the analysis.

A different problem affected the use of the size and type of community variable. NAEP reported two demographic variables for each school, urbanicity (urban, suburban, rural), which was taken from Quality Educational Data files and STOC (size and type of community). STOC is a NAEP-generated variable that reflects a composite of community size and location and an occupational profile of parents provided by the school principal. Unfortunately, the two were not consistent. For example, 24 percent of those schools classified as Big City and 32 percent of those classified as Small Place by NAEP were classified as suburban by QED. Neither measure appeared to be reliable across all values. As a result, we opted to focus on three of the seven levels of STOC reported by NAEP. We chose to use only the three extreme values—the 10 percent of urban schools with the highest occupational profile (High Metropolitan), the 10 percent of urban schools with the lowest occupational profile (Low Metropolitan) and the 10 percent of rural schools with the lowest occupational profile (Extreme Rural). These categories were the most reliable when compared to urbanicity and the easiest to interpret. The other STOC categories did not correspond to urbanicity in any predictable manner. (Unfortunately, for an indicator system, only NAEP computes and reports size and type of community.)

Finally, other research points up at least one oversimplification (or oversight) in both NAEP and NSSME. The American Institute of Physics found that approximately 72 percent of public schools offer physics on an annual basis, but another 18 percent of public schools offer it biennially (Czujko and Bernstein, 1989). Both NAEP and NSSME ignored this distinction, leaving it up to the respondent to decide whether or not last year's physics course should be counted on this year's survey. This may cause a small underestimation in the proportion of schools that offer such courses, and the underestimation is most likely to occur in small schools, where advanced courses may be offered every other year or irregularly.

EVALUATION OF INDICATORS

What are the strengths and weaknesses of alternative indicators of course availability at the secondary level? Are they valid for the intended purposes and resistant to corruption?

This discussion will address five issues relating to the definition and interpretation of potential indicators of course availability: the choice between a measure of access and a measure of existence, the interpretation of an indicator based on course titles, the universe of generalization for course availability statistics, the use of extreme groups and extreme group ratios, and the resistance of the indicators to corruption in a high-stakes context. A related topic, the identification of a more parsimonious subset of courses for reporting, will be discussed in the section on indicators of course completion.

There are two possible ways to operationalize a school-level indicator of course availability: in terms of existence and in terms of access. The former approach addresses the question "Which mathematics and science courses were offered?" The latter addresses the question "How many sections of each mathematics and science course were offered?" Both approaches provide information about courses; however, they provide different portrayals of course availability. Two schools that offer the same course may not be providing equal access to that course depending upon the number of sections that are offered, the time of day they are offered, and the number of students who want to enroll in the course.

How does one chose between the two alternatives for defining an indicator of course availability? The choice should be based on the meaning of the indicators: Which comes closest to our understanding of the underlying construct? The answer to the existence question (Is chemistry offered?) provides an indication of minimum educational opportunities offered by the institution. The fact that a course is offered is a necessary, but not sufficient, condition for students to gain access to the curriculum covered by the course. The answer to the access question (How many sections of chemistry are offered?) provides an indication of the extent to which students *can and do* avail themselves of particular curriculum opportunities. The access measure indicates student course-taking behaviors as much or more than intended administrative policies.

We recommend using the dichotomous measure of the existence of courses as an indicator of minimum institutional standards, because it comes closest to the construct of *course availability* as we understand it. Student factors influence the existence of courses to a lesser degree than they influence the number of sections of a course, so the former measure reflects institutional intentions relatively more than the latter. Of course, this distinction is somewhat artificial. Administrative policies and student actions are like "a pair of intertwined vicious circles" (Neuschatz and Covalt, 1988), and one must not be tricked into thinking they can be untwisted just by choosing between two operational definitions. It is impossible to disentangle the effects of course taking from course offering and produce a pure indicator of either construct.

If one accepts the recommendation to measure course availability in terms of existence, one must still exercise caution regarding its interpretation. First, the dichotomous indicator does not reflect the frequency with which a particular course is taught, nor the proportion of students who are exposed to the content. While geometry and algebra are both offered in over 90 percent of the high schools, only 21 percent of all mathematics courses taught are geometry, while 36 percent are algebra (Weiss, 1987). The indicator suggests that geometry and algebra are equally available; however, they are not equally *prevalent*. In fact, the number of students who take algebra is approximately 60 percent greater than the number who take geometry. Second, it would be incorrect to interpret course availability indicators as an indication of students' opportunity to learn a particular topic. The existence measure provides information about the percentage of schools in which courses are taught at least once each year, not the likelihood that a school will provide courses to all qualified or interested students. Nevertheless, it is the closest we can come to measuring the administrative component of course availability. Furthermore, there is enough variation across schools in the existence of courses to make this measure important.

The second general question that must be addressed is the proper interpretation of indicators based on course titles (be they indicators of course availability or course completion). What is known about students' opportunity to learn the skills of algebra from the statement that 99 percent of the schools offer algebra I? On one hand, it is true that a course called algebra I is taught in almost all schools, so students in almost all schools can learn something about algebra (ignoring for the moment the question of students' access to the course). On the other hand, it is not necessarily true that these courses cover the same material.

While there is some evidence that courses with the same title tend to use the same textbooks (suggesting that the intended curriculum is similar), there is considerable evidence that actual topic coverage varies tremendously between courses with the same title (suggesting that the implemented curriculum is different). McDonnell et al. (1990) found that topic coverage varied enormously across sections of algebra I in six different schools. Topic coverage varied so dramatically that some students in courses called algebra I were receiving no more exposure to algebra topics than some students in general mathematics courses. Similar disparities also have been observed in advanced courses, such as physics (Neuschatz and Covalt, 1988). To the extent that course titles obscure important differences in content, course-availability indicators will provide incorrect impressions about students' access to knowledge and skills.

The one instance in which titles closely match content is the case of Advanced Placement courses. These courses are distinguished by a carefully monitored curriculum that is established by a national consulting board. They also have a common set of examinations that are used formally to certify student mastery of content and informally to allow teachers to monitor their instructional focus. The presence of a common curriculum and a common examination standardizes the content of Advanced Placement courses to a degree not found in any other course. As a result, Advanced Placement courses provide more meaningful curriculum milestones than many other courses, and their inclusion in an indicator system is encouraged.[3]

The third question concerns the desired universe of generalization for reporting course availability statistics. In most cases, the same survey data can be analyzed to answer two or more different questions. For example, NAEP data can be analyzed to produce estimates of the percentage of schools that offered particular courses or the percentage of 11th grade

[3]By noting the value of a standardized curriculum as a basis for meaningful indicators, we do not necessarily endorse the particular curriculum embodied in the Advanced Placement syllabus. There are other approaches to defining secondary mathematics and science curriculum (American Association for the Advancement of Science [AAAS], 1989; National Council of Teachers of Mathematics [NCTM], 1989) that might be preferred. Our point is that the commonality of curriculum across AP classes is unique in mathematics and science at the present time and offers some advantages for developing indicators.

students attending these schools.[4] (See Table 3.8.) The choice of which representation to use is important because the alternatives do not convey the same impression. For example, 38 percent of the schools offer Advanced Placement calculus, but 51 percent of the 11th grade students attend these schools. This difference occurs because large schools are more likely to offer calculus. As Table 3.8 illustrates, similar effects were evident for most intermediate and advanced courses.

Since the two sets of results are equally reliable (they were based on the same data), the choice of which to report must be made on conceptual grounds: which data reflect the construct *course availability* in the most meaningful way? Because the decision to offer courses is made by school administrators rather than students, we opted to present results regarding course availability at the school level. However, if we were more interested in the degree of access to courses, then student-level results might be more informative. Because

Table 3.8

Comparison of Alternative Measures of Access to Science and Mathematics Courses

	Course Availability	
Course Title	Percent of High Schools Offering Course	Percent of 11th Grade Students Attending Those Schools
Mathematics		
Algebra, second year	94	99
Trigonometry	84	95
Probability/statistics	23	32
Precalculus/calculus	67	87
AP calculus	38	51
Science		
Physics, first year	83	96
Physics, second year	13	23
Biology, second year	56	71
Chemistry, second year	28	52
Computer science		
Computer literacy	89	92
Computer programming, first year	75	87
Computer programming, second year	42	60
AP computer science	18	25

SOURCE: RAND tabulations of data from the 1985–1986 National Assessment of Educational Progress.

[4]NAEP results also can be analyzed to estimate the percentage of secondary students attending schools that offer particular courses. However, these results are almost identical to those for 11th grade students, so they were not reported here. Differences between these two measures would be noteworthy because they would indicate a relationship between course availability and student attrition. Fortunately, such differences were not present.

the differences are substantial, some might argue that both approaches should be included in an indicator system.

Fourth, caution must be exercised in the use of extreme groups and extreme group ratios as the basis for indicators. The problem with defining indicators in terms of groups of schools is that the definition of the groups can affect the value of the statistics and the apparent relationship between the underlying variable and the indicator construct. Depending upon the actual distribution of schools on the two measures, it might be possible to show dramatically different relationships by merely changing the cut points (in the case of ordinal variables) or the selection of levels (in the case of categorical variables).

To provide consistent indicators, subgroup definitions would have to be standardized. Quartiles are a reasonable candidate for a standard, and they were used to define school groups based on total enrollment. However, other alternatives should be considered as well. In the case of school population groups, where the variable itself was expressed as a percentage, groups were defined in terms of the values of the variable (0 to 24 percent non-Asian minority, 25 to 49 percent non-Asian minority, etc.). This approach seemed less susceptible to misinterpretation. Groups can also be defined in terms of other student characteristics, such as achievement. Boundary points on the subsidized lunch variable were determined by examining bivariate plots with achievement and dividing the distribution based on achievement differences.

A more extensive study of the relationship between background variables and school status measures (including curriculum, achievement, teacher quality, etc.) might provide a better basis for clustering schools. Certainly, the overall value of the indicator system would be enhanced if the same set of school groups were used to report information about all the components of schooling, including curriculum, achievement, teacher quality, etc.

A number of different statistics could be used to describe variation in course availability across particular background variables. One advantage of using extreme groups is that a ratio based on values from extreme groups focuses on divergent cases and thereby emphasizes discrepancies. An indicator defined in this manner will change little unless variation is reduced between conditions at the bottom and the top of the distribution.

However, ratios of differentiation defined in terms of extreme groups have disadvantages as well. The value of a ratio depends upon the definition used for creating the groups, and the ratio can be changed by defining extreme groups differently. For example, in the case where there is a strong positive relationship between course availability and a background variable, the ratio of differentiation can be made larger or smaller by selecting wider or narrower tails of the distribution. Another drawback to ratios of differentiation is that the underlying notion of extreme values may have little meaning when the classification variables are discrete, as in the case of STOC or school type. In these instances, there is no natural extreme case, so it would be difficult to select a single ratio that captured the degree of nonuniformity.

Finally, we should consider how course availability indicators are likely to behave as the political and educational contexts change. There is some concern that heightened attention to the percentage of schools that offer a course will corrupt the meaning of this statistic. Although data drawn from a representative sample of schools cannot be associated with the actions of any particular school or district (so there is no direct incentive for administrators to change the courses they offer), it would be naive to ignore the possibility that schools or districts would be held accountable by local officials to the same criteria that have been adopted nationally.

Increased pressure at the local level might lead a school or district to offer courses that were not available in the past. If the courses are of high quality and students are adequately prepared to take them, this is all to the good. If the instructors are not qualified or the students are ill-prepared, the result will be detrimental to students, even though the action will improve the school's standing on the indicator of course availability. Furthermore, the eventual outcome may be a decrease in the rigor of the courses. Pressures to increase requirements could lead to a "watering down" of courses and a change in the meaning of the course labels (Clune, 1989). Unfortunately, there is no simple way to mitigate against this possibility. A technique for factoring course quality into the indicator system might have the desired effect; however, the technology to accomplish this does not yet exist. This is another area in which additional research might prove extremely valuable.

4. COURSE COMPLETION

Course completion[1] patterns provide an important measure of students' exposure to the content of high school science and mathematics. Because course completion is a more direct measure of students' actual interaction with mathematics and science than either graduation requirements or course availability, measures of course completion deserve considerable attention in a secondary curriculum indicator system. This chapter presents information about the current status of student course completion, the data sources that are available to describe course completion patterns, and the validity of alternative indicators of course completion.

CURRENT STATUS

What percentage of students completed common secondary-level courses in mathematics and science, and has student course completion changed over time?

Tables 4.1 and 4.2 present course completion results for common college-preparatory mathematics and science courses and course combinations. The tables show the majority of graduates completed the basic courses; about half of the graduates completed the intermediate courses; and fewer than 20 percent of high school graduates completed the advanced courses.

Table 4.3 shows the total number of credits[2] earned by high school graduates in mathematics, science, and computer science. Although the average student earned considerably more credits in mathematics and science than were required for regular high school graduation, and almost as many as were required for an advanced or college-preparatory diploma, the average student did not take advanced, college-preparatory courses. They complied with graduation requirements by taking courses at the basic or

[1]In this report we distinguished between two related constructs—course completion (receiving credit for completing a course with a passing grade) and course taking (enrolling in a course). Some surveys (e.g., the 1987 High School Transcript Study) measure course completion, while others (e.g., NAEP) rely on student self-reports of course taking ("Have you ever taken...?"). Conceivably, the latter group includes students who did not complete the course or did not receive a passing grade. The size of this population is uncertain, although student self-reports of course taking have been shown to be a reasonably accurate reflection of course completion in many cases (Valiga, 1986; National Center for Education Statistics, 1984). Since the correspondence is not perfect, we opted to differentiate between results based on earned credits (course completion) and results based on course enrollment (course taking).

[2]One unit of credit was defined to be one course taken for one period each day for the complete school year (Westat, 1988).

Table 4.1

Mathematics Courses Completed

Course Title (duration)*	Percent of High School Graduates 1982	1987
Individual courses		
Any math	97	99
Any remedial math course/below grade level	33	25
Algebra I	65	76
Geometry	46	62
Algebra II (.5)	35	47
Trigonometry (.5)	12	19
Analysis/precalculus (.5)	6	13
Calculus (all)	5	6
AP calculus	2	3
Statistics/probability (.5)	0.3	0.4
Course combinations		
Algebra II + geometry	28	42
Algebra II + geometry + trigonometry	7	15
Algebra II + geometry + trigonometry + calculus	1	2

*All courses are at least one year in duration, unless otherwise noted.
SOURCE: Westat, Inc., 1988.

Table 4.2

Science Courses Completed

Course Title (duration)*	Percent of High School Graduates 1982	1987
Individual courses		
Any science	95	99
Biology	75	88
Chemistry	31	45
Physics	14	20
Engineering	0.1	0.1
Astronomy (.5)	1	1
Geology (.5)	14	15
AP/honors biology	7	3
AP/honors chemistry	3	3
AP/honors physics	1	2
Course combinations		
Biology + chemistry	28	43
Biology + chemistry + physics	11	17

*All courses are at least one year in duration, unless otherwise noted.
SOURCE: Westat, Inc., 1988.

intermediate level. In fact, between one-third and one-quarter of all graduates completed mathematics courses classified as remedial.

Table 4.3

Credits Earned by High School Graduates

Subject	Mean Number of Credits Earned	
	1982	1987
Mathematics	2.5	3.0
Science	2.2	2.6
Computer science	0.1	0.4

SOURCE: Westat, Inc., 1988.

What were the trends in mathematics and science course completion? The percentage of students completing most of the mathematics and science courses listed in Tables 4.1 and 4.2 increased significantly between 1982 and 1987. Furthermore, the increases were greatest, in relative terms, among courses at the intermediate and advanced levels. For example, the percentage of graduates who completed trigonometry, analysis/precalculus, chemistry, and physics increased roughly 50 percent during that five-year period. An accompanying decline occurred in the percent of students completing remedial or below grade level courses in mathematics.

Comparing trends in course completion with trends in course availability suggests that the low course completion rates for advanced courses were not solely the result of lack of access to courses. (See Tables 3.1 and 3.2.) Not only was the percentage of schools that offered at least one section of advanced mathematics and science courses quite high, but this number did not change very much during the period of rapid growth in the percentage of students who completed advanced courses. This suggests that factors other than course availability, such as student preparation, guidance counseling, and schoolwide press for achievement, were responsible for the increase in student course taking. However, as Oakes et al. (1990) point out, course availability may still limit access to advanced courses if schools (particularly those serving inner-city, urban neighborhoods) do not offer an adequate number of sections to accommodate student demand.

How evenly is course completion distributed across students and schools?

Differences in course completion rates in 1987 will be discussed first, beginning with population-group differences followed by gender-related differences. Differential changes in course completion rates between 1982 and 1987 will be discussed next, also beginning with population-group differences and concluding with gender-related differences. Finally, associations between school and student characteristics and course taking (as measured by NAEP) will be presented.

There were significant population-group differences in mathematics and science course completion in 1987. (See Tables 4.4 and 4.5.) Asian and white students completed intermediate and advanced mathematics and science courses in much greater percentages than black and Hispanic students. Furthermore, the relative differences between the completion rates of the groups increased as the level of the courses increased, particularly the difference between Asian students and the other groups. Asian students completed the more rigorous mathematics and science sequences at approximately twice the rate of white students and approximately four times the rate of black and Hispanic students.

Table 4.4

Combinations of Mathematics Courses Completed by Sex and Population Group

	Percent of 1987 High School Graduates			
Group	Never Taken Geometry	Geometry and Algebra II	Geometry, Algebra II, and Trigonometry	Geometry, Algebra II, Trigonometry, and Calculus
Sex				
Males	39	42	15	3
Females	38	43	14	2
Population group				
White	35	47	17	2
Black	56	29	8	1
Hispanic	60	24	7	2
Asian	19	62	31	15

SOURCE: RAND tabulations of 1987 High School Transcript Study.

Table 4.5

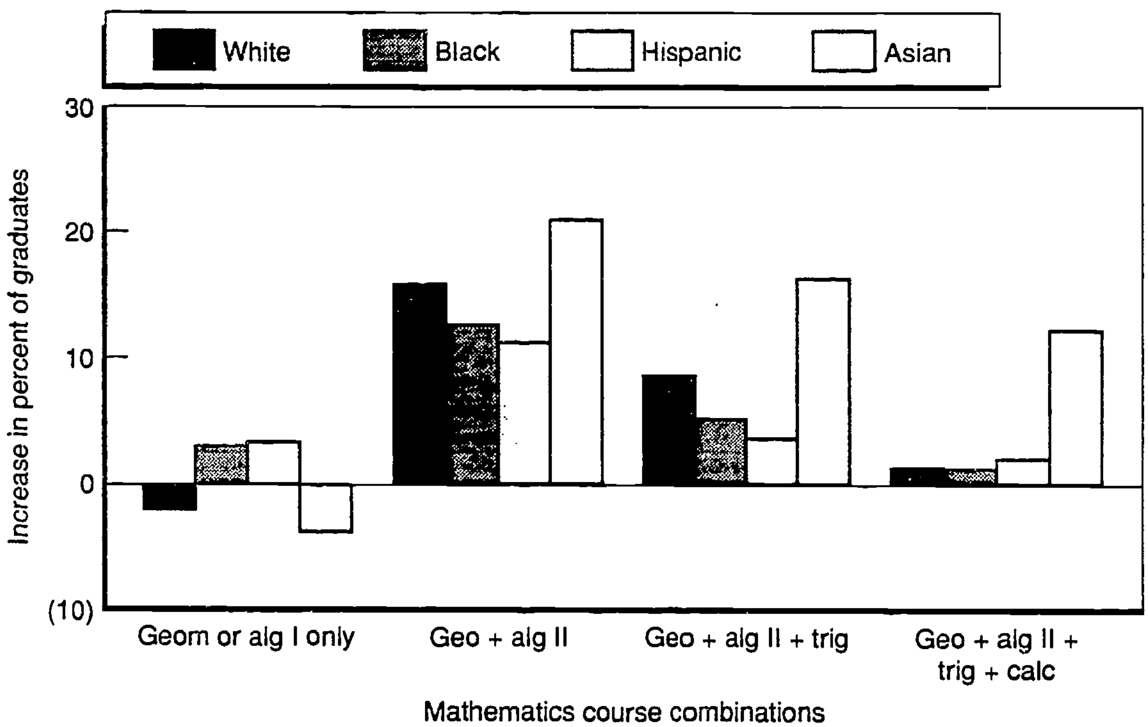
Combinations of Science Courses Completed by Sex and Population Group

	Percent of 1987 High School Graduates			
Group	Never Taken Biology I	Biology I	Biology I and Chemistry I	Biology I, Chemistry I, and Physics I
Sex				
Males	13	87	44	21
Females	10	90	42	13
Population group				
White	11	89	46	18
Black	14	86	29	9
Hispanic	15	85	28	8
Asian	8	92	66	42

SOURCE: RAND tabulations of 1987 High School Transcript Study.

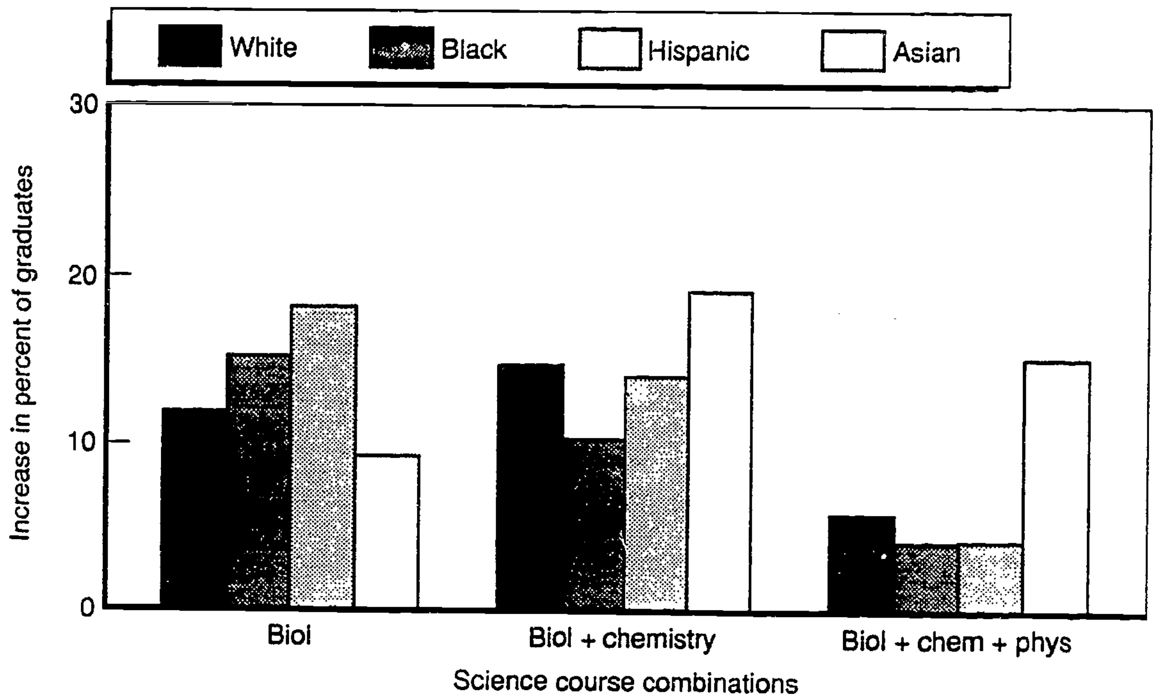
There were almost no differences in mathematics course completion associated with gender, but there were gender-related differences in the completion of advanced science course combinations. (See Tables 4.4 and 4.5.) A far greater percentage of males than females completed the three-course sequence: biology, chemistry, and physics. These results are consistent with those reported in an earlier study based on data from High School and Beyond (West, Miller, and Diodato, 1985).

Although overall mathematics and science course completion rates increased between 1982 and 1987, the increases were not uniform across population groups. Figures 4.1 and 4.2 show that the population-group differences were substantial. Black and Hispanic students showed greater gains in the completion of basic mathematics and science courses than did white and Asian students (whose completion rates for these courses were already quite high). On the other hand, Asian and white students showed greater increases in the completion of intermediate math and science courses than did black and Hispanic students. At the highest level, the percentage of students who completed the most rigorous college-preparatory combinations of mathematics and science courses increased far more among Asian students than any other group. The percentage of Asian students who completed



SOURCE: Westat, Inc., 1988

Fig. 4.1—Change in Graduates Completing College-Preparatory Mathematics 1982–1987 by Population Group



SOURCE: Westat, Inc., 1988

Fig. 4.2—Changes in Graduates Completing College-Preparatory Science Courses 1982–1987 by Population Group

geometry, algebra II, trigonometry, and calculus increased by more than ten percentage points between 1982 and 1987, while the percentage of white, black, and Hispanic students completing these courses increased by only one or two percentage points.

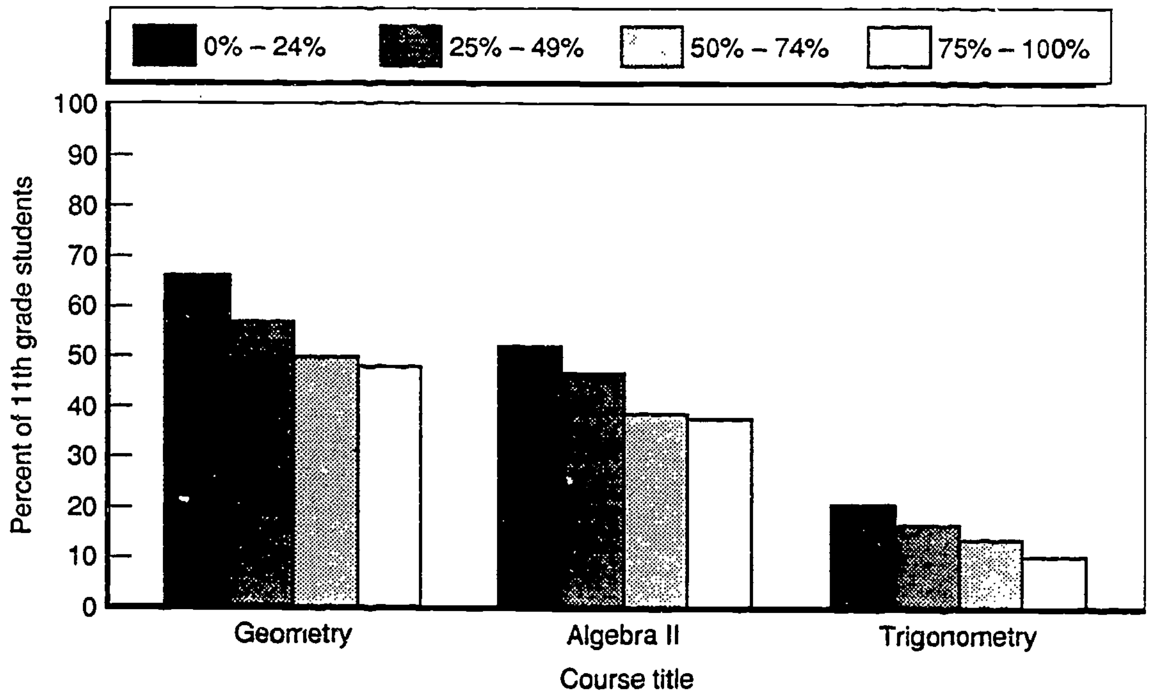
In contrast, the increases from 1982 to 1987 in the percentage of male and female graduates completing basic and intermediate mathematics and science courses were approximately the same.

Using the NAEP data, it was possible to compare the course-taking behaviors[3] of 11th grade students in schools that differed on selected school and student characteristics. (There was little evidence about students' completion of advanced courses, such as precalculus or calculus, which are normally taken in the 12th grade.) The analysis of mathematics course taking was conducted using basic and intermediate mathematics courses (geometry, algebra

[3]NAEP provided self-reported data on course taking ("Did you take chemistry?") rather than transcript-based data on course completion.

II, and trigonometry). The analysis of science course taking was based on student enrollment in biology I, chemistry I, and physics I.[4]

Mathematics course taking was strongly associated with school population groups, size and type of community, subsidized lunch participation and school type. (See Figures 4.3 through 4.6.) Students in low-minority schools, high-metropolitan schools, schools with low percentages of students receiving subsidized lunch, and private and Catholic schools, were more likely to take basic and intermediate mathematics cou ,es by grade 11 than were students in schools with the opposite characteristics. There was no association between mathematics course taking and enrollment. (See Figure C. 18 in Appendix C.)

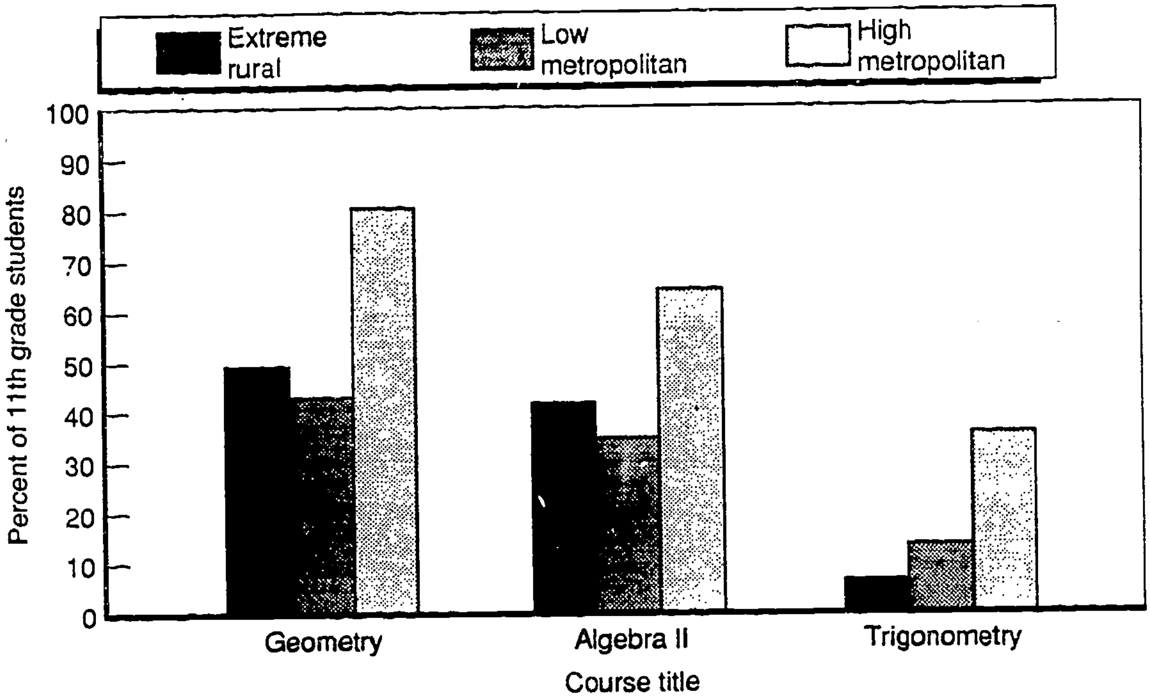


SOURCE: RAND tabulations of the 1985–1986 National Assessment of Educational Progress

Fig. 4.3—Mathematics Courses Taken Through Grade 11 by Percent Non-Asian Minority Enrollment

[4]Physics I was included in the analysis (even though it is an advanced course) because 12 percent of the students in the NAEP sample reported they had taken physics. Although it is possible that students took physics in the 11th grade, this seems unlikely, and the results regarding physics course taking must be interpreted with considerable caution. There was some evidence that students responded incorrectly to this question, indicating they had taken physics when they had actually taken physical science (an introductory course).

The analysis of the distribution of science course taking across schools has another limitation. There was very little between-school variation in the percent of students taking either biology or physics: Almost all students took biology I; very few took physics. As a result, there were almost no relationships between background variables and course taking for these two courses. There was greater between-school variation in the percent of students taking chemistry, and some associations with chemistry course taking were detected.

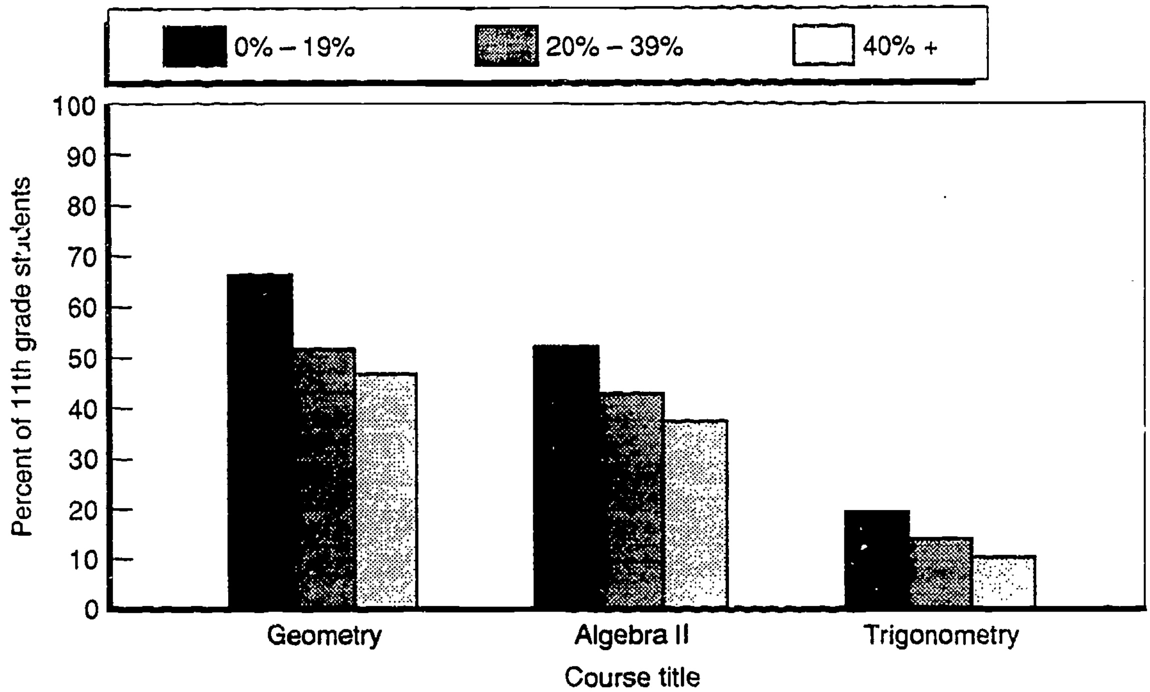


SOURCE: RAND tabulations of the 1985–1986 National Assessment of Educational Progress

Fig. 4.4—Mathematics Courses Taken Through Grade 11 by Size and Type of Community

In general, differences in course taking across schools were more pronounced than differences in course availability. For example, Figures 3.2 and 4.4 show that high-metropolitan schools and extremely rural schools were equally likely to offer geometry and algebra II, but 11th grade students in high-metropolitan schools were far more likely than 11th grade students in extremely rural schools to take either course. Similarly, there were greater differences in course taking than in course availability across schools clustered by population groups, subsidized lunch participation, or school type. (See Figures 4.3, 4.5, 4.6, C.5, C.8, and C.11.)

These comparisons confirm the obvious facts that: (1) offering a course is a necessary, but not sufficient, condition for students to take it, (2) offering a course is not the same as offering enough sections of a course for all students who wish to take it, and (3) offering a course does not, in and of itself, provide adequate preparation and/or incentives for students to take it. (Consequently, remedies that focus merely on promoting more widespread offering of courses are unlikely to eliminate differences in course taking.) These comparisons also provide a strong argument that an indicator of course offerings cannot be used as a substitute for an indicator of course taking.



SOURCE: RAND tabulations of the 1985–1986 National Assessment of Educational Progress

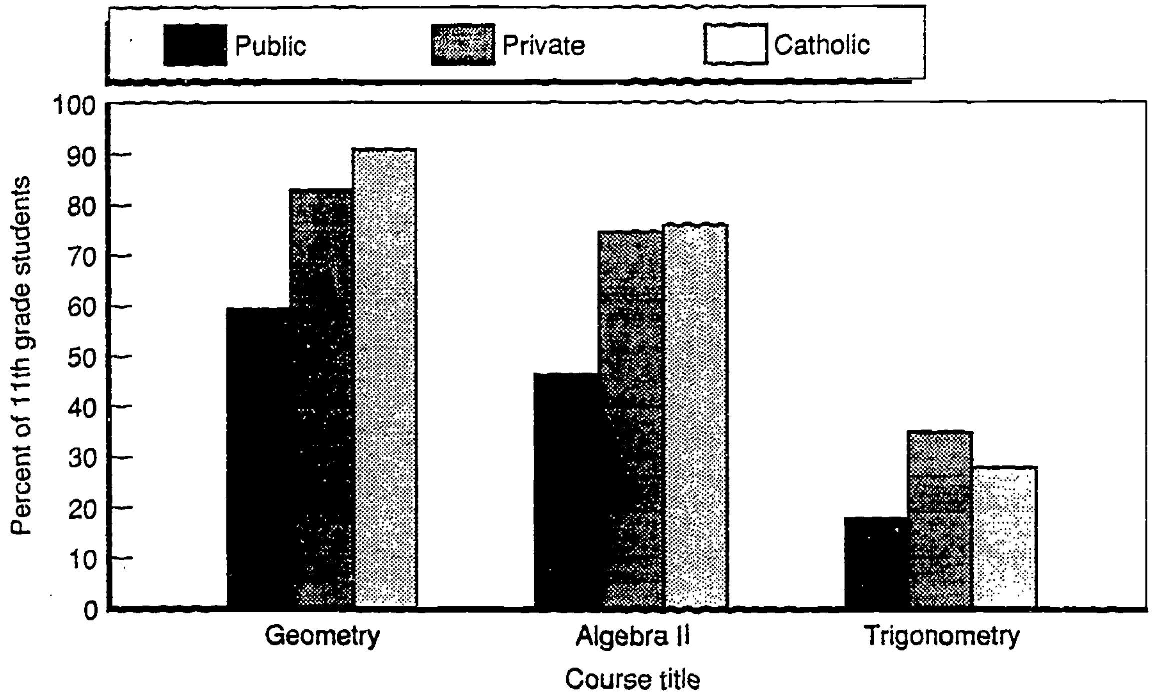
Fig. 4.5—Mathematics Courses Taken Through Grade 11 by Percent Receiving Subsidized Lunch

Figures 4.7 and 4.8 show the relationship between science course taking and size and type of community and school type. These differences were similar in size to those for mathematics course taking. However, science course taking was not associated with school population groups, subsidized lunch participation, or school size. (See Figures C.19 through C.21 in Appendix C.)

AVAILABILITY AND RELIABILITY OF DATA

Are reliable, representative data available on a regular basis to describe course completion at the secondary level?

There is only one recent nationally representative source of data regarding high school graduates' course completion patterns, the 1987 High School Transcript Study (Westat, 1988). Unfortunately, the study is not ongoing, it does not contain information about the characteristics of the schools that students attended, and it does not provide a detailed tabulation of computer science courses. The first of these is the most serious limitation from the point of view of an indicator system. To our knowledge there are no current plans to undertake transcript studies on a regular basis in the future. (The other two problems could be remedied easily in any future national transcript studies.) We assume that high school



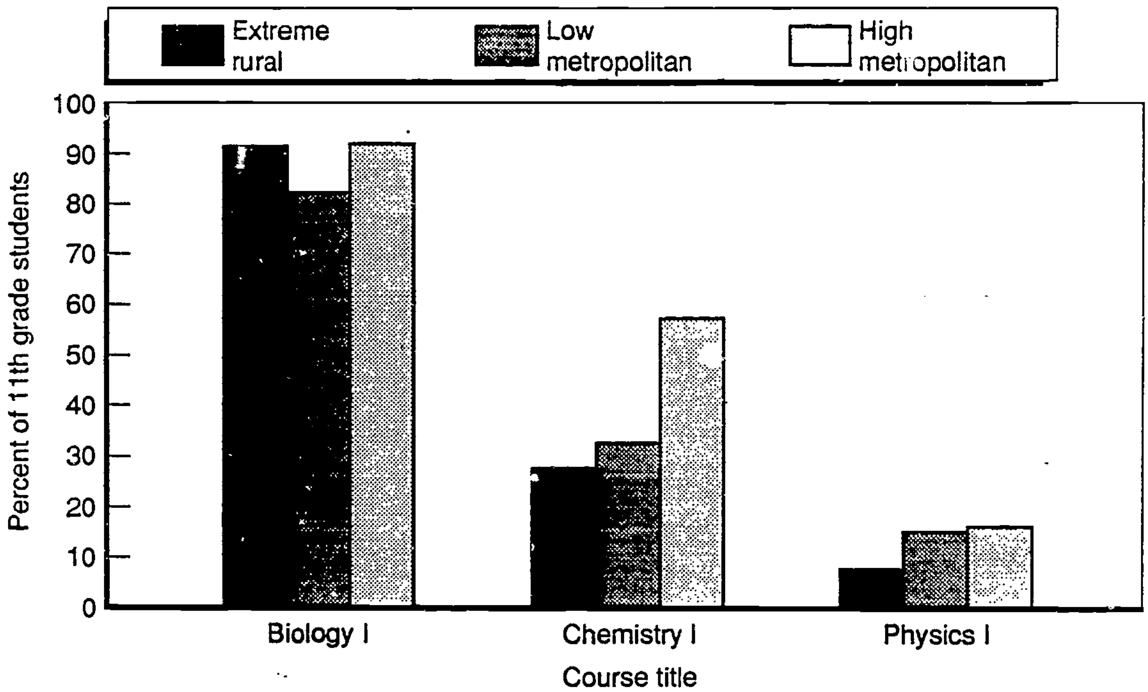
SOURCE: RAND tabulations of the 1985–1986 National Assessment of Educational Progress

Fig. 4.6—Mathematics Courses Taken Through Grade 11 by School Type

transcripts will be collected and analyzed by the National Education Longitudinal Study (NELS) in 1992, or shortly thereafter, when the original eighth grade cohort graduates from high school. These transcripts would provide a database from which comparable 1992 course-completion indicators could be developed, but they will not address the long-term problem of ongoing transcript data.

Because of the limitations of the 1987 transcript data, we supplemented the analysis with information from the 1985-1986 NAEP.[5] NAEP is an ongoing data collection effort, so it overcomes the most serious problem with the transcript study. However, NAEP has shortcomings of its own. Most important, students were in the 11th grade at the time they participated in NAEP, so the database lacks any information about courses taken in 12th grade. In addition, there were some inconsistencies in the data regarding physics course taking. The percent of students saying they took physics was higher in high-minority schools than in low-minority schools, which runs counter to all other evidence about course

[5]The High School Transcript Study was designed to use the same sample of schools and students as the 1985-1986 NAEP. However, operational problems interfered with this plan, and while the final school sample matched that in NAEP, the final student sample did not.



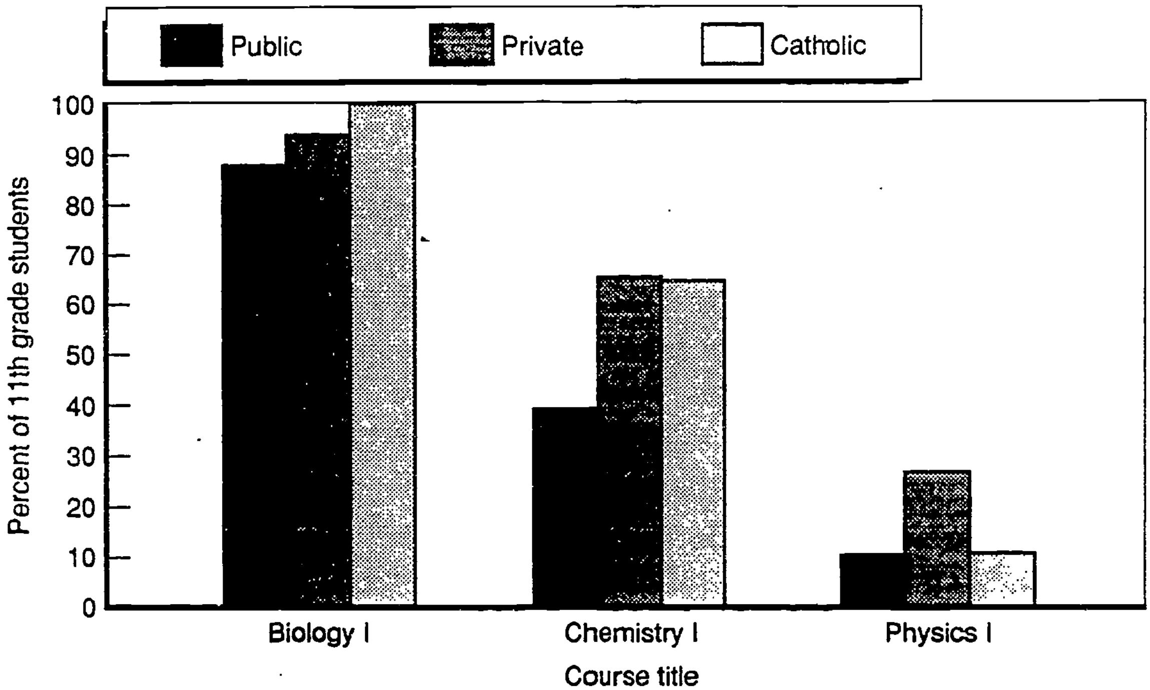
SOURCE: RAND tabulations of the 1985–1986 National Assessment of Educational Progress

Fig. 4.7—Science Courses Taken Through Grade 11 by Size and Type of Community

completion among students in these schools. We suspect that students responded positively to questions about physics when they had actually taken physical science.

Using the two data sources, it was possible to compare course-taking behavior through grade 11 with course-completion patterns of the same cohort of students after graduation. This comparison provided information about the reliability of the data. We would expect the percentage of students completing basic courses in mathematics and science to be approximately the same for the two groups (since these courses are usually taken prior to grade 11). In contrast, the percentage of 11th grade students completing advanced mathematics and science courses should be significantly lower than the percentage completing these courses a year later upon graduation. This is exactly what the data reveal.

Looking toward the future, the major problem with NAEP has already been addressed; the survey will be administered to 12th grade students in 1990 and thereafter. However, there are still some problems that will have to be resolved if data from NAEP are to be used to estimate student course-completion patterns. First, NAEP course-taking data are derived from student self-reports rather than transcript analyses. Although previous research has found a high correlation between self-reported grades and course-completion information and



SOURCE: RAND tabulations of the 1985–1986 National Assessment of Educational Progress

Fig. 4.8—Science Courses Taken Through Grade 11 by School Type

comparable data taken from transcripts (National Center for Education Statistics [NCES], 1984; Valiga, 1986), the correlations were far from perfect. In one study the overall match between student reports of courses taken and transcripts was 95 percent; however, the percentage of errors was greater than 10 percent for certain mathematics and science courses (Valiga, 1986). In another study, the correlations between student reports of coursework taken in mathematics and science and values obtained from transcripts ranged from .63 to .70 (NCES, 1984). The conclusion we draw from these results is that self-reported course-taking data are reasonably accurate, although transcript-based data are preferable.

Second, NAEP surveys are administered in the winter and spring. Consequently, they cannot reflect course completion through the end of the school year. NAEP must either report course taking through the first semester or must rely on student projections of course taking for the remainder of the year. The reliability of such projections is unknown. In either case it would be appropriate to undertake separate benchmarking studies to validate the results of future NAEP assessments against actual student transcripts. Finally, as noted previously, NAEP needs to expand the range of courses on which it collects data and improve the quality of its data regarding school background characteristics.

EVALUATION OF INDICATORS

What are the strengths and weaknesses of alternative indicators of course completion at the secondary level? Are they valid for the intended purposes and resistant to corruption?

A variety of statistics have been used to summarize student course enrollment patterns. These include the percent of graduates completing specific courses or combinations of courses (Westat, 1988), the number of sections of each course offered per 100 students (Oakes et al., 1990), the distribution of credit hours completed through graduation (Tuma et al., 1989), the percent of college-bound seniors (who took the SAT) reporting completion of specific courses (Educational Testing Service [ETS], 1989), and the percent of 11th grade students reporting completion of specific courses (Dossey et al., 1988; Mullis and Jenkins, 1988; Goertz, 1989). Indicators could be developed using any of these statistics.

We used three criteria for choosing among these alternatives when developing indicators: the indicators should (1) reflect the course-completion behaviors of individual students, (2) differentiate between courses by title or level (rather than assigning an equal value to all courses in a subject), and (3) include advanced college-preparatory courses, which usually are taken during the senior year. Consequently, the course-completion indicators we examined were almost all based on the percentage of high school graduates of a particular type (such as female students, Hispanic students, and students attending private schools) who completed a course or combination of courses.

Many of the evaluative comments made in the previous discussion of course-availability indicators—the interpretability of an indicator based on course titles and the use of extreme groups and extreme group ratios—are relevant to course-completion indicators as well, and they will not be repeated here. However, there are three additional issues that relate to the definition and interpretation of course-completion indicators. The first issue is whether to define indicators in terms of single courses or combinations of courses. The second is the possibility of identifying early indicators that predict later course-taking behavior; the third is the problem of identifying a restricted set of courses to include in an indicator system. After discussing these topics, we will consider the corruptibility of course completion indicators.

A careful review of the information contained in Tables 4.1 and 4.2 shows that the vast majority of students who completed the traditional college-preparatory courses in mathematics and science did so in the same combinations. For example, 45 percent of 1987 high school graduates completed chemistry, and 43 percent completed chemistry and biology, thus only 2 percent completed chemistry but not biology. Similarly, only 3 percent completed physics, but not biology and chemistry. One implication of this might be that an indicator of course completion based on single precollege mathematics and science courses would have provided roughly the same information as an indicator based on combinations of courses. However, a recent study of course taking in five districts in two states found marked differences in the order in which science courses were taken (McDonnell et al., 1990). Furthermore, at least one major science curriculum reform effort has called for changes in the traditional grade levels at which core science courses are presented (American Association for the Advancement of Science [AAAS], 1989). As a result, indicators based on single courses may become less descriptive of student course completion behaviors in the future, particularly in the field of science.

The second issue to explore is the possibility of developing early indicators that predict advanced course-taking behavior. For example, it does not seem unreasonable to hypothesize that students who complete algebra I in eighth grade (ahead of the normal sequence) are more likely than other students to complete advanced or accelerated mathematics courses in high school. In the other direction, students who have not completed algebra I by the time they finish the ninth grade or biology I by the time they finish the 10th grade (behind the normal sequence) are less likely than other students to complete advanced or accelerated math and science courses. To the extent that these hypotheses are true, they permit the development of early predictors of the flow of students into the mathematics and science pipeline.

Evidence from a nonrepresentative transcript study suggests that standardized course-by-grade sequences do exist in many districts, and that both prediction hypotheses are true to a certain extent (McDonnell et al., Technical Report, in press). Students who took algebra I in grade eight or nine were two and a half times as likely to take geometry as students who took algebra I later. Alternatively, less than 10 percent of the students who took biology in a grade other than 10 took any other science courses. The authors concluded that lead indicators of the type described here were moderately useful in predicting mathematics and science course completion. Furthermore, the predictive power held for minority as well as majority students.

Additional research needs to be done to test the validity of this type of course-completion prediction on a representative sample of students. However, initial evidence suggests that it would be possible to develop advanced indicators of the mathematics and science pipeline based on eighth and ninth grade course completion.

Third, one of the problems that complicates the development of both course completion and course availability indicators is the large number of different courses offered by schools. Even after restricting the presentation to common mathematics, science, and computer science courses, the tables in the previous chapter contained 35 different courses. This is too much information for efficient review. The tables fail to meet one important criterion of an effective indicator; they are not a parsimonious set of statistics that describe the status of mathematics and science curriculum. Furthermore, this encyclopedic approach displays course data without reference to the nature of the courses (e.g., level, difficulty, sequence, etc.). The reader must rely on his or her own understanding of curriculum to interpret the results meaningfully.

There are a number of ways one might try to select subsets of courses or define clusters of courses to focus the presentation of course-related results (be they course completion or course availability). We will briefly consider two methods: courses clustered by level and subsets selected on the basis of relationships between course completion and other student outcomes or behaviors. A third approach, selecting key individual courses, was discussed previously.

A natural way to cluster courses is by level: introductory, intermediate, and advanced. These clusters would be constructed by taking the typical college-preparatory sequence and subdividing it into groups of courses based on sequence and grade level. Introductory courses are those taken by college-preparatory students in grades 9 and 10, intermediate courses are taken by college-preparatory students in grades 10 and 11, and advanced courses are those taken by college-preparatory students in grade 12. In fact, the correspondence between sequence, grade level and difficulty is quite high, so it might be accurate to identify these as levels of difficulty.

Using this designation, one can report that introductory college-preparatory mathematics courses (algebra I and geometry) are available in over 90 percent of high schools, while intermediate courses (such as algebra II and trigonometry) are available in approximately 60 percent to 90 percent of the schools. Already the problem becomes apparent. Although the cluster of intermediate course may make sense from the point of view of grade level, there is no sensible way to summarize statistics from the individual courses to obtain a clusterwide value. What is true of algebra II—in terms of course availability, course completion or any other feature—will not necessarily be true of trigonometry (or any other course). This suggests that the courses in the cluster are more dissimilar than similar.

Alternatively, it should be possible to select a subset of courses that have particular significance and include only these in the indicator system. For example, recent evidence suggests that students who successfully complete algebra and geometry are more likely to be admitted to college and to complete college than students who do not complete this sequence of courses (Pelavin and Kane, 1990). These results give special significance to the completion of algebra and geometry as predictors of college success, and these courses have been referred to as *gatekeeping* courses.

However, there are many other courses that represent important mathematics- or science-related curriculum milestones (e.g., a course that is needed for college admission, a course that seems to differentiate between vocational and college-bound students, or a course that identifies students who are likely to pursue advanced mathematical and scientific studies). The subset of courses that is relevant to one decision or one policy question will not necessarily provide information that is relevant to another. If one were interested in curriculum reform, it would be important to monitor courses with changing availability. If one were interested in preparing students to be admitted to college, it would be important to monitor the core of courses that corresponded to basic admissions requirements. If one were interested in the production of future mathematicians and scientists, it would be important to monitor the most advanced courses, those whose content was equivalent to college-level courses. There appears to be no convincing argument, either theoretical or empirical, for choosing a specific subset of courses to monitor.

Another problem in identifying a subset of courses for inclusion in an indicator system is that selections may not retain their relevance over time. For example, a comparison of science courses offered in 1977 and 1986 showed rapid growth in the availability of courses in Life Science, Earth Science, and Physical Science. (See Table 4.7.) However, many people would have omitted these courses from a reduced indicator set deemed relevant in 1977, thus failing to reveal the only dramatic changes in science course availability that occurred during the next decade. Furthermore, as curriculum reform accelerates, it will become more difficult to select subsets of courses that will be of lasting relevance. For all these reasons we are less than sanguine about the possibility of selecting a reduced set of courses to use as indicators of course completion and course availability.

Finally, it is important to consider how measures of course completion will behave in a highly charged indicator context. Fortunately, measures of course completion may be somewhat more robust than indicators of course availability. In general, students' course-taking behaviors are not easily manipulated, and there is little likelihood that an indicator system, in and of itself, would unduly influence student decisions. Were it easy to change students' choices, enrollment in advanced courses would have increased far more dramatically than it has. To the extent that national attention on course completion encourages qualified students to take math and science courses they might not otherwise elect to take, it is probably to the good.

On the other hand, there is some concern that pressures to increase the percentage of students taking more advanced courses will lead to inappropriate placements. This would be detrimental to the students, who would be placed in courses for which they were not prepared, and to the curriculum, which might have to be changed to accommodate underprepared students. While we doubt that a national indicator system would have this strong an effect, there is some evidence that such changes could occur. Certainly caution would be warranted if local authorities were to adopt national standards as local accountability measures. Supplemental research regarding the content of courses would be needed to provide baseline data to determine whether courses were being watered down due to the high visibility of course completion indicators or due to other causes.

5. COURSE CONTENT

To this point the portrait of secondary mathematics and science curriculum has been drawn at a very high level of aggregation—years of study, courses available, and courses completed. While the results reported in the previous chapters provide some useful information about high school students' exposure to mathematics and science, none of the data directly describe the content of the classroom curriculum, e.g., what it taught, how it is taught, and what resources are used in teaching it. Even indicators based on specific course titles provide only indirect evidence of students' opportunity to learn specific knowledge and skills.[1]

In contrast, the present chapter focuses on the actual subject matter of classroom instruction, i.e., the mathematical and scientific knowledge, skills, procedures, and dispositions to which secondary students are exposed. The current status of secondary course content is described first, followed by a discussion of the availability and quality of course content data and an evaluation of alternative indicators of course content at the secondary level. To organize the presentation, course content is broken down into three components — topic coverage, curriculum-specific instructional strategies, and instructional materials and resources.

Measures of topic coverage describe *which* facts, procedures, algorithms, etc. are presented. In comparison, measures of instructional strategies describe *how* these facts, procedures and algorithms are presented, i.e., the specific approach taken by the teacher when discussing mathematical and scientific knowledge and skills.[2] Finally, measures of instructional equipment and materials describe what resources were available to support instruction and to what extent they were used in mathematics and science classes.

Unfortunately, the major importance of this chapter may be in what it fails to reveal about curriculum rather than what it reveals. As will be illustrated below, current

[1]Recent studies of course content suggest that a tremendous amount of curriculum differentiation exists within courses and within grade levels (McDonnell et al., 1990; McKnight et al., 1987), so course taking can be interpreted as a measure of exposure to subject matter only in very general terms.

[2]Excluded from this discussion are measures of general instructional style (e.g., pacing, management techniques, rapport, etc.).

nationally representative surveys provide little information about most aspects of course content in mathematics and science at the secondary level.[3]

CURRENT STATUS

What is the content of secondary-level mathematics and science courses and how has this content changed over time?

The principal theme that will be repeated throughout this chapter is the limited range of measures that exist to describe course content. Neither topic coverage nor instructional strategies can be depicted in any detail, although there are relatively more data available on instructional equipment and materials. Some information will be presented regarding certain aspects of selected courses (primarily eighth grade general mathematics and science courses and precalculus/calculus courses), but the discussion will be limited.

The following discussion has three major purposes:

1) To provide information about the status of mathematics and science course content in a narrow range of courses;
2) To illustrate the types of course content descriptions that would be possible on a broader scale if information were gathered more extensively;
3) To highlight the gaps in our knowledge of course content that could be filled only through additional measures not presently available.

Topic Coverage[4]

Three aspects of topic coverage will be described: which topics did teachers *intend to present*, which topics actually *were presented*, and what was the *nature of the presentation*, e.g., was it introductory, review of past material, or coverage in depth;[5] did it receive major

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[3]Most of the results are drawn from the Second International Mathematics Study (SIMS), and they may be of limited generalizability because they are almost a decade old and because the U.S. samples were not representative of the nation.

[4]The reader should be alerted to the fact that the view of "topic coverage" implicit in these results is not universally held. The approach to subdividing content taken by most surveys suggests that the substance of mathematics and science can be divided into discrete pieces that can be measured and, by extension, taught in isolation. Current research on scientific thinking suggests that mathematics and science are highly integrated disciplines that are best learned in a real-world context. The notion of topic coverage outlined in the following paragraphs tends to ignore these complexities. (This concern is elaborated in the discussion of the validity of course content indicators later in this chapter.)

[5]We follow the lead of SIMS in interpreting information on coverage as a measure of curriculum sequence rather than instructional practice, i.e., what was the place of the particular topic in the developing sequence of mathematical content—was it review, taught in depth, or only alluded to as an introduction to future teaching?

emphasis, minor emphasis, review only, or was it not covered at all? No data regarding trends in topic coverage were available.

The discussion will include information about two groups of students, those in grade 8 (regardless of course title) and those in precalculus or calculus classes (regardless of grade, though typically in grade 12). The former group comprised the population A sample used in SIMS as well as the initial cohort of NELS; the latter group was the population B sample from SIMS. Because many people are unfamiliar with the eighth grade mathematics or science curriculum, comparative results may be more meaningful than absolute ones. In this case most of the data were drawn from SIMS, an international survey, so many of the results compare the situation in the United States to the situations in other countries. Results from SIMS were reported in Crosswhite et al. (1986).

The SIMS survey attempted to differentiate the intended curriculum from the implemented curriculum. It included questions about the importance of topics within courses, the intended coverage of topics by teachers, the actual amount of classroom exposure to topic areas, and the nature of the exposure. For example, Table 5.1 shows mathematics educators' ratings of the importance placed on various topics in precalculus/calculus courses. There were noticeable differences between the rating in the United States and in other countries. For example, international mathematics educators placed greater emphasis than U.S. mathematics educators on elementary functions and calculus, probability and statistics, and finite mathematics. The U.S. sample was not adequate to estimate the degree of variation within the country.

The intended curriculum also was measured by asking teachers to project the number of days they would spend on each major topic area during the year. Teachers in grade eight

Table 5.1

Topic Importance Ratings for U.S. and International Calculus Curriculum

Topic	U.S.	INT
Sets and relations	5.0	3.8
Number systems	7.6	7.4
Algebra	8.3	7.3
Geometry	5.3	4.0
Elementary functions and calculus	6.2	8.6
Probability and statistics	2.0	4.4
Finite mathematics	4.0	6.0
Computer science	4.0	4.0
Logic	4.0	0
Average	5.1	5.0

SOURCE: Crosswhite et al., 1986.

intended to devote as much time to sets, relations, and properties as to algebra and geometry combined. Little or no attention was to be paid to probability or statistics, topics which have received greater emphasis in recent years in the college curriculum. Teachers of calculus classes in the U.S. SIMS sample intended to place a heavy emphasis on differentiation and integration with much less time spent on the related concepts from analytic geometry.

Actual topic coverage did not always match intended coverage (though it is difficult to draw direct comparisons from the SIMS results because topics were classified in different ways for different questions). Although the vast majority of U.S. calculus classes covered the topic area that was rated most important internationally—elementary functions and calculus—*fewer than half of the calculus classes in the U.S. sample covered seven of the eight curriculum topic areas.* On the other hand, topic coverage in the United States was greatest for those topics rated the highest in importance by U.S. mathematics educators.

Other international comparisons of eighth grade topic coverage also show U.S. classes lagging behind other countries. Eighth grade topic coverage in the United States was at or below the median for the 12 participating countries and provinces in five of the six topic areas (numbers and operations; relations, functions and algebra; geometry; measurement; data organization and interpretation; and logic and problem solving) measured in the International Assessment of Educational Progress (IAEP) (Lapointe, Mead, and Phillips, 1989).

In an attempt to explore the sequence of topics across courses, teachers participating in SIMS were asked to indicate whether topics were covered during the current year, during previous years or not at all. These results differed markedly from those just reported. Teachers indicated that students in the majority of calculus classes in the U.S. SIMS sample had been exposed to seven of the eight calculus topics during the current year or during prior years. (See Table 5.2.)

Another way one might measure exposure is to determine the number of class periods that were devoted to studying each topic and the nature of the exposure — studying the topic as new, review, or review and extend. Responses from calculus teachers to an abbreviated list of subtopics in analytic geometry are summarized in Table 5.3. The information in the table permits one to differentiate between subtopics that received a lot of attention overall (equations and graphs of conics) and newly introduced subtopics that received a lot of attention (vectors and vector operations). U.S. precalculus and calculus classes in the SIMS sample spent relatively little time reviewing topics introduced previously in comparison with the time that was spent reviewing and extending topics or introducing new topics. It should be noted that these patterns may not be typical of all U.S. mathematics courses; calculus

Table 5.2

Content Exposure by Topic

Topic Area	Percentage of U.S. Classes: Precalculus: Taught Before	Precalculus: Taught This Year	Precalculus: Never Taught	Calculus: Taught Before	Calculus: Taught This Year	Calculus: Never Taught
Sets/relations	31	50	19	50	40	10
Number systems	39	42	19	75	14	11
Algebra	34	52	14	53	41	6
Geometry	21	40	39	41	26	33
Elementary functions and calculus	8	37	55	9	83	8
Probability and statistics	29	14	57	50	6	44
Finite mathematics	29	21	50	62	8	30
Other areas	8	8	84	15	4	81
Total	22	40	38	38	45	17

SOURCE: Crosswhite et al., 1986.

Table 5.3

Analytic Geometry Subtopic Coverage in Calculus Classes (Abbreviated)

Subtopic	Average Number of Class Periods: New	Review and Extend	Review Only
Parametric equation of line	1.5	.1	.1
Analytic proof of theorems	1.3	.2	.2
Equations and graphs of conics	2.2	3.6	.5
Vectors and vector operations	2.9	.2	.1
Translations of axes	1.0	.3	.2
Rotation of axes	0.9	—	.1

SOURCE: Crosswhite et al., 1986.

courses attract the best students, and the balance between review and new material may be different than it is in courses with different groups of students.

There are other ways one might try to measure curriculum emphasis. Eighth grade science and mathematics teachers who participated in NELS were asked to describe the emphasis they placed on a number of mathematics and science topics as one of the following: major, minor, review only, or not covered at all. In mathematics, algebra, problem solving, ratios and percents, and integers were major topics in the majority of the classes; probability and statistics, measurement, and geometry were major topics in less than one-quarter of the classes. In science, only earth science was described as a major topic in the majority of the classes. The next most frequently taught topics were weather/astronomy, chemistry, atomic theory, and physics subjects (Horn and Hafner, in press).[6] It is interesting to note that earth sciences and weather and astronomy were the most popular subjects, yet, according to NSSME, few junior high schools had access to telescopes (29 percent), weather stations (10 percent), or portable planetariums (7 percent) (Weiss, 1987).

Curriculum-Specific Instructional Strategies

Classroom-level instructional strategies are an important element of curriculum, since the nature of the teacher's presentation determines students' learning opportunities. A topic can be presented in many different ways with equal enthusiasm and skill. For example, Boyle's Law (describing the relationship between temperature, pressure, and the volume of a gas) can be taught with an emphasis on the computational algorithm or on the conceptual relationships among the variables. A measure of topic coverage alone would not fully describe students' opportunity to learn in these two situations; additional measures of instructional approach would be needed to portray the differences accurately.

Selected results from SIMS, NELS, and NSSME will illustrate some measures of classroom-level curriculum implementation that have been collected. This discussion presents information about the choice of goals and objectives for mathematics instruction, the representation of specific concepts, and the application of concepts.

Table 5.4 shows the percentage of junior high school mathematics classes placing heavy emphasis on various objectives for mathematics instruction. It is interesting to note that the primary objectives for mathematics instruction changed little across grade levels; approximately the same percentage of elementary school, junior high school, and high school teachers emphasized the three most common objectives shown in Table 5.4. Three other goals were emphasized relatively more strongly in the lower grades: performing computations with speed and accuracy, becoming aware of the importance of mathematics in everyday life, and becoming interested in mathematics. The only goal that received substantially more emphasis at the secondary level was learning about the career relevance of mathematics (Weiss, 1987).

Teachers also exercise choices about the ways in which concepts are represented or interpreted. For example, there are a number of ways to model the concept of a fraction. More than 80 percent of the teachers in grade eight emphasized the interpretation of

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[6]It is difficult to know how to interpret these ratings, since no operational definitions were given for the levels of emphasis. This is an instance in which additional research would be necessary to validate any interpretation of the results.

Table 5.4

Objectives of Mathematics Instruction

Objective	Percent of Mathematics Classes with Heavy Emphasis*
Know mathematical facts, principles, algorithms, or procedures	80
Develop a systematic approach to solving problems	76
Prepare for further study in mathematics	67
Perform computations with speed and accuracy	59
Become aware of the importance of mathematics in daily life	61
Develop inquiry skills	50
Learn to effectively communicate ideas in mathematics	54
Become interested in mathematics	40
Learn about the applications of mathematics in technology	27
Learn about the career relevance of mathematics	28
Learn about the history of mathematics	5

*Teachers were given a 6-point scale for each objective, with 1 labeled "none," 2 "minimal emphasis," 4 "moderate emphasis," and 6 "very heavy emphasis." These numbers represent the total circling either 5 or 6.
SOURCE: Weiss, 1987.

fractions as decimals and as quotients, while fewer than 40 percent emphasized fractions as parts of regions, ratios, or points on a number line.

Mathematical and scientific concepts have many applications in the real world, and teachers incorporate different applications into their lessons. For example, calculus teachers asked students to apply the concepts they learned in trigonometry to a variety of different situations. The most common were inaccessible distance problems (66 percent of teachers), other surveying problems (58 percent), periodic motion (42 percent), and vector applications (39 percent). Most problems were drawn from the textbook, although approximately 40 percent of the teachers created their own problems.

These examples illustrate the kind of information about instructional strategies that would contribute to a fuller description of mathematics and science curriculum if they were collected more extensively.

Instructional Equipment and Materials

One factor that affects both the content and the quality of mathematics and science instruction is access to appropriate instructional equipment and materials. By instructional equipment and materials we mean textbooks, supplemental reading materials, instructional films and videos, calculators, computers, laboratory facilities, laboratory equipment, and any other tangible resources used to support the instructional program.

Data will be presented separately to describe the status of textbooks, laboratory facilities, computers, calculators, and other equipment. Each picture was pieced together with information from many different, and incomplete, sources. As a result, the description is uneven, and it is rarely possible to describe trends over time.

Textbooks were used in more than 90 percent of all mathematics and science classes, and this percentage remained essentially unchanged between 1977 and 1986 (Weiss, 1987). Because mathematics teachers make only limited use of other curriculum resources when setting content or teaching methods (McKnight et al., 1987), a content analysis of these textbooks might be used to reveal the common elements of the text-based curriculum underlying most mathematics classes. However, such an analysis would not necessarily provide an accurate picture of the actual instructional content of classes, since teachers tended not to cover all the material in their textbooks. Table 5.5 shows that almost one-half of the science teachers and almost one-third of the mathematics teachers covered less than three-quarters of the material in their textbooks.

How good are the textbooks? Only indirect measures exist. For example, the majority of high school mathematics and science teachers did not consider textbook quality to pose a serious problem for their instructional program. On the other hand, more than half of the science teachers were dissatisfied with the provision of examples to reinforce concepts and the quality of supplementary materials that accompanied the texts, and approximately two-thirds of the mathematics teachers were dissatisfied with the examples of applications of mathematics and with suggestions for calculator and computer use. Finally, approximately 30 percent of the high school science classes were using textbooks published before 1980 (Weiss, 1987). There are other methods for assessing textbook quality, such as expert reviews of pedagogical approaches and content, but these have not been done on a large scale.

Science laboratories (including lab facilities in regular classrooms, general purpose labs, and specialized labs) were found in more than 70 percent of all high schools. (See Table

Table 5.5

Textbook Coverage

	Percent of High School (Grades 10 to 12) Classes	
Percent of Textbook Covered	Mathematics	Science
Less than 25	2	1
25 to 49	6	11
50 to 74	24	37
75 to 90	45	34
More than 90	23	16
Unknown	1	1

SOURCE: Weiss, 1987.

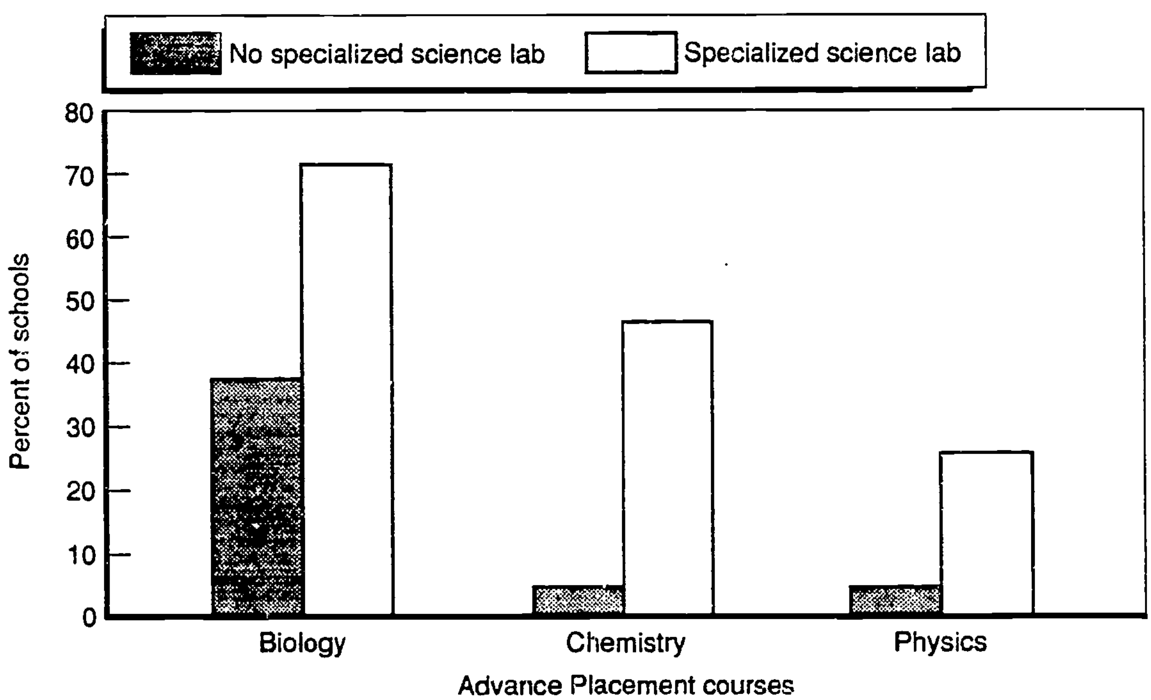
5.6.) Because many advanced science courses emphasize experimentation, the presence of laboratory facilities is particularly important. In fact, Figure 5.1 shows a direct relationship between the presence of specialized laboratories and the offering of Advanced Placement courses in science. Schools without specialized science laboratories are half as likely to offer AP biology and less than one-quarter as likely to offer AP chemistry or physics than schools with specialized science labs. In comparison, only 21 percent of schools reported that they had a mathematics laboratory (Weiss, 1987).

Table 5.6

Science Laboratory Facilities

Type of Facility	Percent of Schools
Lab facilities in classroom	75
General purpose labs	71
Specialized labs	70

SOURCE: RAND tabulations of data from the 1985–1986 National Assessment of Educational Progress.



SOURCE: RAND tabulations of the 1985–1986 National Assessment of Educational Progress

Fig. 5.1—Advanced Placement Science Course Availability by Presence of Specialized Science Laboratories

Computer terminals and/or computers were much more widely available in 1986 than in 1977. Almost all high schools (98 percent) reported that they had computers or computer terminals available in 1985-1986 compared to only 36 percent of high schools in 1977 (Weiss, 1987). Furthermore, the percentage of 17-year-old students reporting that they had access to a computer for learning mathematics more than doubled between 1978 and 1986 (Dossey et al., 1988). Similar results have been reported by other surveys conducted at approximately the same time (Quality Education Data [QED], 1985; Johns Hopkins University, 1986). All agree that the decade of the 1980s was marked by dramatic growth in the number of computers in schools. While the annual rate of growth had declined by 1989, the absolute number of computers acquired each year continued at a fairly uniform rate throughout the decade (Becker, 1990).

The fact that almost all schools have computers available may be misleading in a number of ways. It says nothing about the degree to which teachers and students can gain access to the computers, the degree to which computers are actually used by teachers and students, nor the purposes to which the computers are put when they are used.

It is possible to construct a minipatchwork from a number of different sources to describe computer access and use more completely. The median number of computers per high school was 45 in 1989 compared to 21 in 1985 (Becker, 1990). Furthermore, the percentage of all schools with a minimum of 15 computers, "enough computers so that if they were located in one place, one class of students — working in pairs — could be simultaneously served," doubled from 24 percent in 1985 to 57 percent in 1989 (Becker, 1990). However, despite this dramatic growth, the number of students per computer was still quite high. In 1985 there was only one computer for every 31 students (on average) at the high school level (Johns Hopkins University, 1986).

Ultimately the number of computers is not as revealing as the degree to which teachers and students can use computers. Table 5.7 shows that only 29 percent of mathematics teachers and 20 percent of science teachers reported that computers were "readily available" for instructional uses. Computer coordinators estimated that less than one-quarter of all 11th grade students used a computer for 30 minutes or more each week in any classes, and they estimated that only 8 percent of students' time on computers was spent learning mathematics and only 5 percent learning science[7] (Martinez and Mead, 1988).

Students, too, reported very little computer use in mathematics and science. Only 29 percent of 11th grade students reported that they had *ever* used a computer in mathematics

[7]In contrast, at least one-half of all student time on computers was occupied learning computer-specific skills, e.g., how to use word processing and other software (Becker, 1990).

Table 5.7

Availability of Computers for Science and Mathematics Instruction

	Percent of Classes	
	Mathematics	Science
Not available	24	24
Available but quite difficult to access	23	28
Available but somewhat difficult to access	23	27
Readily available	29	20
Missing/inconsistent	2	2
Unknown	1	1

SOURCE: Weiss, 1987.

class, and only 22 percent reported that they currently used a computer to practice mathematics. Only 15 percent of 11th grade students reported they had ever used a computer in science classes and only 13 percent had used computers to do science problems. Granted, computer use has increased. In 1985, only 11 percent of high school teachers reported that they used computers with their students during a typical week (Johns Hopkins University, 1986); by 1989, 41 percent of high school math teachers and 36 percent of high school science teachers reported that computers were used by students in at least one of their classes (Becker, 1990). However, much of this increase in use was only marginal. Only 23 percent of math teachers and 11 percent of science teachers had students in any classes use computers to a "substantial" degree (Becker, 1990).

With the exception of hand-held calculators, access to other types of equipment and materials either remained approximately the same or declined between 1977 and 1986. (See Table 5.8.) However, although the availability of calculators at the school level is high, student use is still quite low. Although 94 percent of high school principals reported their school had hand-held calculators available for use (Weiss, 1987), only 26 percent of grade 11 students reported their schools had calculators for use in mathematics classes (Dossey et al., 1988). At the eighth grade level, 60 percent of the students had some access to calculators in mathematics classes, but only about one-third used the calculators more than once each week (Horn and Hafner, in press).

Another way to examine the use of instructional equipment and materials is to investigate the use of specific tools in specific subjects. For example, 82 percent of the students in calculus classes used calculators for solving trigonometric problems, 73 percent used trigonometric tables, 15 percent used logarithms and trigonometric tables, and 12 percent used computers. In contrast, calculus teachers used few instructional aids. Only 19 percent used surveying instruments, circle function plotters or graphing devices (Crosswhite

Table 5.8

Availability of Selected Instructional Equipment and Materials

Equipment	Percent of High School Classes (10 to 12) 1977	1985–1986
Greenhouse	26	30
Telescope	29	29
Darkroom	75	73
Weather station	22	7
Hand-held calculators	77	94
Microscopes	95	99
Cameras	81	84
Models (e.g., the solar system)	79	82
Small group meeting room	59	59
Learning resource center	—	67
Outdoor study area	—	31
Vivarium	—	3
Portable planetarium	—	6
Videocassette recorder	—	98
Videodisc players*	—	43

*The data on availability of videodisc players are suspect; they are much larger than those reported by other recent studies. It is possible that some principals did not distinguish between videodisc players and videocassette players.

SOURCE: Weiss, 1987.

et al., 1986). One can assume that many of the teachers plot functions on the chalkboard without aids, but it is still interesting to note how few aids they use.

How evenly is course content distributed across secondary schools and students?

Little information is available regarding the differentiation of topic coverage by school or student characteristics. The U.S. SIMS sample was too small to permit subsample comparisons. Results from NELS, which do permit some such comparisons, are just beginning to appear. The following examples illustrate the type of analyses that would be possible were such data more widely available. Findings regarding NELS were drawn from Horn and Hafner (in press).

Topic Coverage

The U.S. mathematics curriculum in grade eight was much more diffuse than the Japanese, Belgian, or French curricula, placing intermediate emphasis on a larger number of topics. The U.S. curriculum lacked "intensity" or sustained focus on any single aspect of mathematics (McKnight et al., 1987). For example, the Japanese curriculum in the seventh grade provided an intensive introduction to algebra with a strong secondary emphasis on geometry. The Belgian and French curricula placed primary emphasis on geometry with considerable attention to fractions. (In a similar manner, regional, state, or district comparisons could be made within the United States if the sample had been drawn with this purpose in mind.)

In the eighth grade, exposure to topics was associated with class level, school type, and certain school and community characteristics. Algebra I classes in grade eight covered more algebra and enriched topics than pre-algebra or general math classes (Horn and Hafner, in press). However, content coverage varied considerably across classes. In fact, some pre-algebra and general math classes exposed students to as many algebra and enriched math topics as some algebra I classes (McDonnell et al., 1990).

Eighth grade students in private schools were more likely to be exposed to algebra topics than eighth grade students in public schools. The most common topics taught in public schools were ratios and percents, problem solving, and fractions, while the most common topics in private schools were algebra, problem solving, and integers.

Similarly, eighth grade students in suburban schools were more likely to be exposed to algebra as a major topic than were students in urban and rural schools. Within public schools, the percentage of eighth grade students for whom algebra was a major topic was inversely related to the percentage of students in the school who were receiving subsidized lunch.

Curriculum-Specific Instructional Strategies

The following results illustrate the types of distributional analyses that would provide useful information about curriculum implementation.

Secondary teachers' emphasis on instructional objectives were affected far more by student abilities and class groups than by school characteristics. For example, teachers of high-ability classes were significantly less likely to emphasize the importance of science and mathematics in everyday life and the importance of computations than were teachers in low-ability classes. Instead, teachers of high-ability classes placed more emphasis on objectives such as inquiry skills, lab techniques, interest, basic concepts, and facts and principles (Oakes et al., 1990).

On the other hand, some instructional variables were related to school and/or student characteristics, including the amount of time spent in whole group instruction, the frequency of science experiments, and the amount of homework assigned. For example, students were more likely to receive whole group instruction in mathematics and science if they were in Catholic schools than public or private schools; 70 percent of Catholic school students compared to 49 percent of public school students attended mathematics classes in which 50 to 75 percent of the time was spent in whole groups, and similar results were reported for science instruction.

The amount of time spent in whole group instruction also was related to subsidized lunch participation, race/ethnicity, and school environment variables, but the relationships were different for instruction in mathematics and science. Students in schools with high subsidized lunch participation spent more time in whole group instruction in mathematics than did students in schools with low subsidized lunch participation, but the latter group spent more time in whole group science instruction than the former. The implication seems to be that small group instruction in mathematics is often remedial, whereas small group instruction in science involves participation in science experiments.

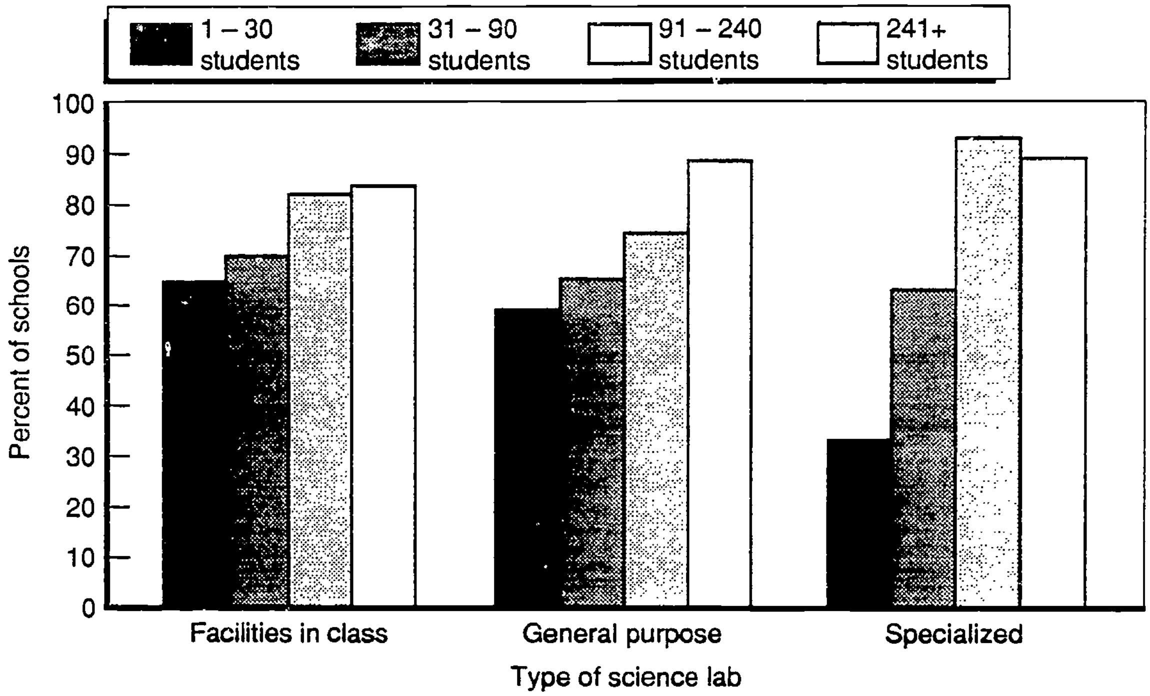
Private school eighth grade science teachers were more likely to conduct weekly science experiments and assign homework than were other teachers. Private school science classes were also smaller than classes in other schools. Specifically, 66 percent of private, nonreligious school science teachers conducted weekly science experiments compared to 55 percent of teachers in Catholic schools, 47 percent of teachers in public schools, and 9 percent of teachers in private religious (non-Catholic) schools. The pattern was similar for class size: 58 percent of students in private religious schools were in classes with no more than 15 pupils compared to 41 percent of students in private nonreligious schools, 14 percent of students in Catholic schools, and 11 percent of students in public schools.

Instructional Equipment and Materials

Available data permit only incomplete descriptions of the distribution of textbooks, laboratory facilities, computers and calculators.

Science laboratory facilities, particularly specialized science labs, were not uniformly distributed across schools. Larger schools were much more likely than smaller schools to have laboratory facilities of any type. (See Figure 5.2.) In addition, hig-metropolitan schools were more likely to have general and specialized labs, while extremely rural schools were more likely to rely on laboratory facilities in class. (See Figure 5.3.) There was only a mild relationship between school population groups and subsidized lunch participation and the availability of laboratory facilities.

Computers were less available to teachers and students in schools with a low percent of parents in professional occupations and inner-city high schools than in high schools with a high percent of parents in professional occupations. Although 95 percent of the principals in high occupational-profile high schools reported that they had access to computers for



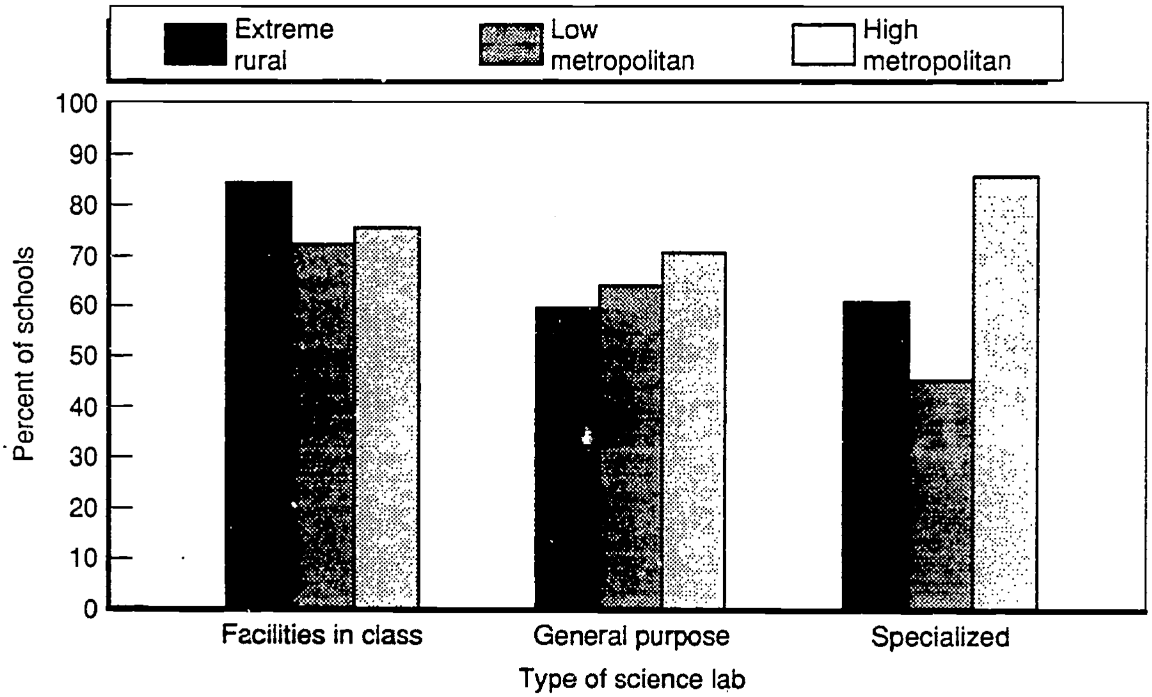
SOURCE: RAND tabulations of the 1985–1986 National Assessment of Educational Progress

Fig. 5.2—Presence of Science Laboratories by Grade Level Enrollment

instructional use, only 77 percent of the principals of low occupational-profile high schools reported availability of computers for instruction. Similarly, teachers in low occupational-profile and inner-city schools reported that computers were less readily available at their schools, and students in high-minority, inner-city schools had access to far fewer computers, even when they were available. (Oakes et al., 1990).

Although Oakes et al. reported there were fewer computers available in high-minority schools, almost the same percentage of minority and nonminority 11th graders reported they had ever used a computer, and approximately the same percentage of the three groups were actually studying computers. (See Table 5.9.) However, almost 50 percent more white students than black or Hispanic students reported that their families owned a computer.

Telescopes, calculators, and other materials were not evenly distributed across schools or students. Schools with high concentration of low-income or minority students and schools concentrated in the inner city had fewer calculators and other equipment available than did other schools. Furthermore, teachers in high-poverty, high-minority inner city schools reported greater problems associated with the lack of instructional resources than did teachers in other schools (Oakes et al., 1990).



SOURCE: RAND tabulations of the 1985–1986 National Assessment of Educational Progress

Fig. 5.3—Presence of Science Laboratories by Size and Type of Community

Table 5.9

Student Experience with Computers

Group	Percent of 11th Graders		
	Used a Computer	Studying Computers	Family Owns Computers
Race/ethnicity			
White	89	20	32
Black	81	21	22
Hispanic	80	19	21
School type			
Public	87	20	29
Nonpublic	88	22	44
Size and type of community			
High metropolitan	93	21	41
Low metropolitan	80	22	22
Extreme rural	90	29	19

SOURCE: Martinez and Mead, 1988.

AVAILABILITY AND RELIABILITY OF DATA

Are reliable, representative data available on a regular basis to describe course content?

Despite the potential value of course work information for educators and policymakers (McDonnell et al., 1990), such information has not received high priority in the design of ongoing national data collection efforts.

For example, the most extensive information regarding the topics covered in the secondary mathematics and science curriculum in the United States comes from the second round of international mathematics and science studies, SIMS and SISS (the Second IEA Science Study), conducted in 1981-1982. Designed and conducted primarily by mathematics and science educators, these studies (and their predecessors in the 1960s) gathered information about the general representation of content areas in the U.S. curriculum and the opportunity provided to students to learn specific topics. Unfortunately, neither study assessed a representative sample of students (the SIMS sample is probably the more representative of the two) so the results cannot be generalized with confidence, and the sample sizes were too small to permit any analyses by population subgroups. Furthermore, both studies are now almost a decade old, so the information is useful only as baseline data in an indicator system.

The only national study that currently collects topic coverage data is NELS, a longitudinal study of 1988 eighth grade students. The limited topic coverage questions in the base NELS survey were expanded in the first follow-up to NELS administered in 1990-1991 when the student cohort was in grade ten. There is every reason to believe that similar questions will be asked of the mathematics and science teachers responsible for the courses taken by the students when they are in grade 12 in 1992. However, NELS will continue to follow the 1988 eighth grade cohort as it progresses through school; it will not continue to supply data about the curriculum in the grades they have completed. In addition, the 1988 International Assessment of Educational Progress (IAEP) collected some data regarding students' opportunity to learn topics included in the test battery. However, the focus of this study was international comparisons of achievement, and only limited data were gathered regarding curriculum coverage within the United States.

Similarly, no ongoing, representative source of information exists concerning curriculum-specific instructional strategies. The most extensive examination of these elements of instruction was conducted by SIMS in 1981. NELS included adaptations of items from SIMS in 1988 and 1990, and we anticipate they will continue to ask teachers about their implementation of curriculum in mathematics and science in 1992. However, that will probably be the last school-based survey from NELS. NSSME included a few questions about teachers' attitudes toward instruction, which were reanalyzed by Oakes et al. (1990) to examine differential effects across schools and students. Occasionally, questions about instructional strategies appear in NAEP, but they are not standardized from assessment to assessment.

Finally, although SIMS, NSSME, NAEP, and NELS each have examined certain aspects of instructional equipment and materials (e.g., calculator use, computer availability, satisfaction with textbooks), these have been isolated investigations. None of these studies had instructional resources as a major focus of attention; none had a framework for measuring the topic comprehensively. Furthermore, of the four sources of data used in this report, only NAEP is ongoing.

Although the surveys fail to meet our needs in terms of coverage, replication, and sampling, they appear to satisfy our criterion for reliability. In the few instances in which results can be compared within or across surveys, they were reasonably consistent.

EVALUATION OF INDICATORS

What are the strengths and weaknesses of alternative indicators of secondary-level course content in mathematics and science? Are they valid for the intended purposes and resistant to corruption?

Because of the paucity of data regarding course content and the lack of a framework for analyzing and presenting the information, no specific course content indicators are recommended. Instead, we suggest that two or three courses, grade levels, or course/grade level combinations be selected as targets for further indicator-defining research. Because of the extensive amount of research already conducted at the eighth grade level, this is a natural starting place. However, much of this work fails to distinguish between courses within grade level, so we suggest additional targets be defined in terms of specific courses. One strategy would be to select three courses each in mathematics and science—one introductory, one intermediate, and one advanced—and try to develop a core of content measures for each course. Likely candidates would be algebra I, algebra II, and calculus in mathematics, and biology I, chemistry I, and physics I in science.

It is considerably more difficult to decide which aspects of course content should be measured. Further research needs to be done within each subject area to evaluate alternatives, operationalize and validate measures, and define specific indicators. Ideally one would like to be able to measure breadth of coverage within a subject as well as depth of coverage in selected topic or thematic units. Instructional strategies and resources should be selected on the basis of the topic/thematic units being assessed, and, to the extent possible, they should be comparable across courses. Developing such measures will require considerable additional study, both to select useful concepts to measure and to develop effective measurement techniques. For example, teacher self-reports, which are an efficient way to gather such information, may fail the test of robustness in a high-stakes context.

The following discussion will highlight some of the problems that are encountered in developing measures of topic coverage, instructional strategies, and instructional equipment and materials.

Topic Coverage

Information about topic coverage is critical to a mathematics and science indicator system. Measures of course availability and course completion assume a commonality of content within courses that may no .xist. Measures of topic coverage are needed to help interpret the more highly aggregated measures based on course titles. In addition, topic coverage is of interest in its own right, because it illuminates the actual content presented to students and differentiates curriculum in a much more refined manner than indicators defined at the course level. However, there are a number of problems that must be overcome in order to develop indicators of topic coverage.

The first difficulty encountered when trying to measure topic coverage is the problem of definition. There are no guidelines regarding what constitutes a topic or a subtopic in mathematics or science, or how finely differentiated topics or subtopics should be. Individual discretion is a large factor in subdividing the curriculum into chunks of related content, and so the definition of topics is discretionary as well.

The clustering of mathematical or scientific facts and theories into groups (whether they are called topics or themes or ideas) is designed to maximize the similarity of the content within a group while maximizing the differences in content between groups. In theory, this could be done in innumerable ways. In practice, curriculum experts in mathematics and science have been able to agree that certain content distinctions are reasonable. In both international surveys cited here, educators were able to reach consensus on the definition of topics within secondary mathematics and science. Nevertheless, there may be theoretical and practical disagreement regarding the definition of topic categories used to subdivide curriculum.

A related concern has to do with the level of detail with which topics are specified. Most comprehensive descriptions of the secondary mathematics or science curriculum include an exceptionally large number of topics and subtopics. For example, the SIMS content matrix for grade 12 precalculus and calculus included 19 topics and 150 subtopics

(Crosswhite et al., 1986). This is not necessarily a bad thing; it suggests the richness of the subject matter. However, an unfortunate consequence of the multiplicity of topics within a course is the difficulty of monitoring them all. Any practical topic coverage indicator would have to focus at a fairly coarse level of aggregation or on a subset of topics defined at a finer level. One negative consequence of the latter approach is the tendency to trivialize the curriculum.

Certainly, the goals of the curriculum should be reflected in the selection of topics to be monitored. This may not be as simple as it seems, because different policymakers emphasize different curriculum goals. For example, it may serve NSF's purpose to focus on topics from advanced mathematics and science because these courses prepare the students who are likely to become the mathematicians and scientists of the future. However, others might focus on different goals. For example, the National Research Council (1989) notes that "students rarely learn mathematics appropriate to enlightened citizenship or to the needs of the workplace." A topic coverage indicator focused on mathematics for enlightened citizenship would reflect different topics than one targeted at future mathematicians and scientists.

Assuming that these problems can be resolved, there is a more fundamental problem with topic coverage information that must be considered before such indicators are developed. The tendency to try to break the curriculum into discrete pieces runs counter to current understanding about the process of learning mathematics and science. Learning mathematics and science is no longer seen as the mastery of isolated pieces of information but as a process of constructing meaning in context. The fractionalization of content that characterizes attempts to assess topic coverage is diametrically opposed to curriculum reform efforts, which aim to integrate mathematical and scientific thinking in the service of real world questions and problems (National Council of Teachers of Mathematics [NCTM], 1989). Topics, as commonly defined, fail to reflect current beliefs about the integrated structure of mathematics and science. A more complete description of mathematics and science would measure something about the topics discussed and the nature of the cognitive learning that takes place.

For example, it might be possible to collect data that portrayed mathematics and science in more modern terms by basing the data collection on a different type of curriculum taxonomy. The mathematics curriculum and evaluation standards (NCTM) might be used to develop measures in a manner more congruent with the principles of organization that guide current curriculum reform. The major thematic units might be problem solving, communication, reasoning, mathematical connections, etc., rather than ratio and proportion, sets and relations, etc. In a similar manner, one might develop a taxonomy based on the nature of science, mathematics and technology or on the basic knowledge of the world from the perspective of these disciplines (American Association for the Advancement of Science [AAAS], 1989).

Finally, one must be careful when developing topic coverage indicators not to emphasize breadth of coverage at the expense of depth. Whichever approach one adopts to classifying course content, it is important to learn more than merely whether or not a topic was presented. Far more useful is knowledge of the amount of time spent discussing the topic, the importance placed upon it, the degree to which it is elaborated, the other topics to which it is related, etc. SIMS, NELS, and SRA (the School Reform Assessment project) provide models of alternative methods for exploring some aspects of the depth of coverage of a particular topic. Supplemental research is needed to refine topic coverage indicators. In particular, research to assess the consistency of topic coverage within course titles would help make both types of indicators more meaningful.

Instructional Strategies

The instructional strategies employed by teachers affect students' opportunity to learn mathematics and science as much as any other element of the curriculum. Consequently, measures of classroom-level curriculum implementation strategies would be desirable elements in an indicator system. Yet these aspects of curriculum have not been measured systematically; they remain largely unexamined and unreported.

Curriculum-specific instructional variables include such items as:

- Goals for learning
- Content organization
- Mode of presentation
- Classroom organization
- Representation of concepts
- Expectations for students
- Homework policies

The potential impact of these factors can be seen by translating them into classroom terms. For example, the opportunity to learn mathematics and science will differ considerably if teachers have different goals (one striving to increase students' facility with algorithms, another emphasizing the relationship of topics to other subject fields); different content organization (one basing the order of presentation on the order of historical development, another on the relationship of topics within real world problem situations); different modes of presentation (one stressing lecture and written problems, another experiments and hands-on explorations); different classroom organization (one preferring whole class activities, another small group work); different representations for concepts (one choosing a geometric model to illustrate a concept, another an algebraic model); different perceptions and expectations for students (one expecting students to master the material by the end of the course, another hoping only to introduce the concepts); and so on. The choice of approach will affect both the skills and concepts students have an opportunity to learn and the ways they have of learning them, i.e., it will affect the curriculum. A portrayal of curriculum absent information about these aspects of classroom implementation clearly is incomplete.

One major impediment to expanding the scope of instructional practice measures collected in national surveys is the lack of a conceptual framework for structuring the effort. Another is the paucity of empirical work regarding the definition and validation of indicators of curriculum-specific instructional constructs. Much research needs to be done to understand how best to define and operationalize constructs within the domain of curriculum-specific instructional strategies. Supplemental research to design and validate practice measures (such as McDonnell et al., 1990) are necessary first steps.

Furthermore, we need to understand better the relationship between instructional strategies and outcomes to help determine which instructional features are most important to monitor. Indicators of curriculum-specific instructional strategies should at least be sensitive to research on effective teaching techniques, such as small group cooperative learning, problem posing, writing and communication, etc. (Cooney and Hirsch, 1990). Finally, priorities for developing indicators of instructional variables should depend on the goals that are set for mathematics and science education, because different indicators will be relevant to different instructional goals (Oakes and Carey, 1989).

The measurement problems may be greater in this area than in the other areas of course content because of the need to rely on teacher self-reports. A concern has been raised about the tendency of teachers to give socially desirable answers when asked about specific practices within their classrooms (McDonnell et al., 1990). There is no basis for judging the effects of social desirability on the results of previous studies, but it should be a concern in the development of classroom content measures in the future. Supplemental research to assess the validity of responses obtained from classroom teachers should be an important part of any effort to incorporate teacher-based measures of course content into a national indicator system because the stakes associated with performance may be quite high.

Instructional Materials and Equipment

Although instructional equipment and materials may not appear to be as significant an element of curriculum as some of the school- and course-level constructs presented previously, the development of indicators of instructional equipment and materials can be justified on a number of grounds. First, certain resources, such as textbooks, play an extensive and important role in instruction and must be considered core elements of the mathematics and science curriculum (Weiss, 1987; McKnight, 1987). Second, research has established links between the use of certain instructional materials, such as textbooks and calculators, and student achievement at the secondary level (Dossey et al., 1988). Third, some instructional resources, such as computers and videodiscs, reflect educational innovations whose ultimate impact on the curriculum and achievement is unknown. It is important from a policy perspective to monitor the infusion of these reforms and their impact on instruction and outcomes.

The major problem associated with developing indicators of instructional equipment and materials is the lack of a sound empirical basis for framing such indicators (Shavelson et al., 1987; Oakes and Carey, 1989). Research offers little guidance for deciding which resources to monitor or which features of the resources to assess to provide useful information.

It is difficult to choose which instructional equipment and materials to monitor because we understand neither the specific role of instructional resources in the overall curriculum nor their relationship to instruction and achievement. Certain resources represent enabling conditions that are necessary for instruction to occur: one cannot teach laboratory science without laboratory facilities, nor (most would argue) can one teach computer programming without computers. These are clear candidates for inclusion in an indicator system. In addition, there is empirical evidence of links between other resources and student achievement at the secondary level, which would argue for the inclusion of these resources. For example, "hands-on" science curricula (which rely upon laboratory activities) were found to be related to certain aspects of achievement (Shymansky, Kyle, and Alport, 1983). Similarly, evidence from SIMS suggests that the lack of certain equipment and materials has been a source of problems to secondary school teachers (Crosswhite et al., 1986). Supplemental research is needed to build a firmer basis for deciding which instructional resources, if any, to include in an indicator system.

Furthermore, it is not clear which aspects of the instructional resources should be monitored. There are at least four features that might be included in an indicator system: availability (Do schools provide particular equipment and materials?), access (Are teachers and students able to obtain the resources when needed?), use (What role do the resources play in learning and instruction?) and quality (Are the equipment and materials accurate and current from a mathematical and/or scientific perspective; are they well designed from a pedagogical standpoint, etc?). Each of these elements appears to provide meaningful information about the nature of the instructional resources that support the mathematics and science curriculum.

Measuring the quality of instructional resources appears to be a particularly difficult task. There have been a few attempts to gather information related to the quality of textbooks (Weiss, 1987; Crosswhite et al., 1986) and the condition of equipment (NELS), but this is uncommon. This lack of information is due, in part, to the difficulty of measuring quality. It may also be due to confusion about the meaning of the construct itself.

Quality has both pedagogical and content dimensions. From a pedagogical standpoint, schools should use instructional resources that reflect the way students learn science and give meaning to mathematical and scientific concepts. Materials' design and development should be informed by the latest research on learning and cognition. From a content standpoint, instructional materials should be current and accurate. Scientific discoveries that affect our understanding of basic principles that are taught at the secondary level, that should be part of the framework of any scientifically literate citizen, or that represent new ways of investigating phenomena should be integrated into the curriculum as rapidly as possible. Students are not well served if the content of their science textbooks or materials are out of date or inaccurate. Thus, it would seem appropriate to include measures of quality as well as measures of availability, access, and use in an indicator system.

6. CONCLUSIONS

Unfortunately, it is not possible to construct an adequate system of curriculum indicators based on existing data sources. The indicator patchwork pieced together from existing sources is incomplete or uneven in four important ways. First, the patchwork does not cover many important aspects of curriculum, i.e., there are significant gaps in our ability to describe opportunities to learn mathematics and science. For example, there are no data to describe the quality or the sequence of instruction in science or mathematics.

Second, the patchwork is temporally uneven. Some data are current, others are almost a decade old; some are updated biennially, and some quadrennially and others are unlikely to be updated for a decade. For example, NAEP general information is collected every two years; NAEP mathematics and science assessments occur every four, six, or eight years. Longitudinal surveys, such as High School and Beyond (HSB) or NELS, are launched less than once a decade. The description of curriculum that can be created using data that are updated on a regular basis is quite rough.

Third, the patchwork is of uneven quality. To fill in some gaps it is necessary to rely on data from less well-implemented or less rigorous surveys. For example, results based on SIMS or SISS are only suggestive of national trends because neither survey was based on a nationally representative sample of students.

Fourth, measures drawn from different data sources are not always congruent, so it may not be possible to draw desired comparisons. For example, it is not possible to compare information on science laboratories with information on science courses because the data were not collected from the same schools.

As a result, our knowledge of the status of mathematics and science curriculum in U.S. secondary schools is inadequate for effective policymaking. Reliable, valid data exist to describe some aspects of the curriculum (e.g., graduation requirements, course availability, and course completion), to track the status of some of these constructs over time, and to examine the distribution of some curriculum elements across schools and students. In contrast, little or no data are available to describe other important elements of the curriculum (e.g., the topics that are covered in mathematics and science classes and the manner in which they are presented), or the data that are available are unreliable, unrepresentative, or not collected on a regular basis. The greatest gaps in our knowledge of curriculum occur at the classroom level: little is known about the actual content of courses or the manner in which content is presented. At the present time, a patchwork indicator system can provide a picture of curriculum that is adequate only if we are willing to ignore such classroom-level variation.

The lack of information about course content is a serious deficiency. Measures of course completion do not adequately reflect students' exposure to specific mathematical and scientific knowledge and patterns of thought, nor do they reveal the full extent of differences in curriculum opportunities. This limits their value as a monitoring tool. Furthermore, current reform efforts focus on the content and process of mathematics and science education. Curriculum reform is designed to encourage students to reason logically, think scientifically, solve problems, communicate findings, etc. through the actual performance of scientific experiments and the application of mathematics to real problems. The curriculum patchwork that can be assembled from existing data is insensitive to changes likely to be engendered by such reforms, so it is of limited value for monitoring the effects of these efforts.

The partial picture that can be portrayed from existing data reveals that some students have access to broader curriculum opportunities than others, and these differences are not random variations but systematic differences associated with identifiable conditions. It is critical that such differences be more closely monitored through a mechanism such as an indicator system so that problems can be identified, addressed, and, hopefully, alleviated.

RECOMMENDATIONS

Although this analysis revealed serious deficiencies in our ability to describe mathematics and science curriculum and to monitor curriculum changes, most of these deficiencies can be remedied through additional research and data collection. There are four broad areas of action the National Science Foundation might consider to fill the gaps in the existing data network and to build a comprehensive curriculum indicator system.

First, although existing sources provide basic data about graduation standards, course availability, and course completion, there are no assurances that these data will continue to be available on a regular basis in the future. It is likely that data on the first two of these features—graduation requirements and course availability—will continue to be collected (by NAEP, ECS, CCSSO, or other agencies), but this is not a certainty. Neither the National Assessment Governing Board nor the leadership of the Education Commission of the States has specific reasons to collect these data in a style and format appropriate for curriculum indicators. It might be prudent to act to ensure the continued availability of these two types of core data in an appropriate format.

Course completion measures pose a greater problem because complete data are not collected in any ongoing surveys. Only incomplete self-reported measures of course taking are available through NAEP. There are two ways this deficiency might be remedied—new transcript studies or modifications to NAEP. The most reliable course completion data come from transcript studies, and the most satisfactory solution would be to take actions to ensure that regular transcript studies were conducted. As an alternative, NAEP course-taking measures could be expanded to provide a basis for course completion indicators. This would require extending the range of courses on which students were asked to report. It also would require supplemental research to validate these self-reported data against transcript-based results, because it would be unwise to rely on modified NAEP course-taking measures without such validation research.

Second, the greatest gap in current curriculum data concerns course content. A comprehensive curriculum indicator system should be able to describe the content of mathematics and science courses and how this content is presented to students. To accomplish this, measures of course content would have to be developed, validated, and incorporated into ongoing data-collection efforts. NSF already has funded promising research to investigate alternative coursework indicators at the eighth grade level, but much more research is needed to complete this developmental work and to broaden the scope to include subject matter content and instructional strategies at multiple grades.

Third, an indicator system requires ongoing maintenance; it is not enough merely to collect data and compute indicators. Supplemental research is needed to validate and extend the information provided by ongoing data sources. Such research would include validation of specific indicator alternatives, examination of the relationship between curriculum measures and other student outcomes, and targeted studies of specific topics of interest within and across mathematics and science curriculum domains. The maintenance of an indicator system requires an ongoing commitment of resources for such supplemental development and validation research.

Finally, more information is needed to describe the mathematics and science curriculum at the elementary and middle school levels. It is clear from SIMS and NELS that curriculum differentiation has begun already by the eighth grade; it would be valuable to understand much more about the presentation of mathematics and science prior to that grade level. Few sources exist to describe elementary mathematics and science curriculum, so much work would have to be done to fill this gap. It would be necessary to develop surveys to gather relevant data and to define and validate curriculum indicators based on these data.

The National Science Foundation has a number of options regarding curriculum indicators, from fully funding all four of the efforts described above to taking no actions at all. While all four components would be necessary to have an ongoing, comprehensive, and valid mathematics and science curriculum indicator system, they are not equally important. Moreover, the actions suggested above do not have equal priorities for NSF.

It is likely that most of the desired information about graduation standards and course availability will continue to be collected by other organizations. These are the two areas of curriculum where the potential to build a valid indicator patchwork is the greatest. However, small changes and modifications to the work of ECS, NAEP, and CCSSO would increase the value of these data for use in an indicator system. NSF might try to influence or coordinate the design of these surveys so they better meet the needs of an indicator system.

Producing appropriate course completion data may require a somewhat larger effort on the part of NSF. Although an expansion of NAEP course-taking measures conceivably could be accomplished at little cost, it would have to be accompanied by validation research. Transcript studies are the preferred alternative, but such studies are expensive. However, since transcript studies provide data of value to many educational constituencies, it might be possible to develop a collaborative arrangement among educational agencies to share the costs of regular studies of this type.

The most significant gap in our ability to describe mathematics and science curriculum involves course content. NSF has already recognized the importance of this problem, and it has sponsored research to explore the development of coursework measures. These efforts satisfy a need that is largely unmet through other sources, and the agency should consider continuing or even expanding this work until the potential for such indicators is better understood.

Another area in which NSF's efforts may yield significant returns is the ongoing enhancement and validation of the basic curriculum indicators derived from other surveys. No other group is actively supporting this important work. Such research is necessary to maintain the quality of the existing incomplete patchwork, to validate additional secondary-level curriculum indicators, and to provide information about other issues of interest within and across mathematics and science curriculum domains.

Once a broad secondary-level curriculum indicator system is operational, attention should turn to curriculum opportunities in earlier grades. Existing data suggest that it is important to monitor students' exposure to mathematics and science at the elementary and middle school levels. However, by postponing development of elementary indicators for a time, future work on this topic can benefit from the research done at the secondary level.

Resources might be used more efficiently as a result. A study to investigate the costs and feasibility of developing elementary and middle school curriculum indicators in mathematics and science might be a reasonable first step toward a more complete set of elementary and middle school curriculum indicators.

Appendix A

PRINCIPAL DATA SOURCES FOR BUILDING CURRICULUM INDICATOR PATCHWORK

ADMINISTRATOR AND TEACHER SURVEY (ATS) FROM HIGH SCHOOL AND BEYOND

ATS was designed to explore relationships suggested by research on effective schools using a broadly representative sample of teachers and students. The survey, which was funded by the Office of Research, U.S. Department of Education, and conducted in 1984 by a consortium of five federally supported research centers, was a supplement to the national longitudinal survey of high school students known as High School and Beyond. The nationally representative sample of teachers and administrators answered questions regarding goals, pedagogical practices, interpersonal relations, workloads, attitudes, etc. The data's greatest use in the present investigation related to graduation standards. To our knowledge, there are no plans to repeat ATS in the future.

COUNCIL OF CHIEF STATE SCHOOL OFFICERS' STATE EDUCATIONAL INDICATORS (CCSSO)

In 1984, CCSSO established the State Education Assessment Center to improve the collection and use of data on education by the states. The center has attempted to expand the breadth of data collected by states, improve the quality of the data that are collected, and facilitate the dissemination and use of these data. Toward this end CCSSO began publishing State Educational Indicators in 1987 as an annual compilation of data from states. Initially, the report included primarily demographic data, but in 1989 it was expanded to include information about school system accountability. Further expansion is planned for the future.

EDUCATION COMMISSION OF THE STATES (ECS) SURVEY OF MINIMUM HIGH SCHOOL GRADUATION REQUIREMENTS

Periodically, the Education Commission of the States surveys state Departments of Education and compiles a summary of state minimum high school graduation requirements. ECS has been publishing the results of these surveys as part of their series of Clearinghouse Notes since roughly 1983. ECS maintains an update file on each state and publishes a new summary report when enough changes have been made to warrant it. The most recent summary was published in 1989.

HIGH SCHOOL TRANSCRIPT STUDY (HTS), 1987

This study was conducted in 1987 for the U.S. Department of Education's National Center for Education Statistics (NCES). The purpose was to provide information for NCES and policy-makers regarding course offerings and course taking in the nation's secondary schools. An attempt was made to sample the same students who participated in the 1985-1986 National Assessment. While the exact sample could not be matched, students were sampled in the same manner from the same schools, so the results reflect the graduation status of students similar to those who participated in NAEP when they were in grade 11. The results were tabulated and reported in Westat, Inc. (1988). There are no plans to repeat this analysis on a regular basis.

INTERNATIONAL ASSESSMENT OF MATHEMATICS AND SCIENCE (IAEP)

IAEP involved representative samples of students from five countries and four Canadian provinces. The project was designed to capitalize on the content and experience of NAEP in the United States and used existing assessment questions and procedures to a large extent. The assessment focused on 13-year-old students from grades seven and eight. In addition to questions regarding mathematics and science, students were asked about their school experience and attitudes, and teachers rated students' exposure to the concepts tested by the items. Results were reported in Lapointe, Mead, and Phillips (1989).

NATIONAL ASSESSMENT OF EDUCATIONAL PROGRESS (NAEP)

NAEP is a biennial national survey of student performance in selected subjects founded by Congress and conducted under contract to the Department of Education. Originally designed to report only national and regional results at three age levels (9 year olds, 13 year olds and 17 year olds), NAEP has begun to report state-level results as well and has shifted its targeted grade levels to 4th grade, 8th grade, and 12th grade. In the past, many different subjects have been assessed, including reading, writing, social studies, history, science, mathematics, and art. Reading and writing have been assessed every cycle; math has been assessed approximately every other cycle. It appears that NAEP results will be available on an ongoing basis every other year, and the size and scope of the endeavor will increase. Achievement is the major focus of the NAEP assessments, and there has been considerable variation in the depth and consistency with which curriculum and instructional practice variables have been measured. Data reported in this study were drawn primarily from the 1985-1986 NAEP that included mathematics, science, and computer competence in addition to reading and writing. Students were sampled from grades 3, 7, and 11 (as well as ages 9, 13, and 17). The results were reported in Dossey et al. (1988); Martinez and Mead (1988); and Mullis and Jenkins (1988) among others.

NATIONAL EDUCATION LONGITUDINAL STUDY (NELS)

NELS is the latest in the longitudinal education surveys sponsored by the U.S. Department of Education's National Center for Education Statistics. (Previous longitudinal surveys included the National Longitudinal Study and High School and Beyond.) NELS began with an eighth grade cohort of students in 1988 and will continue to follow that group of students with biennial surveys through high school and into adult life. Information gathered from students regarding their knowledge and educational experiences will be supplemented with data from parents, teachers, and school administrators. Among the reports describing conditions in grade eight is Horn and Hafner (in press).

NATIONAL SURVEY OF SCIENCE AND MATHEMATICS EDUCATION (NSSME)

NSSME was a national survey of the status of mathematics and science education conducted in 1985-1986 under the auspices of the National Science Foundation. The survey focused on mathematics and science curriculum, teachers, and resources; NSSME did not assess student achievement. The study was designed to update the results of the earlier 1977 National Survey of Science, Mathematics, and Social Studies Education and detect trends in science and mathematics education. The results of NSSME were reported in Weiss (1987). There are no specific plans to repeat the survey on a regular basis.

SCHOOL AND STAFFING SURVEY (SASS)

The Center for Education Statistics (CES) of the U.S. Department of Education initiated the School and Staffing Survey in 1987-1988 to measure critical aspects of teacher supply and demand, the composition of the administrator and teacher workforce, and the status of teaching and schooling. The survey represents a revision of earlier surveys that had been conducted separately for public and private school staff. While the main focus is on teacher supply and demand, there are questions regarding instructional practices, course offerings, etc. that are relevant to curriculum-indicator development. SASS is designed to be an ongoing national data collection effort.

SECOND INTERNATIONAL MATHEMATICS STUDY (SIMS)

SIMS was conducted under the auspices of the International Association for the Evaluation of Educational Achievement (IEA) in 1981-1982. The purpose of the study was to investigate ways in which mathematics was taught, to describe student attitudes and achievement, and to relate outcome variables to curriculum and teaching practices. The study represented an international collaboration among two dozen countries. In the United States, the project was funded by the National Institute of Education, the National Science Foundation, and the National Center for Education Statistics; it was coordinated by a National Mathematics Committee consisting of mathematicians and scholars from major universities. The U.S. National Coordinating Center was located at the University of Illinois. Two populations were sampled: students in grade 8 and students taking precalculus/calculus (typically in grade 12). The study provides a rich and complex array of data regarding mathematics curriculum instruction and achievement. Its major drawback is that the sample of students in the United States who participated in the study was small and unrepresentative. Therefore, the results were not generalizable, though they were quite suggestive of the condition of mathematics education in the United States. Results have been published in Travers and Westbury (1989); Crosswhite et al. (1986); McKnight et al. (1987); Burstein (1991) and other sources. The first international survey was conducted in 1964, and plans are under way for a third study to be conducted soon.

SECOND IEA SCIENCE STUDY (SISS)

Like its counterpart SIMS, SISS was an international comparative study of science achievement and instruction conducted under the auspices of the International Association for the Evaluation of Educational Achievement (IEA) in 1981-1982. Results have been published in Jacobson et al. (1987), Jacobson and Doran (1985), and other sources.

SCHOOL REFORM ASSESSMENT PROJECT (SRA)

SRA was a two-year exploratory design project conducted by RAND and the UCLA Center for the Study for Evaluation and funded by the Office of Educational Research and Improvement, U.S. Department of Education. The purpose of the study was to refine the technical quality of existing coursework indicators and to design indicators that would meet the information needs of policymakers to measure the effects of curriculum policies. The study undertook several benchmarking procedures, including interviews, transcript analyses, and evaluations of course materials in addition to reviewing data from existing sources. The results were reported in McDonnell et al. (1990).

Appendix B

NAEP VARIABLES WITH HIGH RATES OF MISSING VALUES IN 1985-1986

The following is a partial list of variables for which missing values were reported in 10 to 15 percent of the schools in the 1985-1986 NAEP sample:

- Availability of the following courses: algebra II, advanced geometry, AP biology, AP chemistry, physics I, and programming I;
- Percent of students enrolled in remedial mathematics courses and in remedial reading courses;
- Percent of students classified as ESL;
- Percent of students who drop out;
- The number of semesters of the following courses required for graduation: English, history, mathematics, and science;
- Use of ability grouping in English, in history, in mathematics, and in Spanish;
- Presence of specialized science laboratories.

The following is a partial list of variables for which missing values were reported in 16 to 20 percent of the schools in the 1985-1986 NAEP sample:

- Percent of students receiving subsidized lunch;
- Availability of the following courses: physics II, statistics, and programming II;
- Percent of students in academic, general, and vocational programs;
- Presence of classroom laboratories.

Appendix C

ADDITIONAL TABLES AND FIGURES

Table C.1

State-Imposed Regular Graduation Requirements in Mathematics

Years Required	Percentage of States*						
	1974	1980	1983	1985	1987	1989	1990
0.0	29	27	24	12	12	10	12
0.5							
1.0	51	53	18	4	4	2	2
1.5	4	2					
2.0	14	16	49	65	61	59	63
2.5**			2	2	4	6	2
3.0	2	2	8	18	20	22	22
3.5							
4.0							

*50 states plus the District of Columbia.

**Some states required an additional year of coursework in either math or science. For the purpose of this table such a requirement was counted as one-half year in each subject.

SOURCES: RAND tabulations of data from the National Association of Secondary School Principals, 1975 & 1980; Education Commission of the States, 1983 & 1990; Center for Education Statistics, 1987; National Center for Education Statistics, 1989; Clune, 1989.

Table C.2

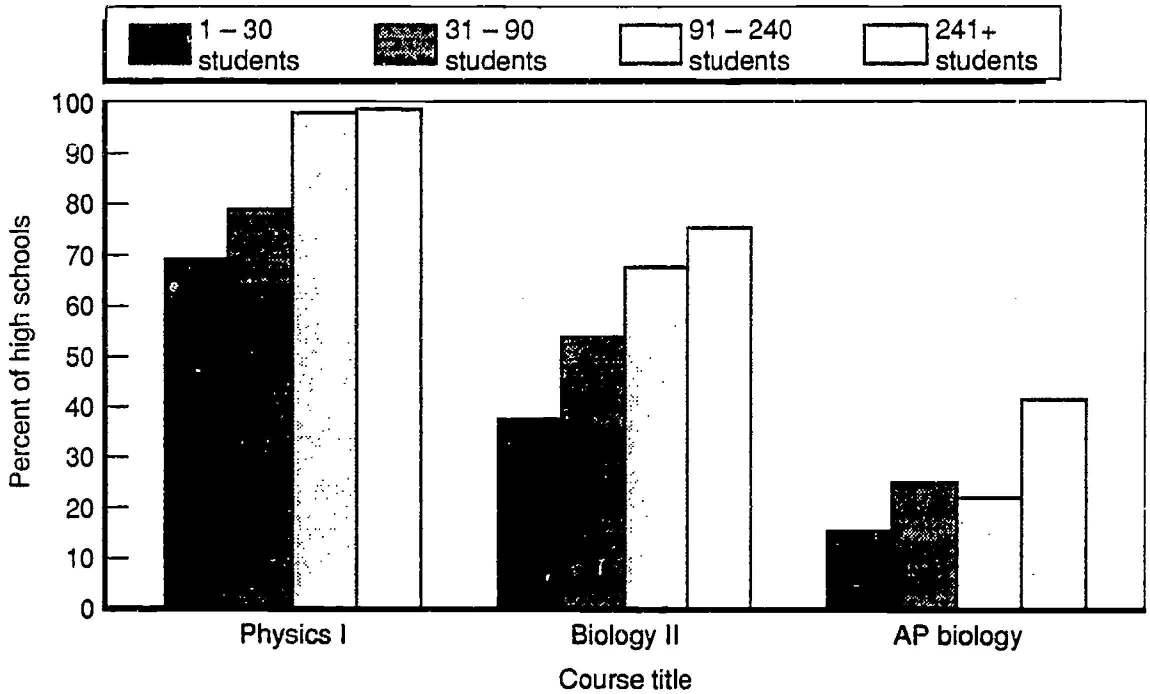
State-Imposed Regular Graduation Requirements in Science

Years Required	Percentage of States*						
	1974	1980	1983	1985	1987	1989	1990
0.0	28	28	24	12	12	10	12
0.5							
1.0	53	53	29	16	10	10	8
1.5	4	2					
2.0	14	18	39	63	67	67	71
2.5**			4	2	4	6	2
3.0			4	8	6	6	8
3.5							
4.0							

*50 states plus the District of Columbia.

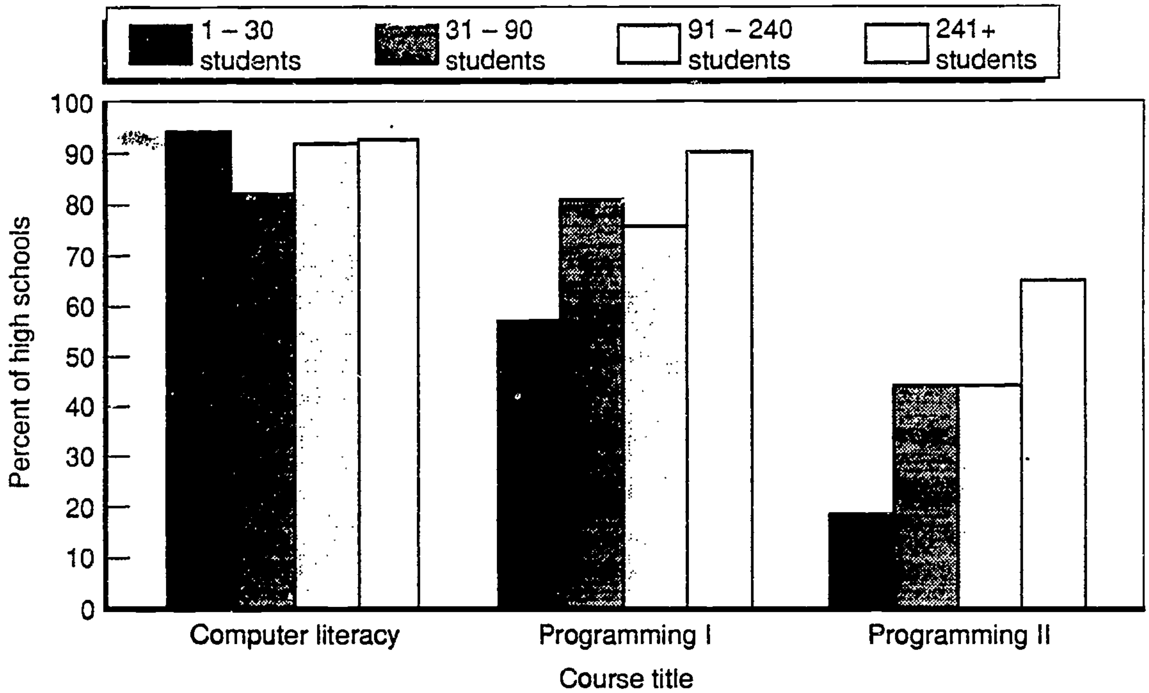
**Some states required an additional year of coursework in either math or science. For the purpose of this table such a requirement was counted as one-half year in each subject.

SOURCES: RAND tabulations of data from the National Association of Secondary School Principals, 1975 & 1980; Education Commission of the States, 1983 & 1990; Center for Education Statistics, 1987; National Center for Education Statistics, 1989; Clune, 1989.



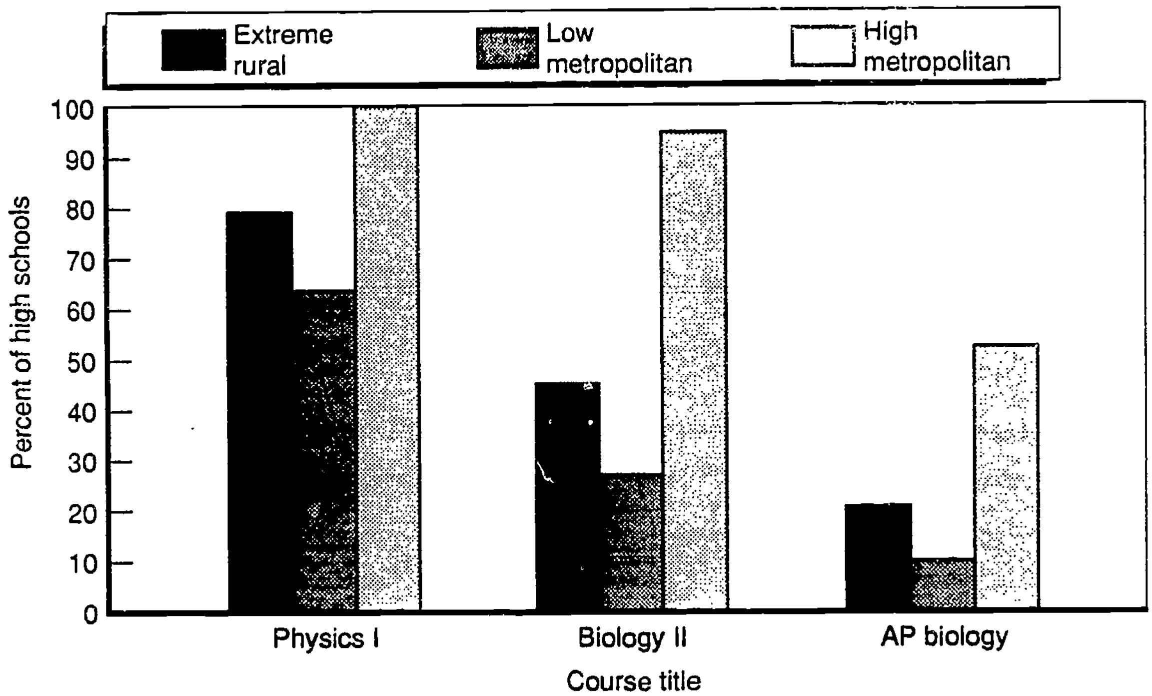
SOURCE: RAND tabulations of the 1985–1986 National Assessment of Educational Progress

Fig. C.1—Science Course Availability by Grade Level Enrollment



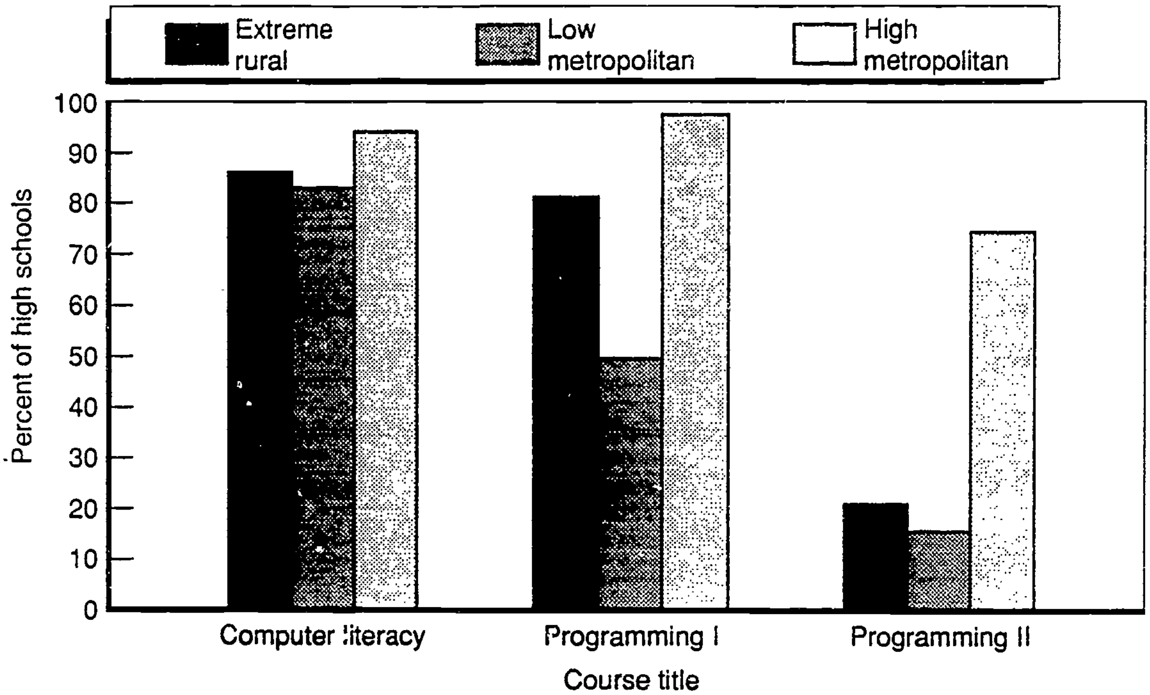
SOURCE: RAND tabulations of the 1985–1986 National Assessment of Educational Progress

Fig. C.2—Computer Science Course Availability by Grade Level Enrollment



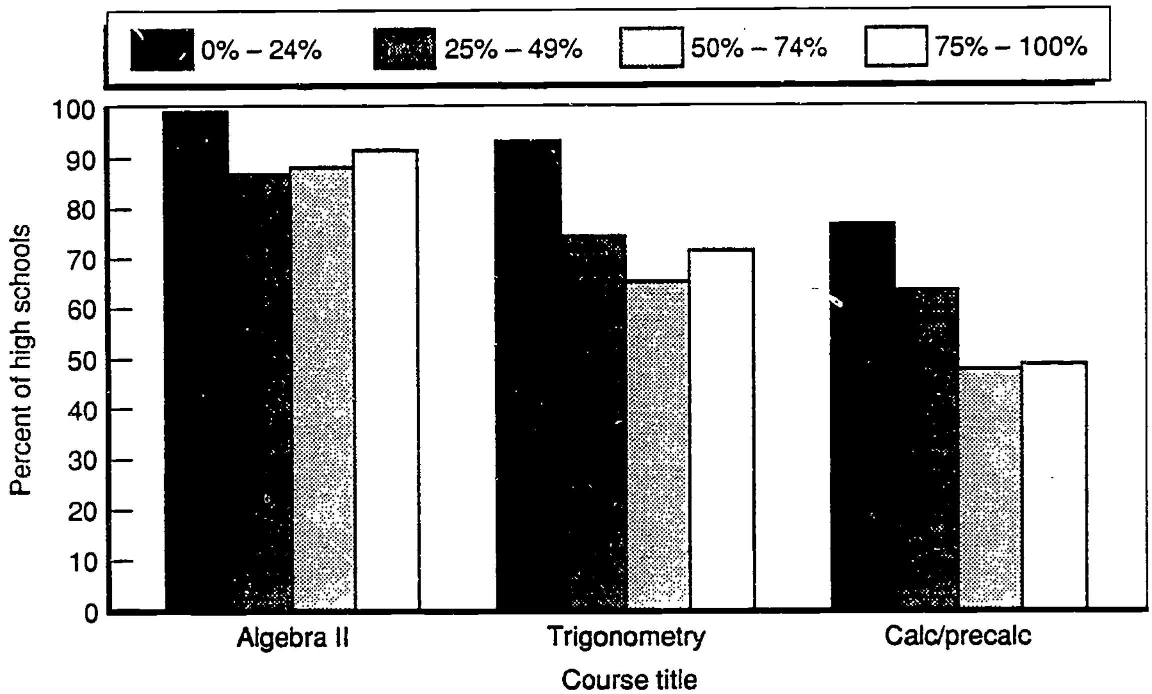
SOURCE: RAND tabulations of the 1985–1986 National Assessment of Educational Progress

Fig. C.3—Science Course Availability by Size and Type of Community



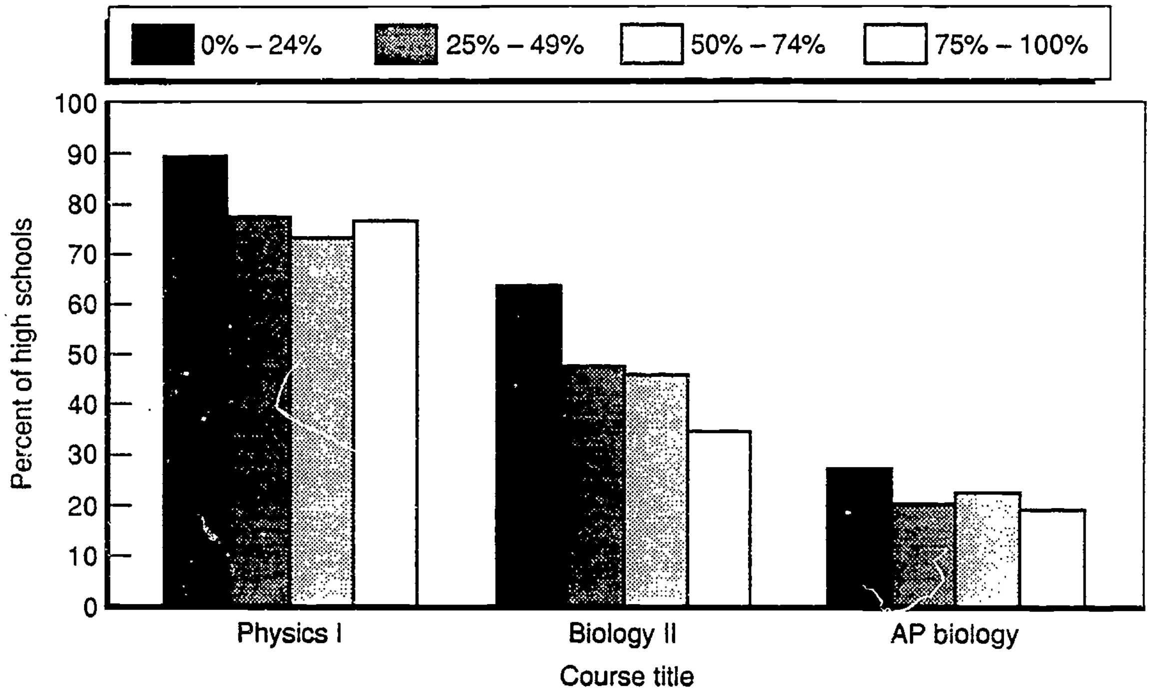
SOURCE: RAND tabulations of the 1985–1986 National Assessment of Educational Progress

Fig. C.4—Computer Science Course Availability by Size and Type of Community



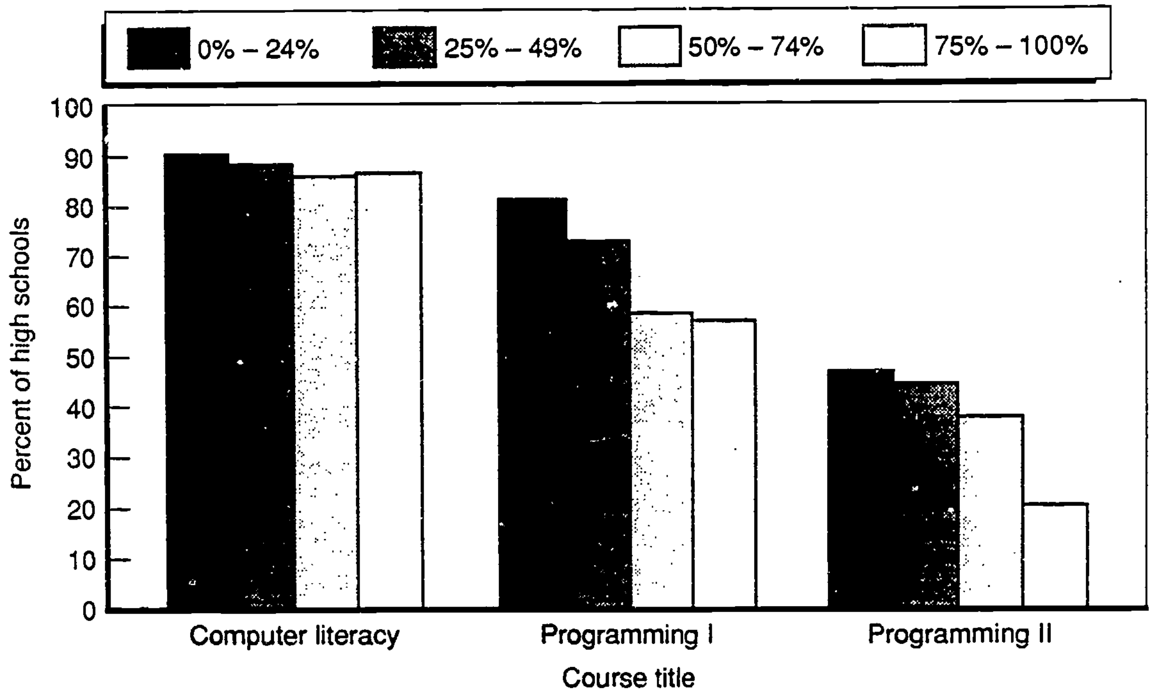
SOURCE: RAND tabulations of the 1985–1986 National Assessment of Educational Progress

Fig. C.5—Mathematics Course Availability by Percent Non-Asian Minority Enrollment



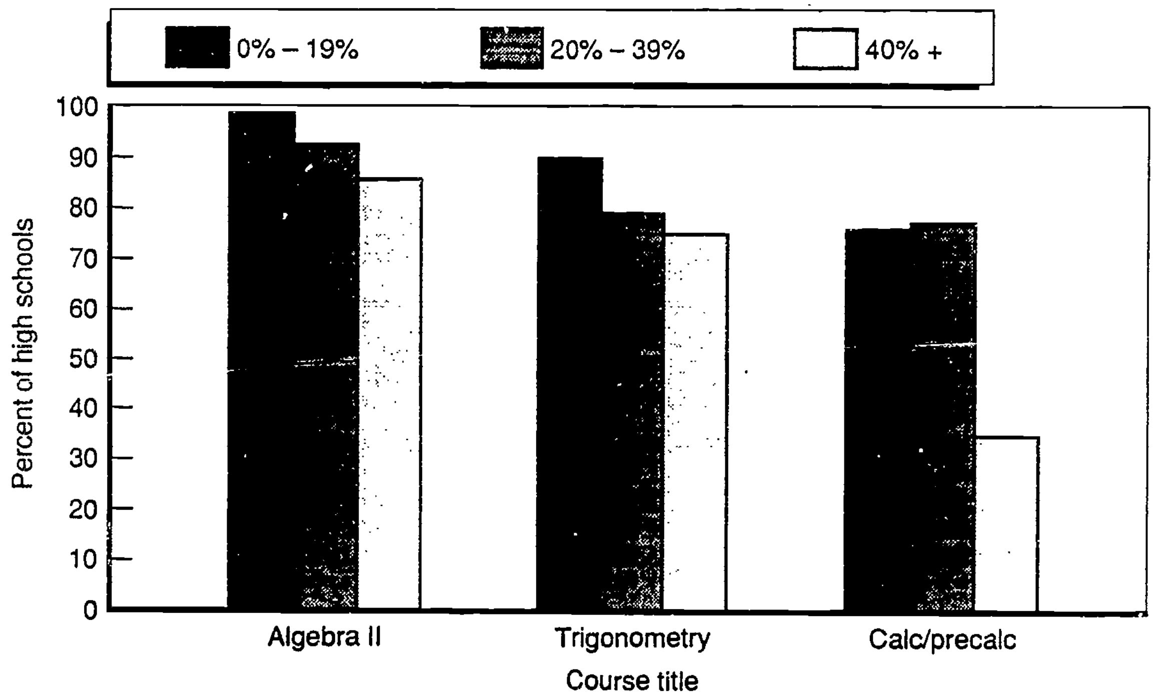
SOURCE: RAND tabulations of the 1985–1986 National Assessment of Educational Progress

Fig. C.6—Science Course Availability by Percent Non-Asian Minority Enrollment



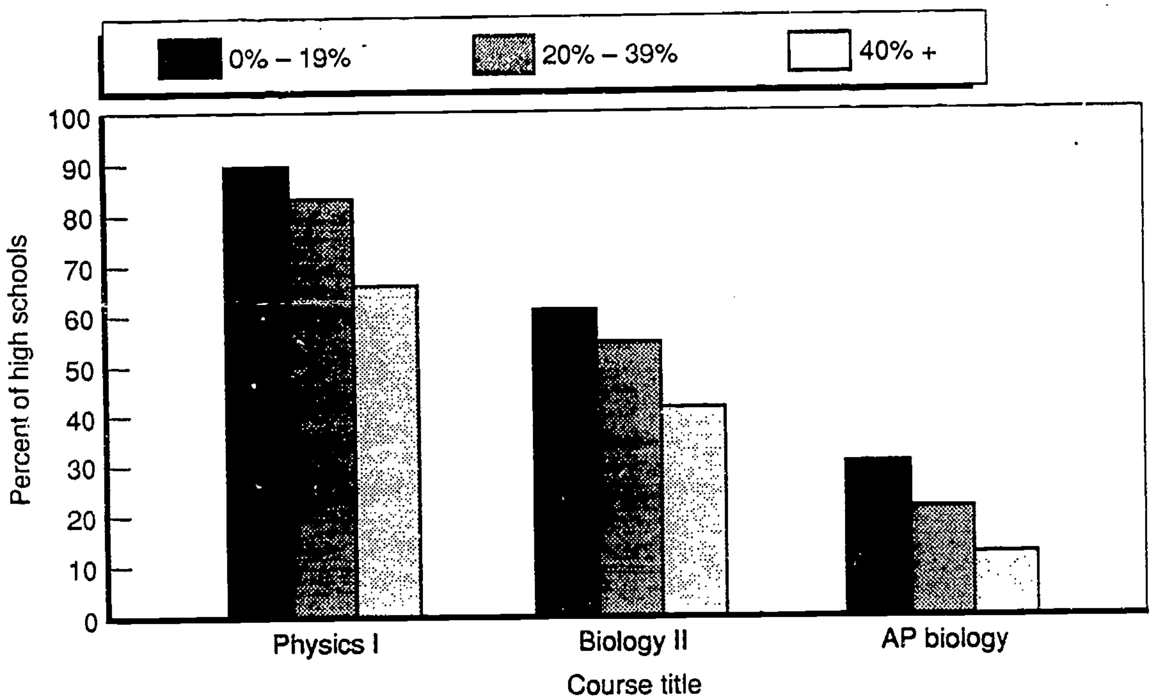
SOURCE: RAND tabulations of the 1985–1986 National Assessment of Educational Progress

Fig. C.7—Computer Science Course Availability by Percent Non-Asian Minority Enrollment



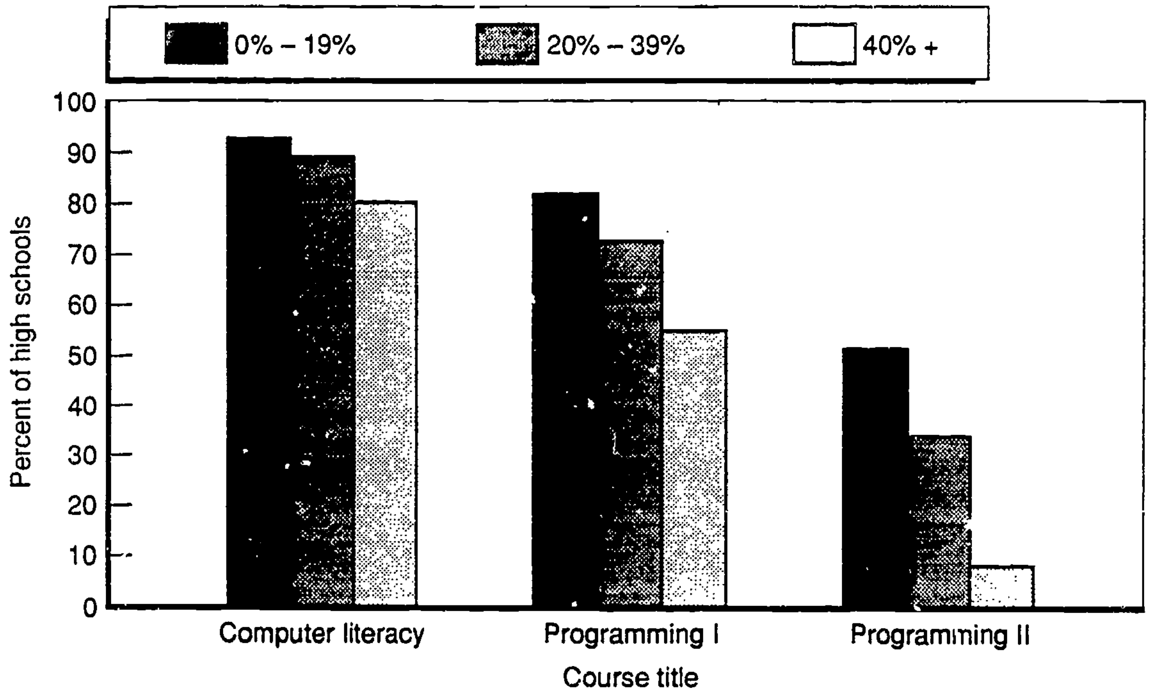
SOURCE: RAND tabulations of the 1985–1986 National Assessment of Educational Progress

Fig. C.8—Mathematics Course Availability by Percent Receiving Subsidized Lunch



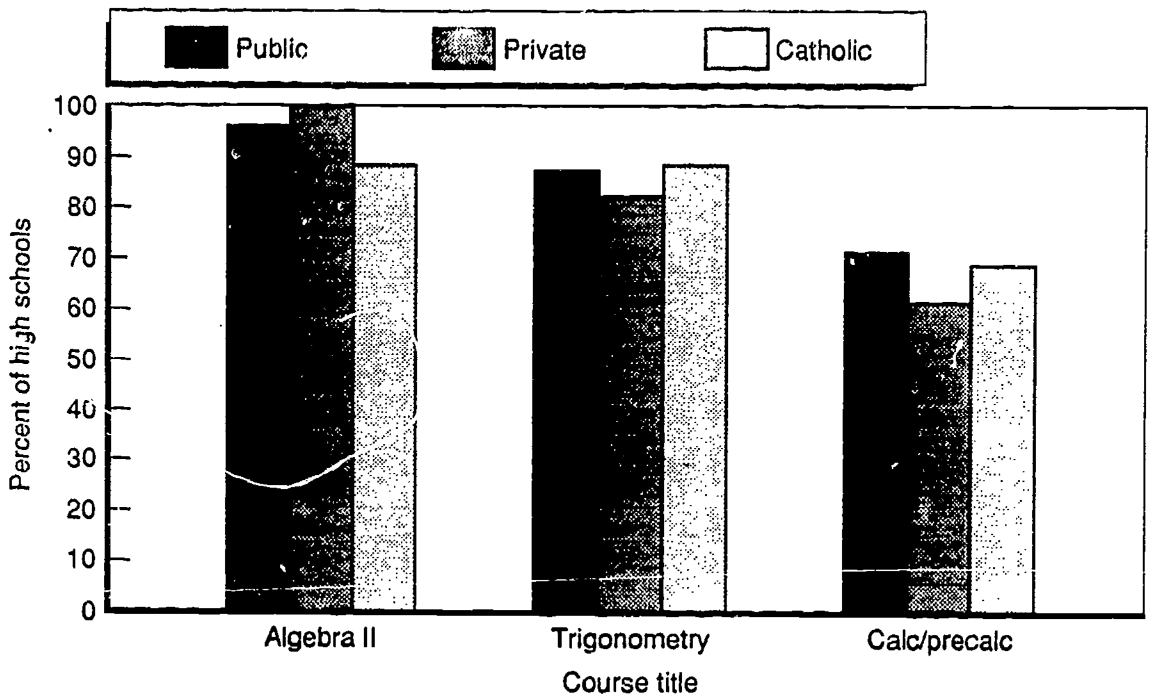
SOURCE: RAND tabulations of the 1985–1986 National Assessment of Educational Progress

Fig. C.9—Science Course Availability by Percent Receiving Subsidized Lunch



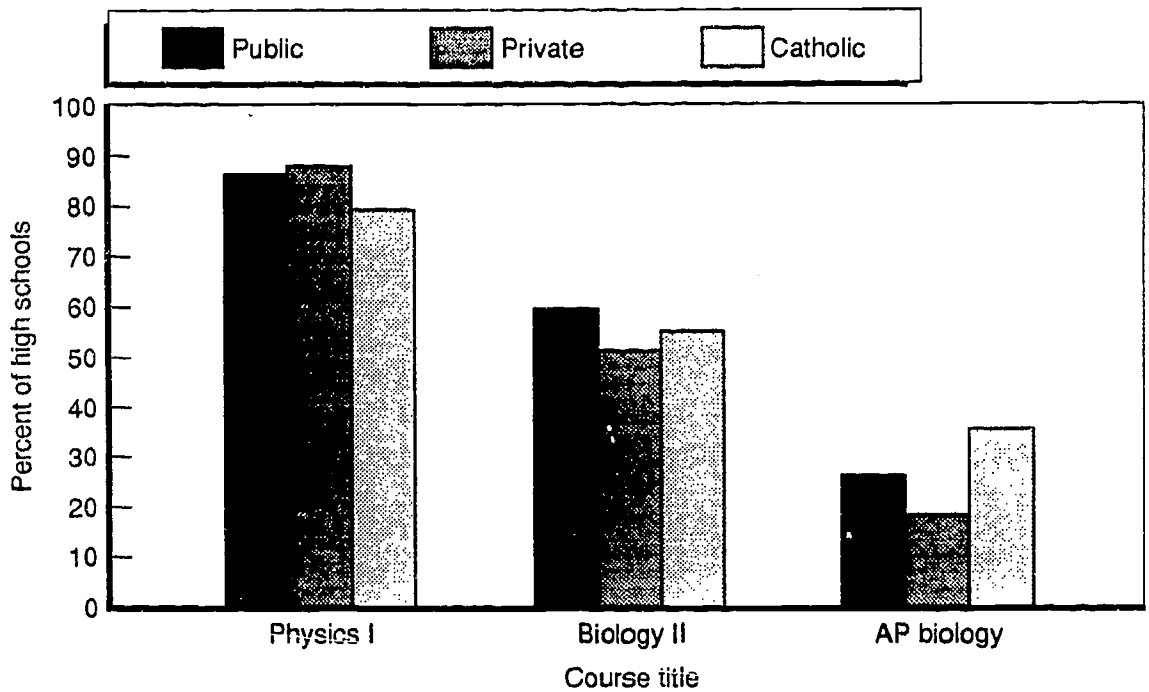
SOURCE: RAND tabulations of the 1985–1986 National Assessment of Educational Progress

Fig. C.10—Computer Science Course Availability by Percent Receiving Subsidized Lunch



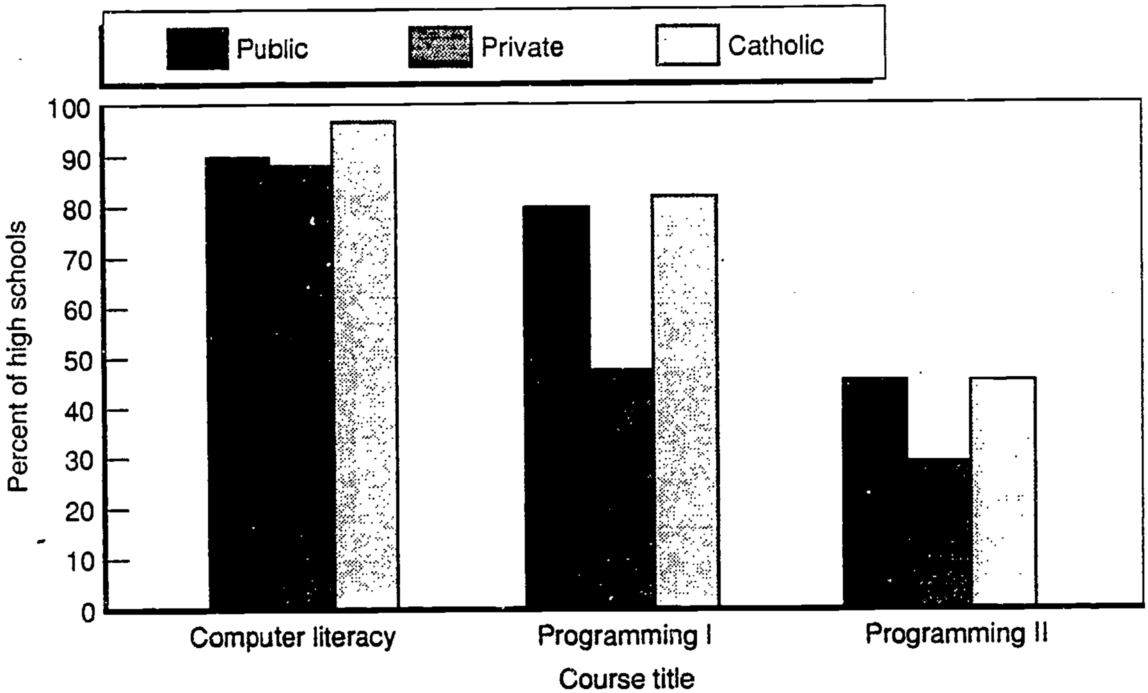
SOURCE: RAND tabulations of the 1985–1986 National Assessment of Educational Progress

Fig. C.11—Mathematics Course Availability by School Type



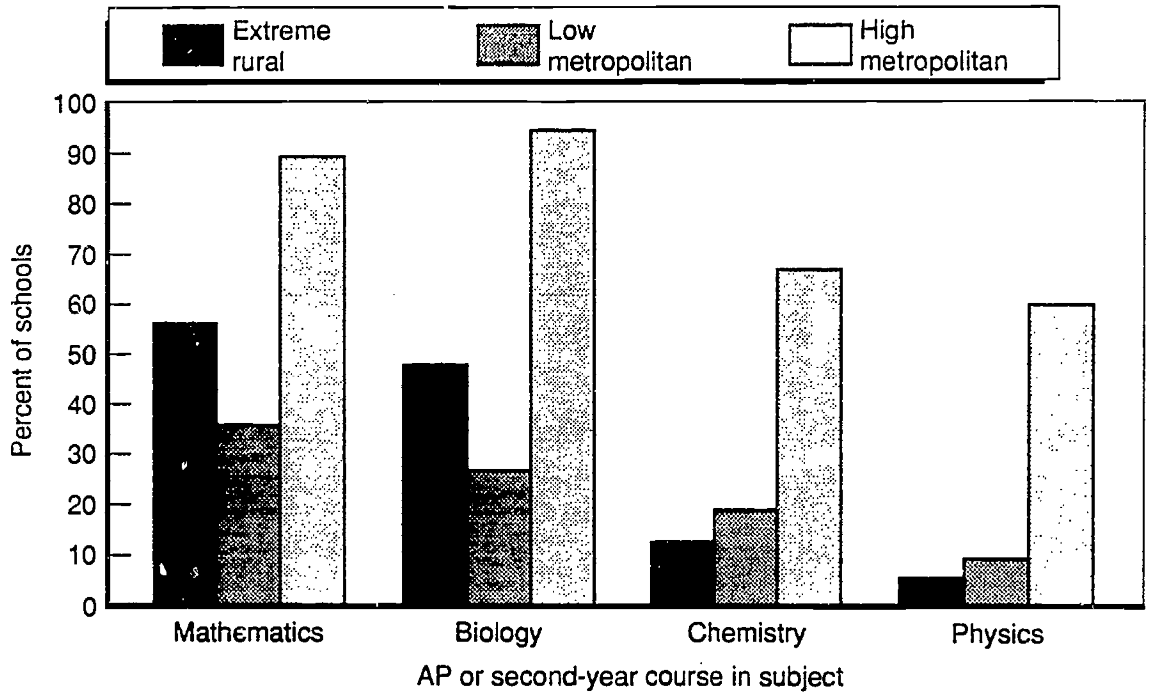
SOURCE: RAND tabulations of the 1985–1986 National Assessment of Educational Progress

Fig. C.12—Science Course Availability by School Type



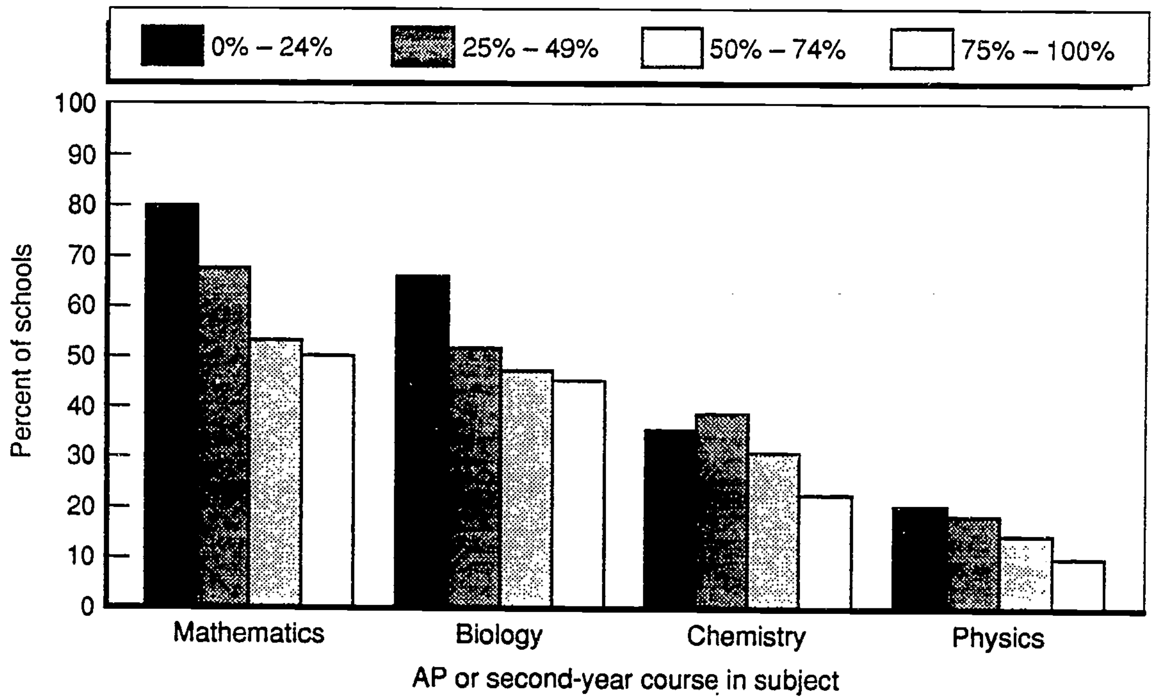
SOURCE: RAND tabulations of the 1985–1986 National Assessment of Educational Progress

Fig. C.13—Computer Science Course Availability by School Type



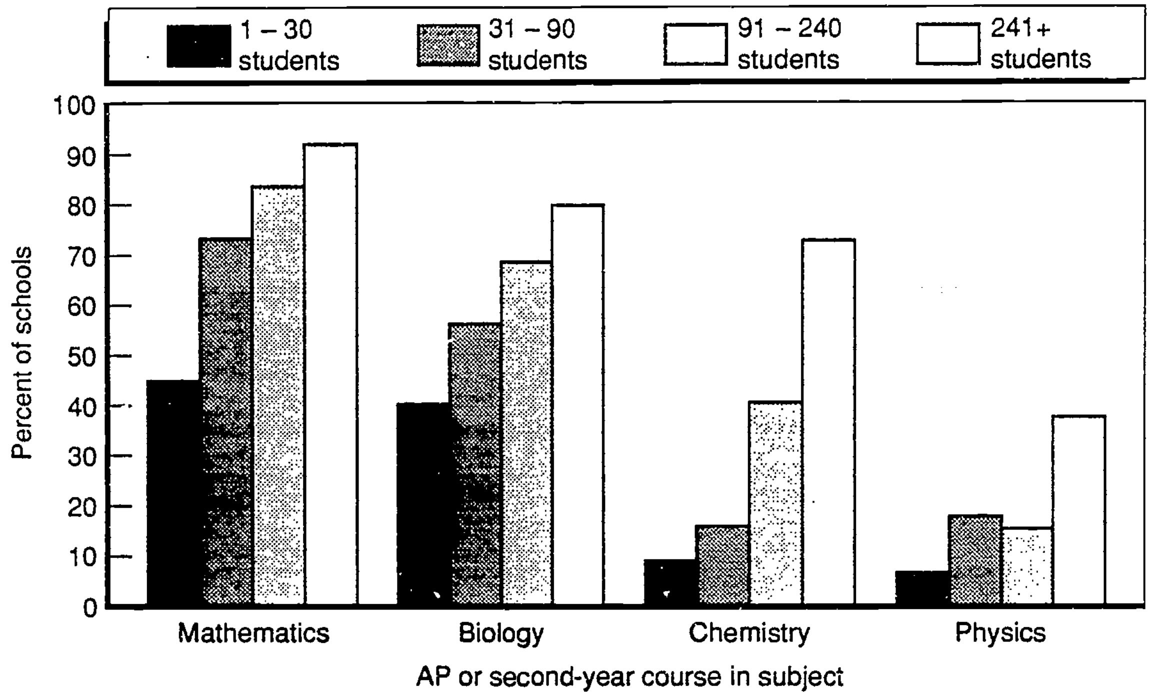
SOURCE: RAND tabulations of the 1985–1986 National Assessment of Educational Progress

Fig. C.14—College-Equivalent Course Availability by Size and Type of Community



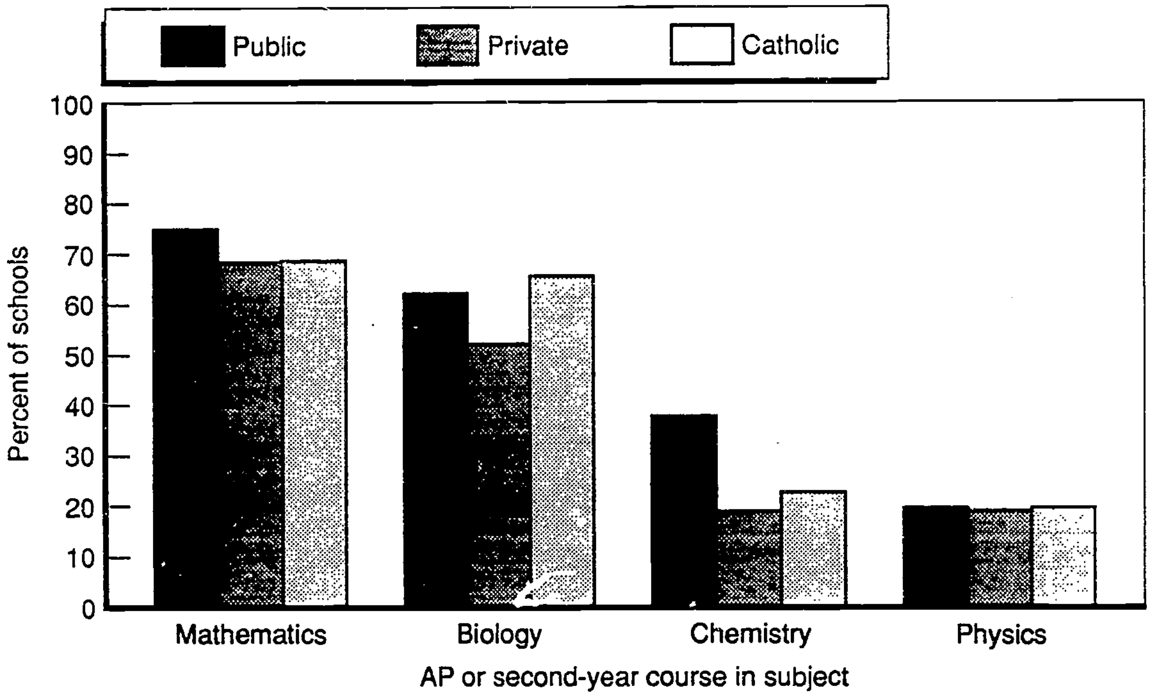
SOURCE: RAND tabulations of the 1985–1986 National Assessment of Educational Progress

Fig. C.15—College-Equivalent Course Availability by Percent Non-Asian Minority Enrollment



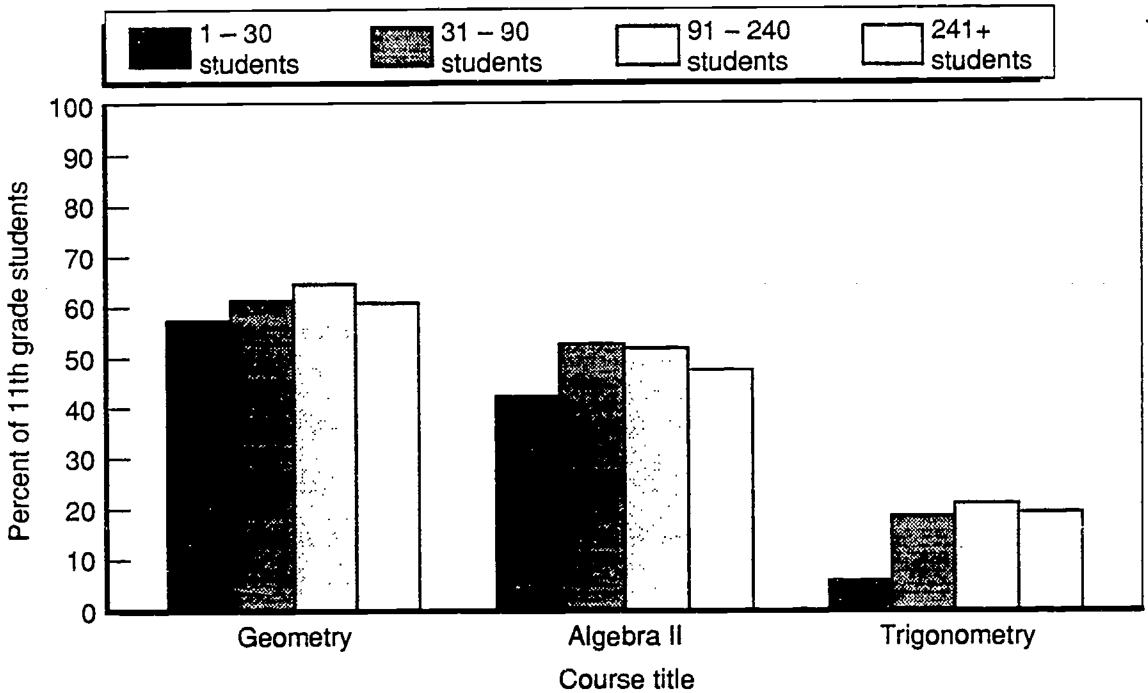
SOURCE: RAND tabulations of the 1985–1986 National Assessment of Educational Progress

Fig. C.16—College-Equivalent Course Availability by Grade Level Enrollment



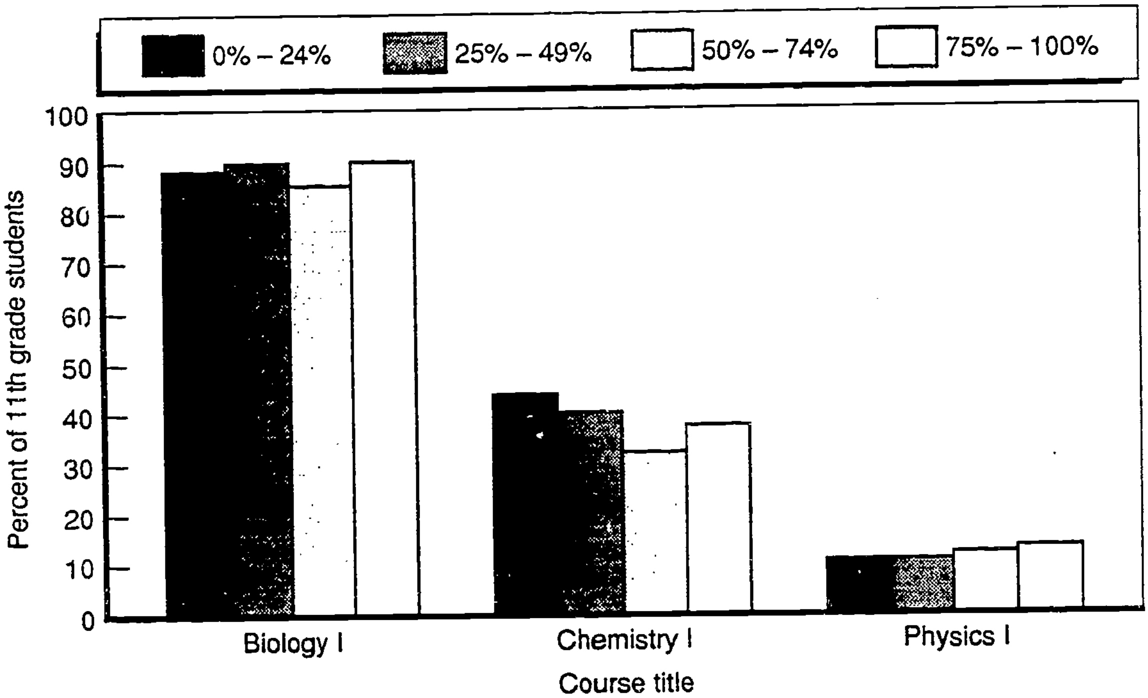
SOURCE: RAND tabulations of the 1985–1986 National Assessment of Educational Progress

Fig. C.17—College-Equivalent Course Availability by School Type



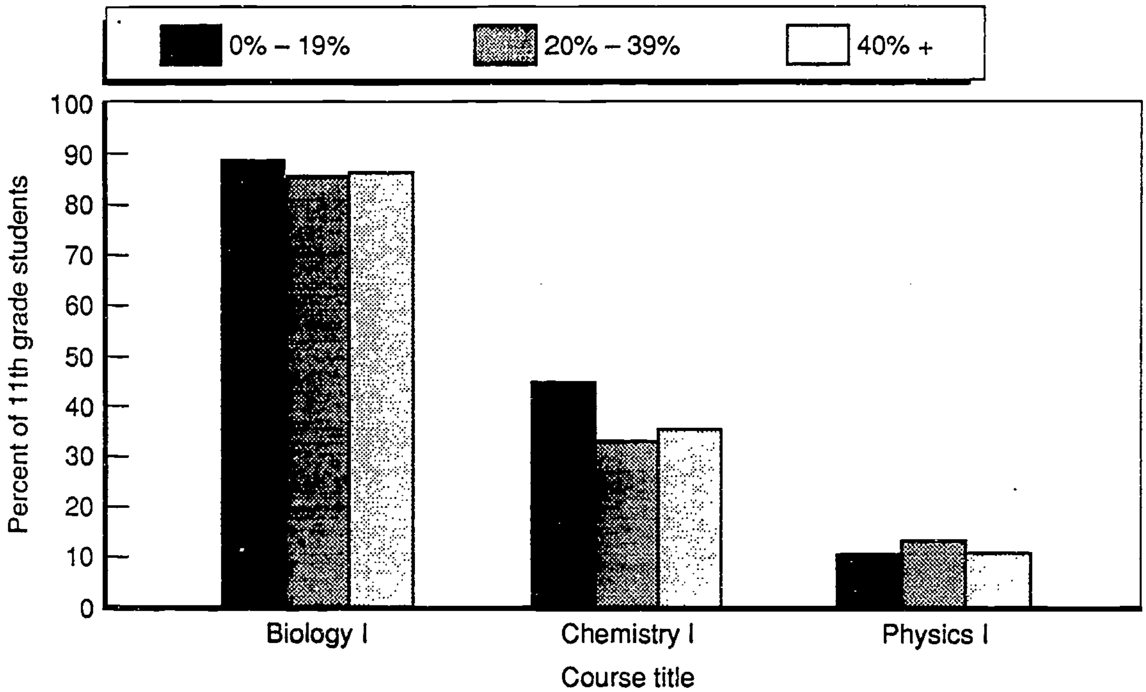
SOURCE: RAND tabulations of the 1985–1986 National Assessment of Educational Progress

Fig. C.18—Mathematics Courses Taken Through Grade 11 by Grade Level Enrollment



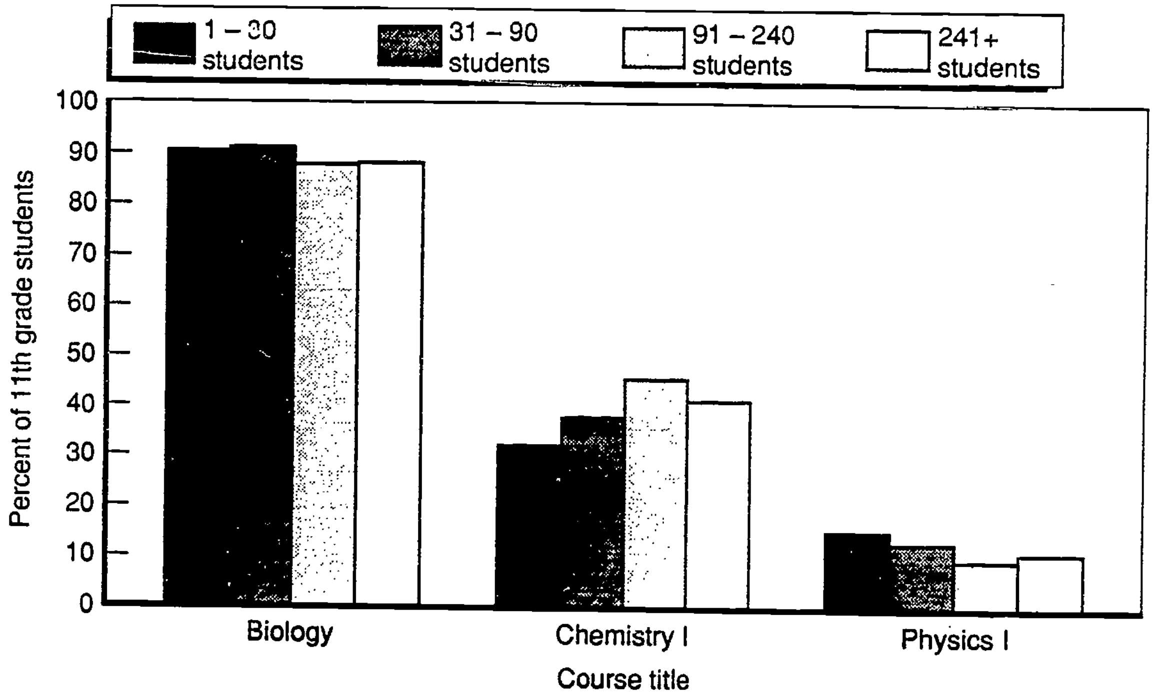
SOURCE: RAND tabulations of the 1985–1986 National Assessment of Educational Progress

Fig. C.19—Science Courses Taken Through Grade 11 by Percent Non-Asian Minority Enrollment



SOURCE: RAND tabulations of the 1985–1986 National Assessment of Educational Progress

Fig. C.20—Science Courses Taken Through Grade 11 by Percent Receiving Subsidized Lunch



SOURCE: RAND tabulations of the 1985–1986 National Assessment of Educational Progress

Fig. C.21—Science Courses Taken Through Grade 11 by Grade Level Enrollment

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