horizon
RESEARCH, INC.

A Profile of Science and Mathematics Education in the United States, 1993

Iris R. Weiss

1994

Horizon Research, Inc.
111 Cloister Court
Chapel Hill, NC 27514
(919) 489-1725

The 1993 National Survey of Science and Mathematics Education was coordinated by Horizon Research, Inc. (HRI) of Chapel Hill, North Carolina with support from the National Science Foundation (NSF). Iris R. Weiss, President of HRI, served as Principal Investigator, assisted by Michael C. Matti and P. Sean Smith. CODA, Inc. of Silver Springs, Maryland served as data collection subcontractor, under the direction of James TerMaat, assisted by Jacqueline Smith. The sample design was developed by Benjamin Tepping and Josefina Lago.

A number of science and mathematics educators contributed to the design of the survey, including Bill Aldridge, Rolf Blank, Joan Ferrini-Mundy, Susan Friel, Frances Lawrenz, Andrew Porter, Senta Raizen, Bill Schmidt, Joan Talbert, and Wayne Welch. Larry Suter of NSF's Division of Research, Evaluation, and Dissemination provided valuable advice during the instrument development and analysis phases of the study. Special thanks are due to the thousands of teachers throughout the United States who took time from their busy schedules to provide information about their science and mathematics teaching.

A Profile of Science and Mathematics Education in the United States, 1993 was prepared with support from the National Science Foundation under grant number RED-9150005. These writings do not necessarily reflect the views of the National Science Foundation.

Executive Summary

The 1993 National Survey of Science and Mathematics Education was designed to provide up-to-date information and to identify trends in the areas of teacher background and experience, curriculum and instruction, and the availability and use of instructional resources. Among the questions addressed by the survey:

- How well prepared are science and mathematics teachers in terms of both content and pedagogy?
- To what extent do teachers support reform notions embodied in the NCTM *Standards* and the *National Science Education Standards*?
- What are teachers trying to accomplish in their science and mathematics instruction and what activities do they use to meet these objectives?
- What are the barriers to effective and equitable science and mathematics education?

Data from the survey indicate that science and mathematics education is moving closer to current reform ideas in some areas, but remains quite far from the ideal in many other areas. In terms of teacher preparation, while 2 out of 3 elementary science teachers have had the very minimal recommended college coursework in science, only 28 percent feel "very well qualified" to teach science. Moreover, relatively little elementary class time—less than one-half hour per day—is typically spent on science instruction. Elementary teachers are more likely to feel well prepared to teach mathematics and they report spending considerably more time on mathematics—nearly one hour—than on science in a typical day. However, it appears that their confidence is primarily in teaching the mathematics topics that have traditionally been taught in the elementary grades; relatively few are confident about introducing their students to basic concepts of geometry, probability and statistics, and other areas recommended by the National Council of Teachers of Mathematics.

While lack of content preparation appears to be a major barrier for elementary teachers, most high school science and mathematics teachers have a fairly extensive background in their field. For example, 94 percent of high school biology teachers have had six or more college courses in biology. For high school teachers, the major constraints appear to be in the area of pedagogy; many high school teachers do not endorse the instructional strategies recommended by the national standards, and they tend to be less comfortable than their elementary school counterparts with a number of the strategies, including using cooperative learning techniques; teaching groups that are heterogeneous in ability; and integrating science and mathematics with other subject areas.

In-service education can provide opportunities for teachers to develop new understandings in both content and pedagogy. While the survey did not ask about the nature or content of the workshops or institutes, there is evidence that more teachers are participating in some type of science and mathematics in-service activities than was the case in the mid-1980s. Still, the small

amounts of time spent on science and mathematics in-service education (typically less than 16 hours over three years) were apparently not sufficient to address the many content and pedagogical needs they expressed.

Teachers were asked their opinions about a number of issues related to collegiality in their school. On the positive side, most science and mathematics teachers in each grade range feel supported by their colleagues to try out new ideas in teaching; indicate that teachers in their school share ideas and materials on a regular basis; feel that they have many opportunities to learn new things in their job; and feel supported by their administrators. However, fewer than 1 in 5 have time during the regular school week to work with their peers on science and mathematics curriculum and instruction, and only about 1 in 8 indicated that science and mathematics teachers in their school regularly observe each other teaching classes as part of sharing and improving instructional strategies. Sizeable proportions of teachers indicated that lack of opportunities for teachers to share ideas created serious problems for science and mathematics instruction in their schools. The picture that emerges is one where teachers feel supported by their colleagues, but lack opportunities to work with them.

With regard to alignment with national standards, it is encouraging that the use of hands-on activities has increased, especially in elementary mathematics where 65 percent of lessons involved at least some use of manipulatives, compared to 45 percent in 1986. However, there continue to be many barriers to the use of this instructional strategy, including inadequate facilities and equipment, and lack of money to purchase consumable supplies. Similarly, inadequate access to computers, a scarcity of appropriate software, and feelings of unpreparedness on the part of a majority of science and mathematics teachers have resulted in meager use of computers (and other technologies) in science and mathematics instruction.

There is also considerable evidence that the goal of quality education for *all* students is far from becoming a reality. While the majority of science and mathematics teachers feel at least fairly well prepared to teach students from a variety of cultural backgrounds, only 45 percent feel well prepared for students with learning disabilities, and only 29 percent consider themselves well prepared for students with limited English proficiency. Moreover, classes with large numbers of minority students are less likely to have qualified teachers and less likely to have the opportunity to learn challenging science and mathematics content. On the positive side, there appears to be a decreased use of tracking, which should lead to increased opportunities for minority students in the future.

A Profile of Science and Mathematics Education in the United States, 1993

Introduction

The 1993 National Survey of Science and Mathematics Education involved a national probability sample of 1,250 schools and approximately 6,000 teachers in grades 1–12 throughout the United States. Teachers were asked to provide information about their course backgrounds, participation in in-service education and other professional activities, pedagogical beliefs, and science and mathematics instruction. Department heads or lead teachers also completed questionnaires about their school's science and mathematics programs. Highlights of the survey results are presented in the following sections; a more complete presentation of results is included in a technical report available from Horizon Research, Inc.

Overview of the Science and Mathematics Education Reform Agenda

Current efforts to reform science and mathematics education began with the development of the *National Council of Teachers of Mathematics* (NCTM) *Standards*. Groups of mathematics teachers, mathematics educators, and mathematicians, working under the aegis of NCTM, and with input from thousands of stakeholders in mathematics education, developed the *Curriculum and Evaluation Standards for Mathematics* (NCTM, 1989) and the *Professional Standards for Teaching Mathematics* (NCTM, 1991). These two documents call for revolutionary changes in mathematics education, shifting from a curriculum emphasizing computation and rote memorization of facts and procedures to one that is conceptually oriented, engaging all students in developing mathematical power. Rather than having the teacher and textbook as exclusive sources of information, students would be engaged in exploring, conjecturing, analyzing, and applying mathematics in both a mathematical and a real-world context.

In 1992, the science education community began to convene groups of science teachers, science educators, and scientists to develop standards for science curriculum, teaching, and assessment under the aegis of the National Research Council. Building on work of national reform efforts such as the American Association for the Advancement of Science's Project 2061 and the National Science Teachers Association's Scope, Sequence, and Coordination Project, the vision described in the *National Science Education Standards* is remarkably consistent with that of the *NCTM Standards*. Both communities agree that science and mathematics education should:

- Emphasize high expectations for all students;

- Focus on in-depth learning of a limited number of powerful concepts, emphasizing understanding, reasoning, and problem-solving rather than memorization of facts, terminology, and algorithms;

- Integrate the nature and processes of scientific and mathematics inquiry with knowledge of science and mathematics concepts and principles;

- Engage students in meaningful activities that enable them to construct and apply their knowledge of key science and mathematics concepts;

- Reflect sound principles from research on how students learn, including the use of cooperative learning, and questioning techniques that promote interaction and deeper understanding;

- Feature appropriate, on-going use of calculators, computers, and other technologies for learning science and mathematics;

- Empower students by enabling them to do science and mathematics, and increasing their confidence in their ability to do so;

- Develop in students the scientific and mathematical literacy necessary to make informed decisions and function as full participants in society;

- Assess learning as an integral part of instruction;

- Ensure that teachers have a deep understanding of their subject matter; and

- Provide on-going support for classroom teachers, including continuing opportunities for teachers to work with one another in planning curriculum and instruction.

The 1993 National Survey of Science and Mathematics Education provides information about the current status of science and mathematics education. How well prepared are science and mathematics teachers to teach these subjects in the fashion recommended by the *NCTM Standards* and the *National Science Education Standards*? To what extent do science and mathematics classes reflect these standards? Are all students provided with opportunities to learn challenging science and mathematics content? In the following sections, data from the 1993 Survey are used to address these questions.

Science and Mathematics Teachers

Teachers' Course Background

Two out of three elementary teachers have had the minimum science coursework recommended by NSTA.

National Standards call for the introduction of challenging science and mathematics content to all students beginning in the early grades. If teachers are to guide students in their exploration of science and mathematics concepts, they must themselves have a firm understanding of these concepts. Because it would be extremely difficult to gauge the extent to which a large national sample of teachers understands science and mathematics concepts (and know how to help their students learn these concepts), proxy measures such as major or number of courses taken in field are typically used. The National Science Teachers Association (NSTA) has recommended that elementary teachers have at least one college course in each of three science areas—biological, physical, and earth science—and roughly 2 out of 3 science teachers in the elementary grades meet that minimum standard.

Few elementary teachers have had college coursework in geometry or in probability and statistics.

Ninety-eight percent of elementary teachers have had college courses in mathematics for elementary school teachers or methods of teaching mathematics. Only about 3 out of 10 have had college coursework in geometry or probability and statistics, areas that the *NCTM Curriculum and Evaluation Standards* suggest should be addressed beginning in the primary grades.

In recent years there has been an increased concern that prospective secondary teachers have a major in their field. Using this measure, high school science teachers are the most qualified group: 63 percent have an undergraduate major in science and 72 percent have a major in either science or science education at the graduate or undergraduate level. High school mathematics teachers are less likely than their science counterparts to have undergraduate majors in mathematics (41 percent) or either graduate or undergraduate majors in mathematics or mathematics education (63 percent).

Among the sciences, earth science is least likely to be taught by teachers with an extensive background in the subject.

There is considerable variation in extent of teacher preparation for the various science subjects taught at the secondary level. As can be seen in Figure 2, only 45 percent of grade 7–12 earth science classes are taught by teachers who have had 6 or more semesters of college earth science. In contrast, 94 percent of grade 9–12 biology classes are taught by teachers who have had at least 6 semesters of college biology.

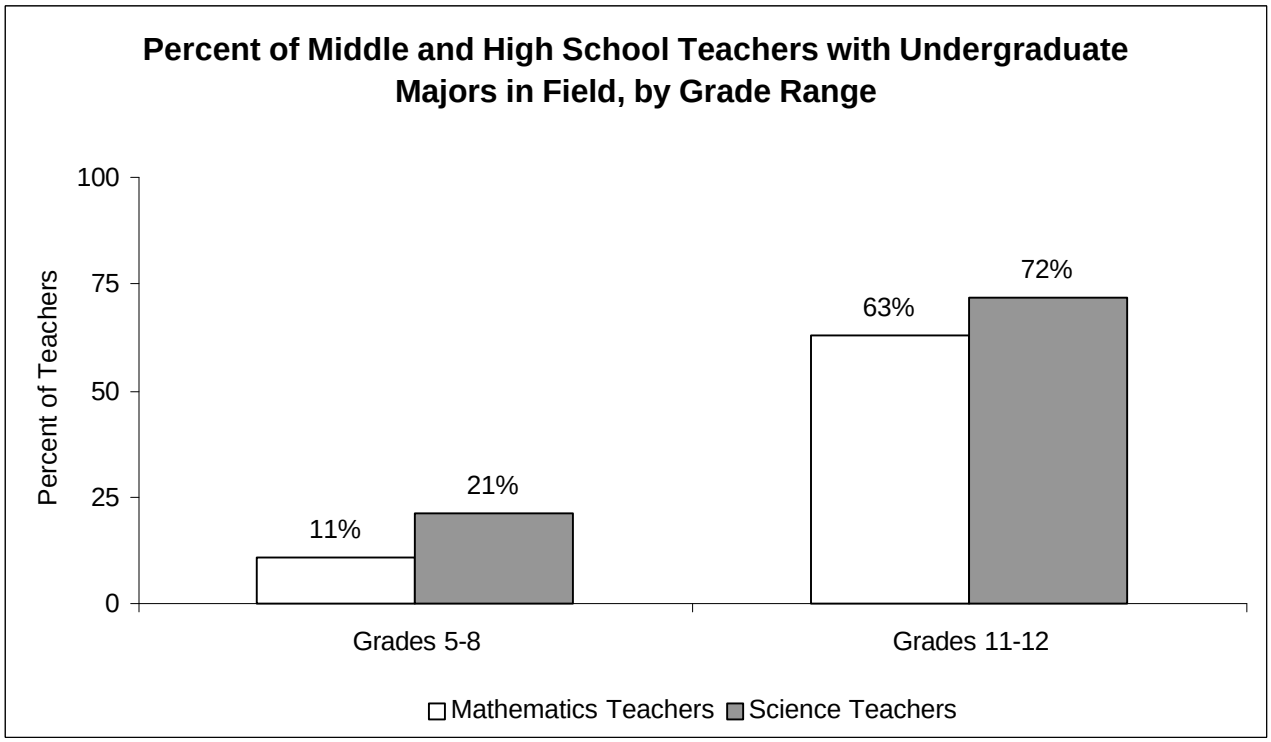

Figure 1

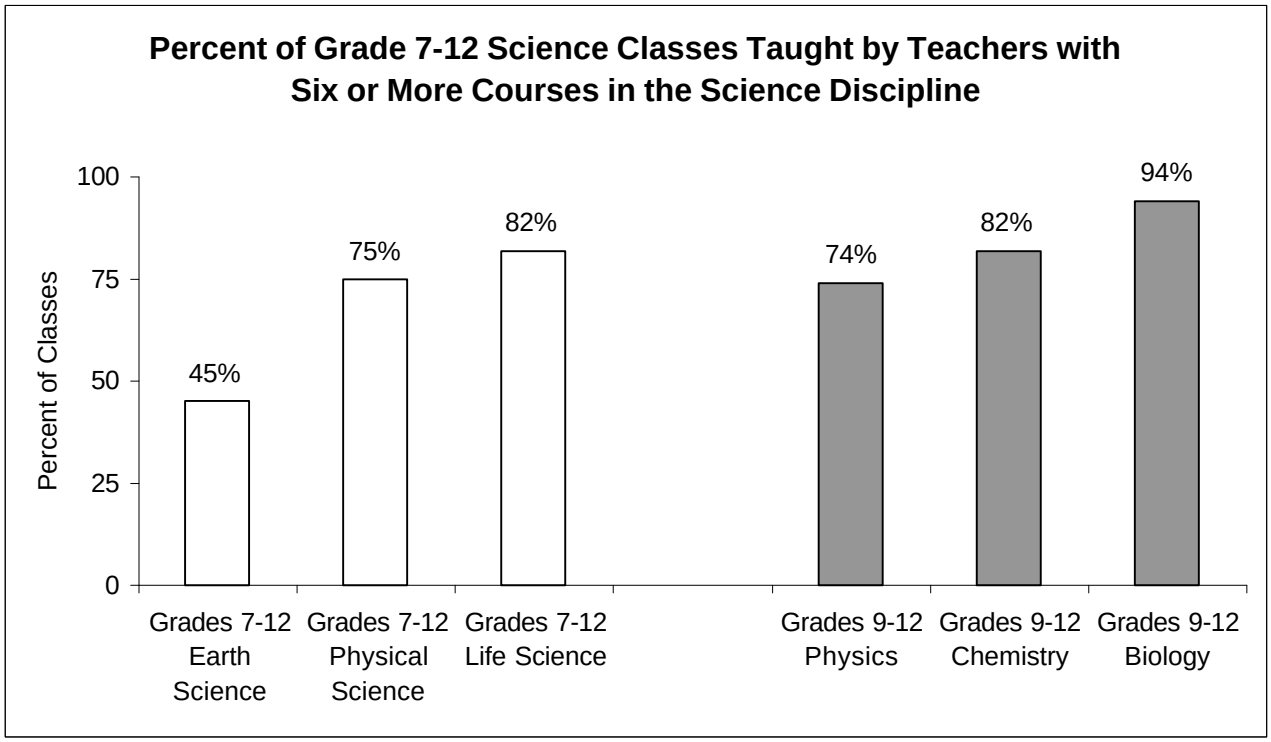

Figure 2

At the middle/junior high school level, NCTM has recommended that mathematics teachers have college coursework in abstract algebra, geometry, calculus, probability and statistics, and applications of mathematics/problem solving. The percentages of grade 5–8 mathematics teachers having completed coursework in these areas range from 22 to 44 percent; for grade 7–9 teachers the range is from 40 to 73 percent.

Fewer than half of high school mathematics teachers have had coursework in the history or applications of mathematics.

At the high school level, NCTM has recommended that mathematics teachers have coursework in the five areas recommended for middle grade teachers and also advanced calculus, differential equations, linear algebra, history of mathematics, and other upper division mathematics. The percentages of grade 9–12 mathematics teachers completing courses in these areas range from 42 percent for history of mathematics to 95 percent for calculus.

While the *NCTM Professional Standards for Teaching* and the *National Science Education Standards* stress the importance of having teachers who are well-versed in the subjects they teach, they also emphasize that subject matter knowledge is not enough; teachers must be willing and able to structure the learning environment to help students develop an understanding of key science and mathematics concepts. The following sections examine teachers' pedagogical beliefs to determine the extent to which they support the views of science and mathematics education expounded in the national standards, and how well prepared teachers feel to implement the recommended instructional strategies.

Teachers' Pedagogical Beliefs

As one measure of the influence of the NCTM *Standards*, mathematics teachers were asked the extent of their familiarity with each of these documents. As can be seen in Figure 3, mathematics teachers in the higher grades are much more likely than their counterparts in the lower grades to say they are familiar with the *Curriculum and Evaluation Standards*. Eighteen percent of elementary mathematics teachers, 28 percent of middle grade mathematics teachers, and 56 percent of high school mathematics teachers indicated that they were "well aware" of the *Curriculum and Evaluation Standards*. (Not surprisingly, teachers in each grade range were less likely to be familiar with the more recently released *Professional Teaching Standards*.)

Of course, whether or not they have read these documents, mathematics teachers may or may not agree with the principles underlying the NCTM *Standards* or the recommendations that flow from them, and science teachers may or may not agree with the reforms embodied in the *National Science Education Standards*. To get an idea of teachers' beliefs as they relate to reforms currently being advocated, teachers were asked if they agreed with a number of statements about science and mathematics education.

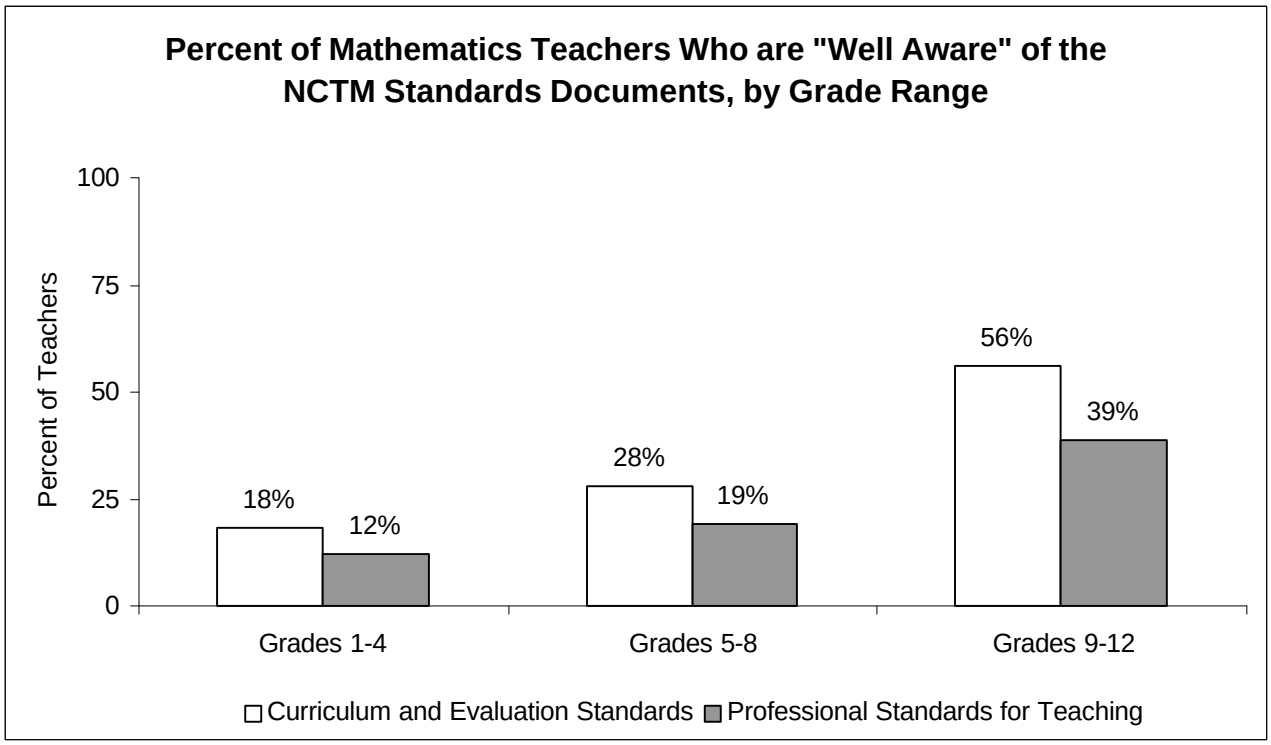

Figure 3

Most science and mathematics teachers believe that students learn best when they study these subjects in the context of a personal or social application, including more than 90 percent of those at the elementary and middle school levels, and 86 percent at the high school level. Similarly most support hands-on instruction, indicating that activity-based experiences "are worth the time and expense for what students learn."

Many mathematics teachers believe students must master computation before going on to algebra; many science teachers continue to emphasize terminology.

However, there is less support among teachers for some of the other tenets of current reform ideas. For example, while the *NCTM Curriculum and Evaluation Standards* argue for the earlier introduction of algebraic concepts, the majority of elementary, middle, and high school mathematics teachers indicated their belief that "students must master arithmetic computation before going on to algebra."

Similarly, there is resistance to the reform notion of teaching science concepts first and only then having students learn the terminology associated with those concepts. Almost one-third of the teachers in grades 1–4, increasing to more than half of all high school science teachers, indicated that "it is important for students to learn basic scientific terms and formulas before learning underlying concepts and principles."

Table 1
Percent of Teachers Indicating that Various Strategies Should be a Part of Science/Mathematics Instruction

Strategy	Science Grades			Mathematics Grades		
	1–4	5–8	9–12	1–4	5–8	9–12
Hands-on/manipulative activities	99	99	97	98	89	78
Applications in daily life	99	99	98	99	99	95
Concrete experience before abstract treatments	93	91	84	97	92	85
Every student studying subject every year	96	93	76	97	96	81
Students working in cooperative learning groups	91	93	81	92	82	78
Coordination of sciences with mathematics	92	90	92	81	75	80
Taking student preconceptions into account when planning curriculum/instruction	87	83	76	79	80	67
Use of computers	77	81	82	87	87	81
Deeper coverage of fewer concepts	69	68	59	72	75	55
Use of calculators	--	--	--	71	80	89
Integration of mathematics subjects	--	--	--	64	65	56

In another attempt to gauge teacher support for reform recommendations, science and mathematics teachers were provided with a list of instructional "strategies" and asked how important they believed each was for effective science and mathematics instruction. Again, it is clear that science and mathematics teachers support some of the current reform notions, but are less convinced about others. And, again, pedagogical beliefs vary considerably by grade taught.

- There is nearly universal support among teachers for including the applications of science and mathematics in daily life in their instruction.

- Support for hands-on activities is also very high, although middle and high school mathematics teachers are less likely than elementary teachers to believe that the use of manipulatives is important for effective mathematics education.

- There is considerable support for the idea of having students work in cooperative learning groups, with about 9 out of 10 elementary teachers and 8 out of 10 high school science and mathematics teachers indicating that cooperative learning is important for effective instruction.

- More than 80 percent of science and mathematics teachers believe that computers are important for effective instruction, with little difference by grade range.
- About 8 out of 10 elementary and middle grade teachers, and 7 out of 10 high school

science and mathematics teachers, indicated that student preconceptions about a topic should be taken into account when planning science and mathematics curriculum and instruction.

- There is less support for the reform ideas on depth versus breadth, with roughly 70 percent of elementary and middle grade teachers and fewer than 60 percent of high school teachers indicating that science and mathematics instruction should focus on deeper coverage of fewer concepts.

- Only 56 percent of high school mathematics teachers believe that mathematics subjects should be integrated (i.e. with algebra, probability, geometry, etc., all taught together every year).

Interestingly, while elementary teachers are generally supportive of the various pedagogical reform notions, there is some resistance to the idea of extensive use of calculators. Only 71 percent of grade 1–4 mathematics teachers, compared to 89 percent at the high school level, indicated that calculators should be used in mathematics instruction at their grade levels. In a related question, most high school mathematics teachers, but relatively few in the elementary grades, indicated that students should be able to use calculators "most of the time."

Teacher Judgements of Their Preparation to Teach Science and Mathematics

Knowing the extent of teachers' course backgrounds provides useful information about the preparation of the nation's science and mathematics teaching force. Of equal importance are teachers' perceptions of their preparation—how well prepared teachers feel they are to teach the various content areas and to use the various instructional strategies recommended for science and mathematics education.

Many elementary teachers continue to feel better prepared to teach reading than mathematics or, especially, science.

Elementary teachers are typically assigned to teach science, mathematics, and other academic subjects to one group of students, but it is clear that they do not feel equally well qualified to teach these subjects. Figure 4 shows the percent of elementary teachers perceiving themselves to be "very well qualified" to teach reading/language arts, social studies, mathematics, and science at three different points in time—1977, 1986, and 1993. In 1993, 76 percent of elementary teachers assigned to teach all four subjects indicated they felt very well qualified to teach reading/language arts, compared to roughly 60 percent for both mathematics and social studies, but only 28 percent for life science.

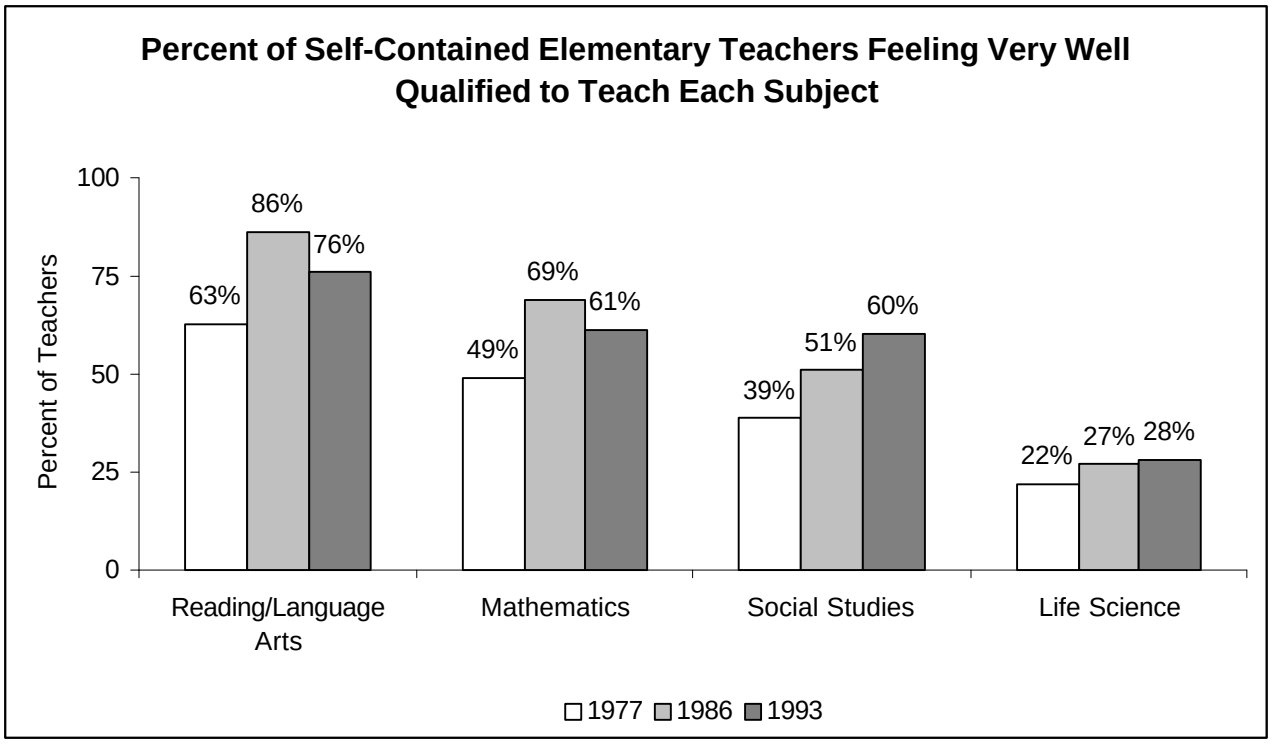

Figure 4

Science and mathematics teachers at all grade levels were also asked how well prepared they felt for each of a number of tasks they might be expected to accomplish as part of their teaching responsibilities. Several areas stood out as ones in which large numbers of teachers feel inadequately prepared.

Many science and mathematics teachers do not feel well prepared to use computers as an integral part of instruction.

- One-half or more of science and mathematics teachers in each grade range do not feel well prepared to use computers as an integral part of instruction.
- More than one-third of elementary teachers and more than one-half of high school science and mathematics teachers feel unprepared to involve parents in the education of their children.
- Roughly 40 percent of all science and mathematics teachers feel lacking in preparation to use performance-based assessment.
- About 1 in 4 science and mathematics teachers feels less than well prepared to use textbooks as a resource rather than as the primary instructional tool.

- About one-third of all science teachers do not feel well prepared to take into account students' prior conceptions about natural phenomena when planning curriculum and instruction.

Elementary teachers tend to be more comfortable than high school teachers with a number of reform-oriented instructional strategies.

Interestingly, elementary teachers tend to be more comfortable than their colleagues in the higher grades with a number of the reform strategies, including using cooperative learning techniques; teaching groups that are heterogeneous in ability; and integrating science and mathematics with other subject areas. On the other hand, elementary teachers expressed more concern than did their middle and high school counterparts about using calculators as an integral part of mathematics instruction, and about presenting the applications of science concepts.

Teachers as Professionals

The *NCTM Standards* documents and the *National Science Education Standards* stress that classroom teachers are in the best position to know their students' needs, interests, and abilities, and should be empowered to use their professional judgement in tailoring instruction to a particular group of students. The 1993 National Survey of Science and Mathematics Education asked teachers about the extent to which they felt they had control over a number of decisions for their science and mathematics classes. Most science and mathematics teachers in each grade range, in some cases as many as 75–80 percent, perceived themselves as having autonomy in selecting teaching techniques; determining the amount of homework to be assigned; choosing criteria for grading; and selecting both the sequence and the pace for covering topics. Overall, fewer than one-half of all science and mathematics teachers, and typically less than one-third of teachers in the elementary and middle grades, perceived themselves as having strong control in determining the goals and objectives of their courses; selecting the content, topics, and skills to be taught; and selecting textbooks.

Having discretion in making curriculum and instructional decisions is one of the hallmarks of teachers as professionals. Another is keeping up with advances in their field. While most science and mathematics teachers reported participating in one or more in-service activities in the last three years, relatively few had devoted a substantial amount of time to such activities. Because elementary teachers are generally responsible for staying current in a number of subjects, including science and mathematics, it is not surprising that the typical elementary teacher spent a total of less than 16 hours on in-service education in each field in the three years prior to the survey. (See Figure 5.) While high school science and mathematics teachers generally devoted more time to in-service education in these fields, still only about 1 in 2 had spent a total of 35 hours or more on these activities in the prior three years.

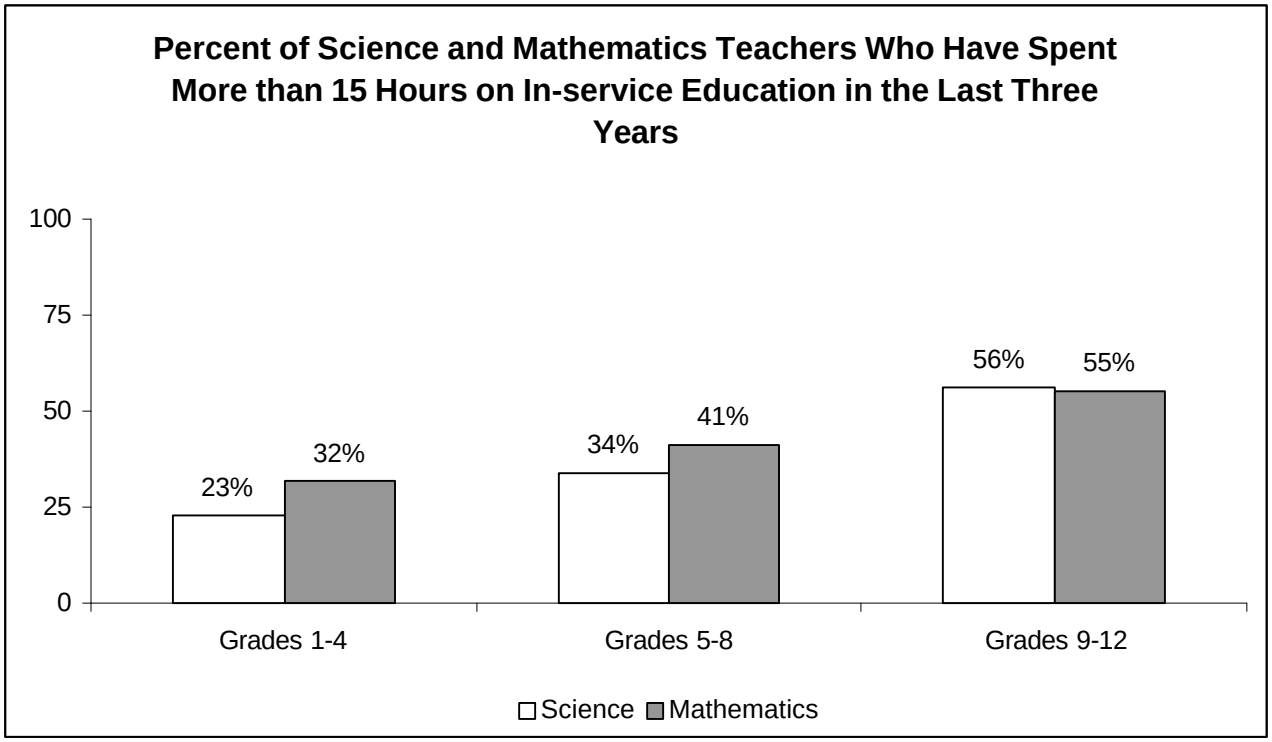

Figure 5

Similarly, science and mathematics teachers in grades 9–12 were most likely (and those in grades 1–4 least likely) to have taken a college course in their field in recent years. The pattern was more pronounced in science than in mathematics: in 1993, 47 percent of grade 9–12 science teachers, compared to 34 percent in grades 5–8 and 20 percent in grades 1–4, had taken a science or science education course for college credit in the previous three years.

Finally, teachers were asked their opinions about a number of issues related to collegiality in their school. On the positive side, most science and mathematics teachers in each grade range feel supported by their colleagues to try out new ideas in teaching; indicate that teachers in their school share ideas and materials on a regular basis; feel that they have many opportunities to learn new things in their job; and feel supported by their administrators. However, fewer than 1 in 5 have time during the regular school week to work with their peers on science and mathematics curriculum and instruction, and only about 1 in 8 indicated that science and mathematics teachers in their school regularly observe each other teaching classes as part of sharing and improving instructional strategies. Sizeable proportions of teachers indicated that lack of opportunities for teachers to share ideas created serious problems for science and mathematics instruction in their schools. The picture that emerges is one where teachers feel supported by their colleagues, but lack opportunities to work with them.

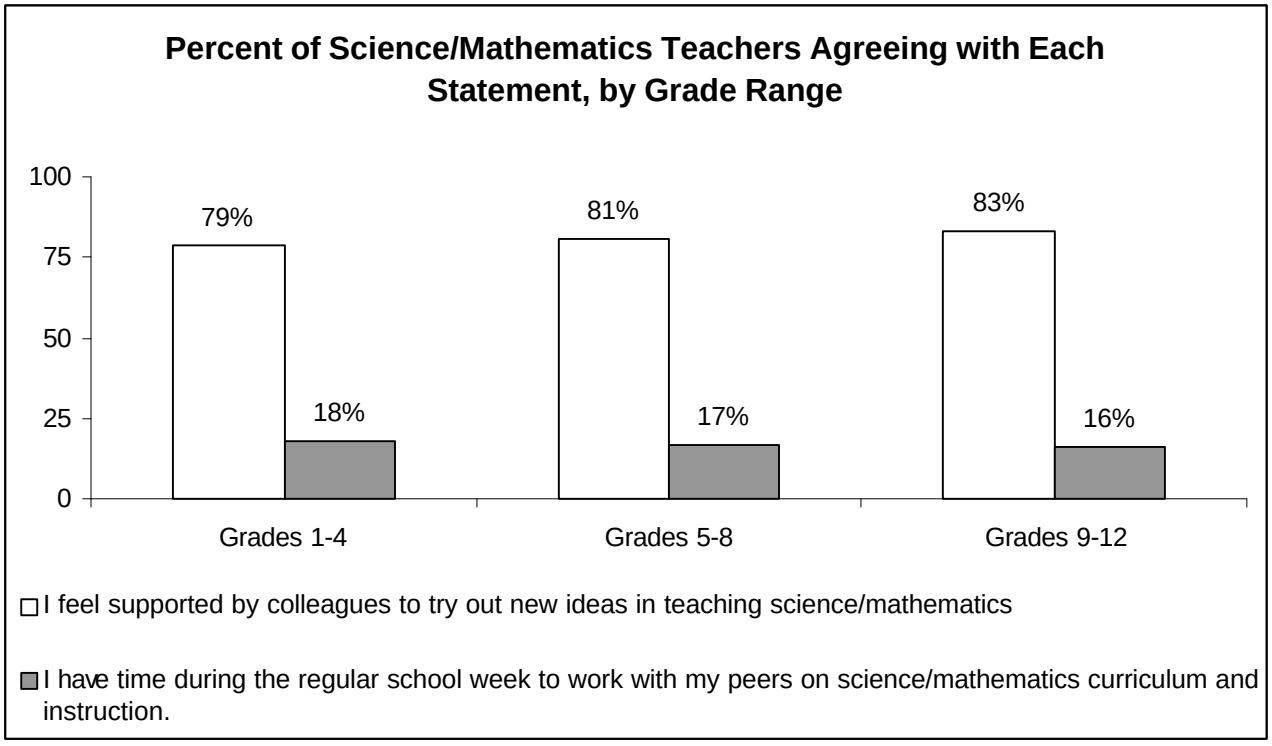

Figure 6

A Look Inside Science and Mathematics Classrooms

The 1993 National Survey of Science and Mathematics Education asked teachers in grades 1–12 a series of questions about a randomly selected science or mathematics class they were teaching. How much time is spent on science and mathematics instruction? What are the objectives of that instruction, and what class activities are used to achieve them? What instructional resources are available and used? These questions are addressed in the following sections.

Time Spent on Science and Mathematics Instruction

Slightly more time is being spent on science and mathematics instruction in the early grades than was the case in the mid-1980s.

Most elementary school classes are "self-contained," where a single teacher is responsible for teaching all or most of the academic subjects to a single group of students. Based on data provided by the teachers, an average of only about one-half hour per day is spent on science instruction, and slightly less than an hour per day on mathematics instruction (compared to roughly 70 minutes on reading/language arts instruction). The science and mathematics figures represent a small increase in the last 15 years, while the amount of time spent on reading/language arts instruction has decreased slightly.

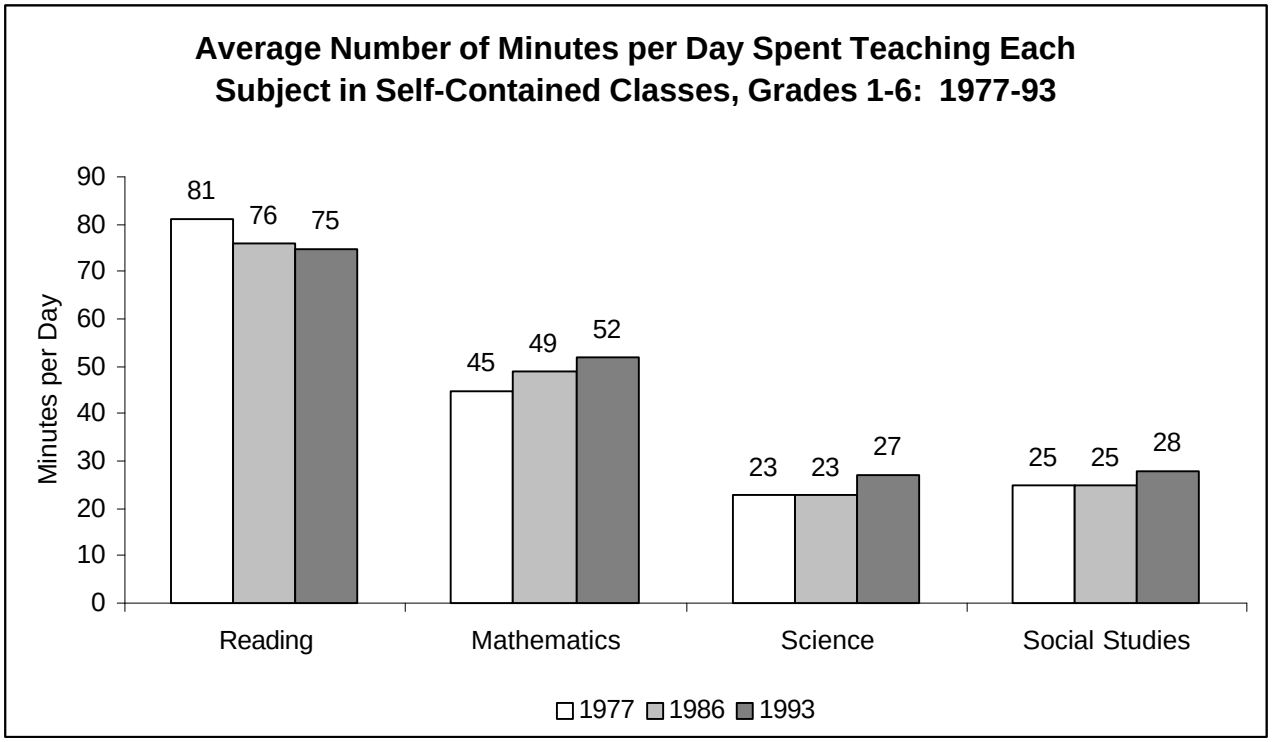

Figure 7

In the higher grades, most science and mathematics classes meet for roughly 50 minutes per day, the same as classes in other subjects. However, the fact the students are usually required to take 4 years of high school English/language arts, compared to 2 or 3 years of high school mathematics and typically 2 years of high school science, translates into a pattern similar to that in the elementary grades, where more instructional time is devoted to language arts than to science or mathematics.

Objectives of Science and Mathematics Education

The *NCTM Curriculum and Evaluation Standards* and the *National Science Education Standards* emphasize the importance of higher order thinking skills, and studying science and mathematics in depth, rather than focusing on a superficial learning of facts, terminology, and algorithms. The curriculum should engage students in seeing the interconnections among concepts and the applications of these concepts in the real world.

How closely do teachers' objectives for science and mathematics classes conform to national standards in these areas? To find out, the 1993 Survey gave teachers a list of possible objectives for their classes and asked them to indicate how heavily each was emphasized in a particular randomly-selected class.

- Based on teacher reports, the most heavily emphasized objectives in science classes are learning basic science concepts (heavily emphasized in 83 percent of science classes overall); increasing the awareness of the importance of science in daily life (77 percent); and developing problem solving/inquiry skills (74 percent).

- In mathematics, the most heavily emphasized objectives are learning mathematical concepts (heavily emphasized in 92 percent of classes); learning how to solve problems (91 percent); and learning to reason mathematically (87 percent).

- Increasing interest in science and mathematics, and increasing awareness of their importance in daily life, are more likely to be emphasized in the lower grades. For example, about three-fourths of the elementary and middle grade classes emphasize increasing interest in science and mathematics, compared to roughly 60 percent of high school classes.

A sizeable proportion of science and mathematics classes have instructional emphases that run counter to the current reform recommendations. For example, approximately 40 percent of mathematics classes and approximately 20 percent of science classes in each grade range give heavy emphasis to preparing students for standardized tests, tests that have been shown to focus on lower level knowledge and skills rather than on the higher order thinking skills called for in the national standards. (Madaus, 1992)

Similarly, while national standards call for deemphasizing factual learning in science and computation in mathematics, many teachers report that they emphasize these objectives in their science and mathematics classes. For example, 1 out of 2 elementary science classes and nearly 2 out of 3 in the middle/high school grades give heavy emphasis to learning "important terms and facts in science." Roughly 40 percent of high school mathematics classes emphasize having students "learn to perform computations with speed and accuracy."

Class Activities

Based on data provided by teachers, elementary, middle, and high school science classes are quite similar in their instructional arrangements. Looking across all science classes, the largest proportion of class time is devoted to lecture/discussion (38 percent of class time), followed by hands-on/laboratory work (23 percent), individual seatwork (19 percent), and non-laboratory small group work (10 percent), with the remaining 10 percent of time spent on daily routines, interruptions, and other non-instructional activities.

Mathematics classes appear to vary considerably more by grade range. For example, the typical high school mathematics class spends 48 percent of class time on whole group lecture/discussion, only 14 percent on non-manipulative small group work, and only 7 percent working with manipulatives. In contrast, the typical elementary mathematics class spends roughly 25–30 percent of class time on each of these activities.

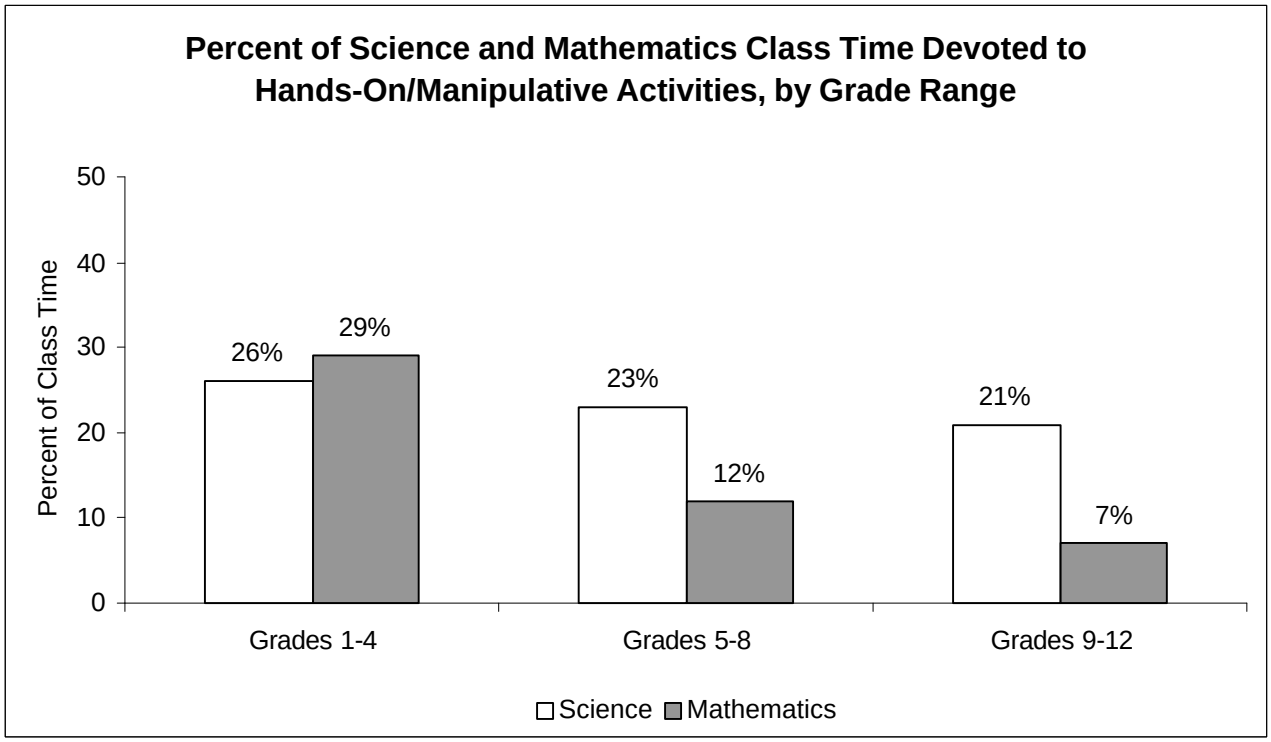

Figure 8

The 1993 Survey found that "traditional" activities continue to dominate science and mathematics instruction. For example:

- Ninety-four percent of high school science and mathematics classes listen and take notes during presentations by the teacher at least once a week; 60 percent do so on a daily basis.

- Ninety-eight percent of high school mathematics classes do mathematics problems from their textbooks at least once a week; 86 percent do so on a daily basis.

While use of hands-on activities has increased since the mid-1980s, lecture/textbook methodologies continue to dominate science and mathematics instruction.

In contrast, teachers report that only 4 out of 10 high school mathematics classes are engaged in making conjectures and exploring possible methods to solve a mathematics problem as often as once a week, and only 3 out of 10 are asked to write their reasoning about how to solve a problem that often. Fifty-eight percent of high school mathematics classes never work on projects of a week's duration or longer and 56 percent never use computers.

Half of high school science and mathematics classes never use computers.

Similarly, 62 percent of high school science classes never take field trips, 54 percent never use computers, and 43 percent never work in class on science projects of at least a week's duration.

There are, however, some encouraging signs. The majority of elementary, middle, and high school science and mathematics classes work in small groups at least once a week and roughly 1 in 4 classes does so on a daily basis. Moreover, the use of hands-on activities has increased since the mid 1980s. The change has been most dramatic in mathematics in the elementary grades, increasing from approximately 45 percent of lessons including the use of manipulatives in 1986 to 65 percent of lessons in 1993.

Instructional Resources

Science and mathematics department heads (or other persons designated by the principal in each school) were given a list of 18 factors that might affect science/mathematics instruction and asked to indicate the extent of the problems, if any, each caused in their school (not a problem, somewhat of a problem, a serious problem). As can be seen in Table 2, areas involving instructional resources were by far the most frequently cited as problematic, including lack of funds to purchase equipment and supplies; lack of materials for individualizing instruction; inadequate access to computers; and lack of appropriate computer software. Far fewer schools cited as serious problems such factors as student absences; maintaining discipline; class size; and interruptions for announcements, assemblies, and other school activities. Moreover, it is interesting to note that state and district testing policies were no more likely to be cited as serious problems for mathematics, where such tests are common, than for science, which is less frequently tested at the state and district level.

The 1993 Survey also investigated issues related to the adequacy of instructional resources at the classroom level by asking each teacher about the availability and use of textbooks, overhead projectors, televisions, videotapes, videodiscs, CD-ROM players, computers, different types of calculators, and science laboratory facilities for a particular, randomly selected class.

Teachers reported that the vast majority of science and mathematics classes use one or more commercially published textbooks or programs, including 95 percent or more of middle and high school science classes and mathematics classes at all levels. (In contrast, only 75 percent of elementary science classes use published textbooks/programs, down from 86 percent in 1986, presumably because more teachers are now using non-textbook-based science programs.) Mathematics classes tend to "cover" more of their textbooks than do science classes; teachers in roughly 7 out of 10 mathematics classes, compared to 5 in 10 science classes, reported covering at least 75 percent of the textbook. Moreover, while reform advocates tend to be critical of science and mathematics textbooks, most science and mathematics teachers are pleased with the quality of their textbooks, with about 3 out of 4 rating their textbooks good or better.

Table 2
Percent of Schools Citing Each Factor as a Serious Problem for Science and Mathematics Instruction

Problem	Science	Mathematics
Funds for purchasing equipment and supplies	43	31
Appropriate computer software	42	30
Materials for individualizing instruction	36	25
Access to computers	30	31
Opportunities for teachers to share ideas	27	20
Facilities	25	6
In-service education opportunities	17	11
Large classes	16	14
Time to teach subject	16	3
Student reading abilities	15	13
State/district testing policies	11	11
Interruptions for announcements, assemblies, other school activities	10	7
Parental support for education	10	12
Teacher preparation to teach subject	9	3
Maintaining discipline	8	6
Student interest in subject	7	7
Student absences	5	5
Teacher interest in subject	3	1

Textbooks and overhead projectors are used in most classes; other instructional resources are used less frequently.

The only other instructional resource included in the survey that is used in three-fourths or more of the science and mathematics classes in each grade range is the overhead projector. Use of computers, calculators, televisions, videotape players, and other instructional resources is considerably less prevalent in science and mathematics classes than is use of textbooks and overhead projectors.

- Videotape players are used in 9 out of 10 science classes and 4 out of 10 mathematics classes.

- Roughly one-half of science classes and one-fourth of mathematics classes watch television programs as part of their instruction.

- Videodisc players are used in 24 percent of science classes but only 5 percent of mathematics classes.

- Mathematics classes are more likely than science classes to use computers. Computer use is most prevalent in elementary mathematics, where 3 out of 4 classes make use of computers.

- The use of more powerful calculators (fraction, scientific, and graphing) increases with grade level; roughly 4 out of 10 high school science classes and 7 out of 10 high school mathematics classes use scientific calculators.

Substantial numbers of teachers indicated that they needed particular kinds of equipment but they were not available. Most frequently cited:

- Computers and computer/laboratory interfacing devices in both science and mathematics.

- In mathematics, fraction calculators and graphing calculators, especially in the middle grades.

- In science, running water, electrical outlets, gas for burners, and hoods or air hoses in laboratories, as well as videodiscs and CD-ROM players.

Many classes do not have access to instructional resources needed to implement national standards.

It appears that the situation is unlikely to improve without a concerted effort to equip schools for hands-on instruction and technology use. Based on data provided by the schools participating in the 1993 Survey, the median amount spent on software in the most recently completed budget year was only $50 for science and $100 for mathematics, at a time when a single piece of software usually costs more than $50 and often more than $100. The typical elementary school spent only $.51 per student on consumable science supplies such as chemicals, glassware, batteries, etc. and $1.00 per student on manipulative materials and other consumable mathematics supplies in the same time period. These amounts are clearly insufficient when a single meter stick costs $3.00 and a set of mathematics pattern blocks costs $24.00. As can be seen in Figure 9, the amount spent on mathematics supplies per student enrolled in the school is lower at the middle and high school levels, while the amount spent on science supplies increases with increasing grade levels.

Either because school funds are scarce and/or ordering procedures are cumbersome, most teachers wind up spending some of their own money for supplies for their science and mathematics classes, with a median amount ranging from $25 to $50 per class. The typical elementary teacher reports spending $80 per year on science and mathematics supplies; the typical high school mathematics teacher spends a total of $125 for five classes; and the typical high school science teacher, a total of $250 for five classes.

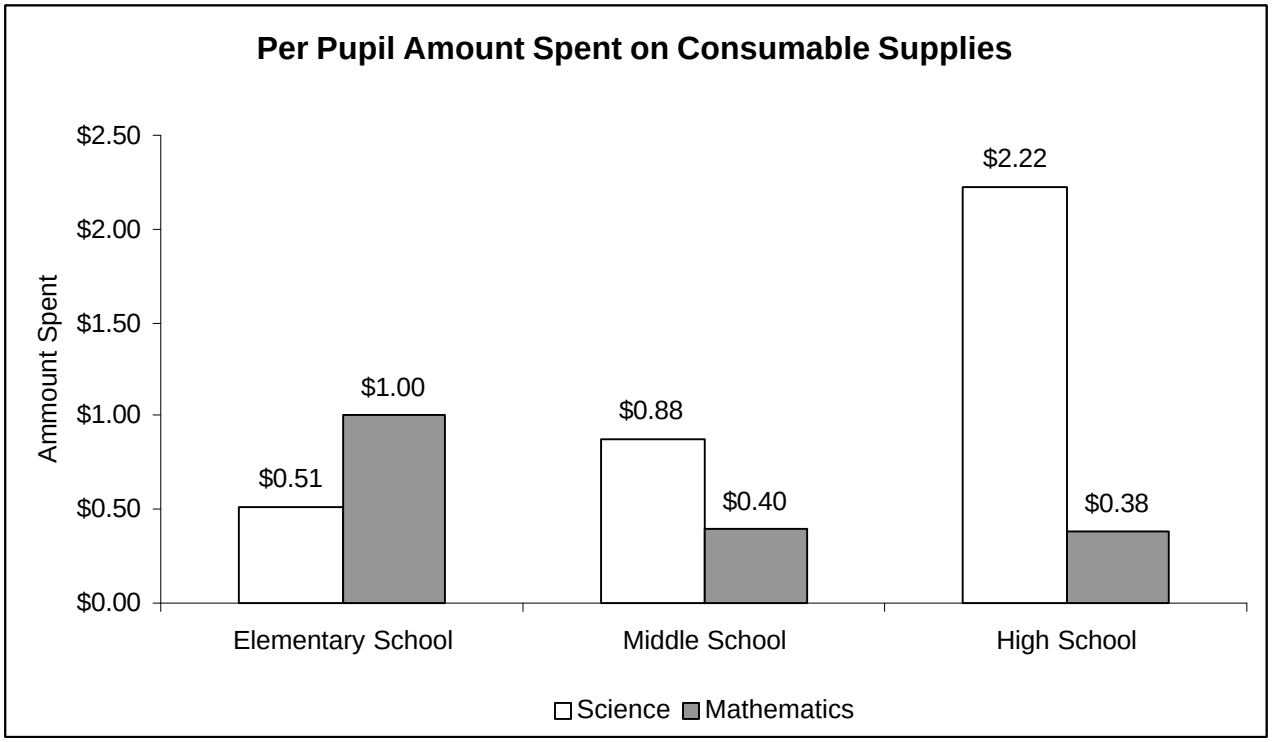

Figure 9

Quality Education For All

In the 1960s, there was particular concern about ensuring an adequate supply of scientists and engineers, and much of the reform effort focused on improving the curriculum for students who seemed most likely to continue in these fields. The current reforms emphasize that *all* students need to have a deep understanding of science and mathematics in order to function in an increasingly technological society, and stress narrowing the gap between the science and mathematics "haves" and "have nots."

Using data collected as part of the 1985–86 National Survey of Science and Mathematics Education, Oakes (1990) found that students who were economically disadvantaged, many of whom are members of minority groups, were less likely to have access to qualified teachers and less likely to have opportunities to learn challenging science and mathematics content. The 1993 Survey found similar evidence that students are not given equal opportunities to achieve high expectations.

Most high school science and mathematics teachers favor ability grouping.

While more than 75 percent of science and mathematics teachers agreed that "virtually all students can learn to think scientifically/mathematically," many teachers are not convinced that heterogeneous grouping is the way to achieve that learning. Roughly 3 in 10 grade 1–4 teachers, rising to more than 7 out of

10 at the high school level, believe that students learn science and mathematics best when grouped with students of similar abilities. (See Figure 10.) And while there has been an increase in the extent of heterogeneous grouping since the mid 1980s, many schools continue to assign students to science and mathematics courses, or sections within courses, by ability levels. Overall, 11 percent of middle/junior high schools assign students to science courses by ability level and 46 percent do so in mathematics. Ability grouping is greater at the high school level, with 34 percent of schools assigning incoming students to science courses by ability level and 57 percent doing so in mathematics.

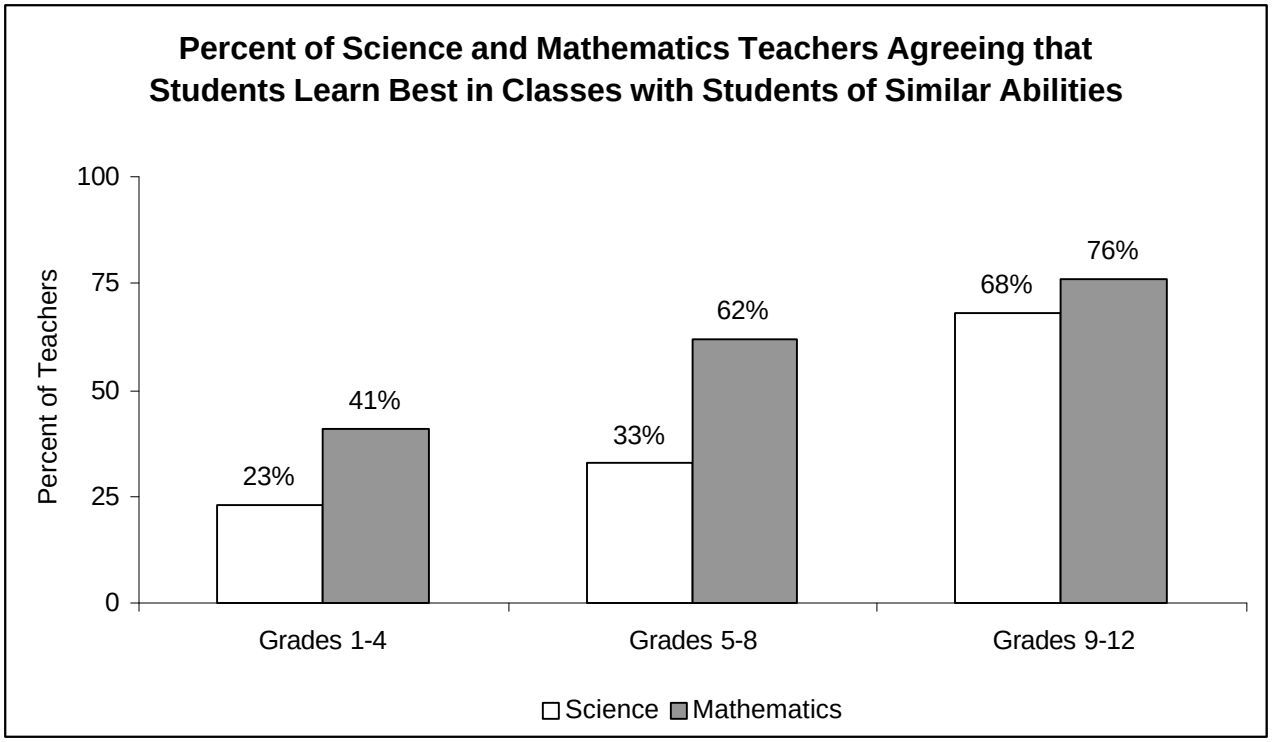

Figure 10

While there are no data available to compare the situation at the school level in 1993 to that in earlier years, data provided by teachers show a trend towards heterogeneous grouping in science and mathematics classes. In 1993, 36 percent of grade 10–12 science and mathematics classes were heterogeneously grouped, up from 22 percent in 1986.

Although national standards call for high expectations for all students, it is clear that teachers have different objectives for their instruction depending on the composition of the class. As can be seen in Figure 11, while both "high" and "low" ability high school science and mathematics classes emphasize the "basics," low ability classes are more likely to emphasize awareness of the importance of science and mathematics in daily life, while high ability classes are more likely to focus on developing reasoning and inquiry skills.

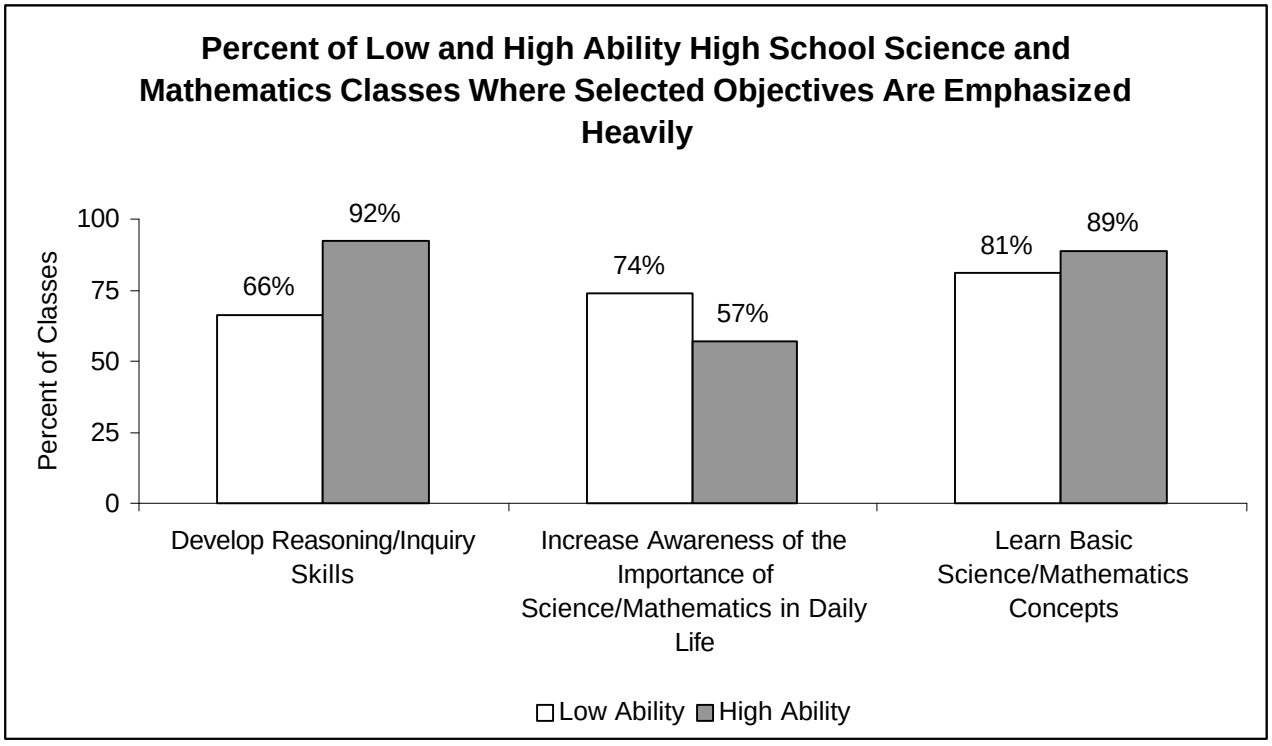

Figure 11

The instructional activities engaged in by these classes follow a similar pattern: low ability science classes are more likely than high ability classes to spend time each week reading from the textbook and less likely to participate in hands-on activities. Similarly, low ability mathematics classes are more likely than high ability classes to spend time each week doing worksheet problems and less likely to be asked to write their reasoning about solving a mathematics problem. (See Figure 12.)

Many teachers do not feel well prepared to teach the diversity of students in our nations's schools.

The 1993 Survey provided evidence that teachers do not feel well prepared to teach the diversity of students in our nation's schools. Overall, 94 percent of science and mathematics teachers reported feeling at least fairly well prepared to encourage the participation of females, and 85 percent to encourage the participation of minorities. Moreover, when asked about their preparation for teaching various types of students, most science and mathematics teachers (70 percent) reported feeling at least fairly well prepared to teach students from a variety of cultural backgrounds. In contrast, only 45 percent feel well prepared to teach students who have learning disabilities and only 29 percent feel well prepared to teach students who have limited English proficiency.

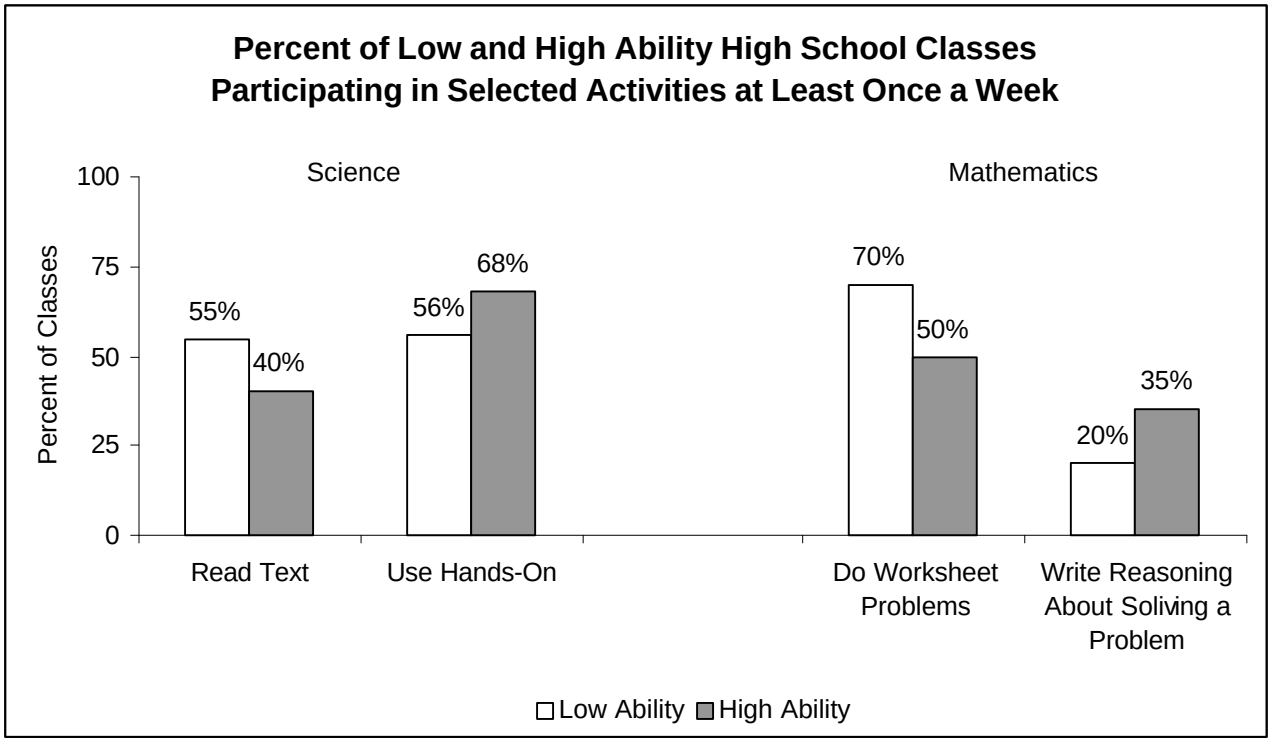

Figure 12

Classes with large proportions of minority students are less likely to have access to well qualified teachers and other important resources.

There is also considerable evidence that classes with high percentages of minority students do not have access to the same resources as other classes. For example, while secondary science classes with various proportions of minority students are equally likely to have teachers with majors in science or science education, high minority mathematics classes are less likely than others to have teachers with majors in field. (See Figure 13.)

Moreover, as can be seen in Figure 14, teachers in classes with high proportions of minority students are more likely than others to emphasize preparing students for standardized tests (which tend to focus primarily on low level skills), and less likely than others to aim towards preparing students for further study in these fields, suggesting unequal opportunities for students to learn challenging science and mathematics content.

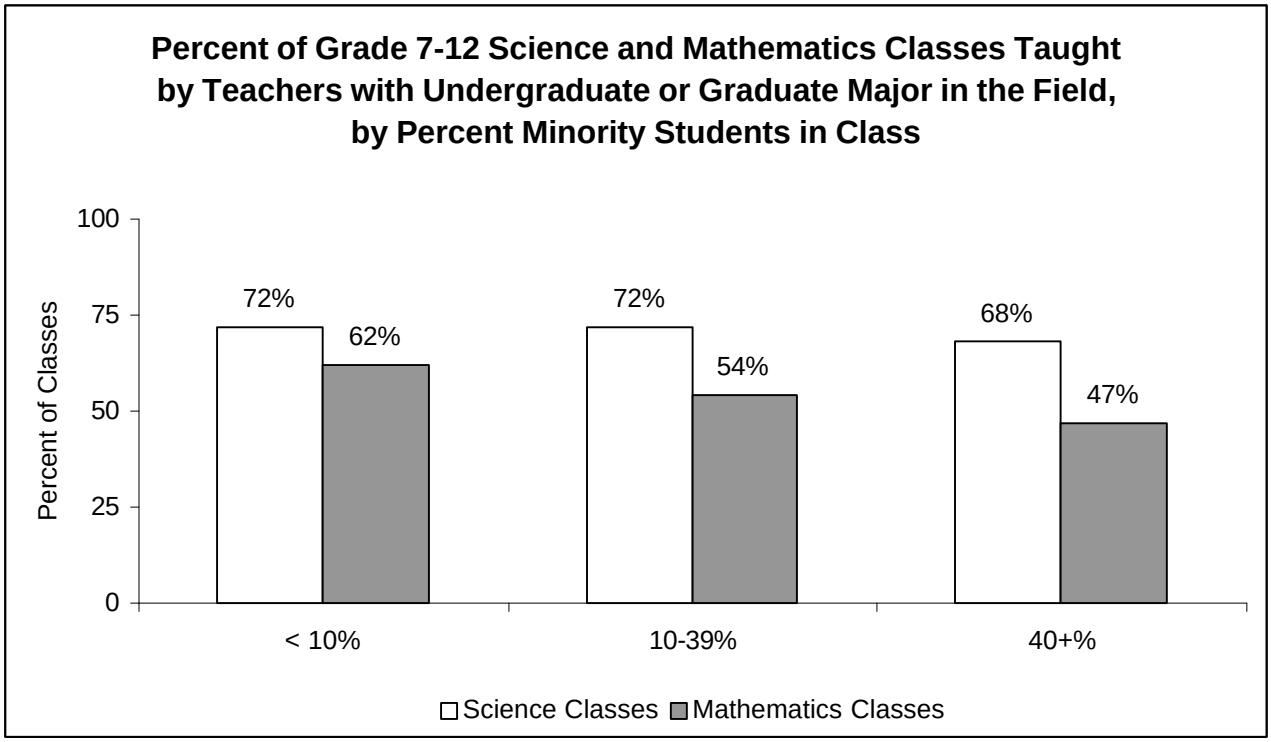

Figure 13

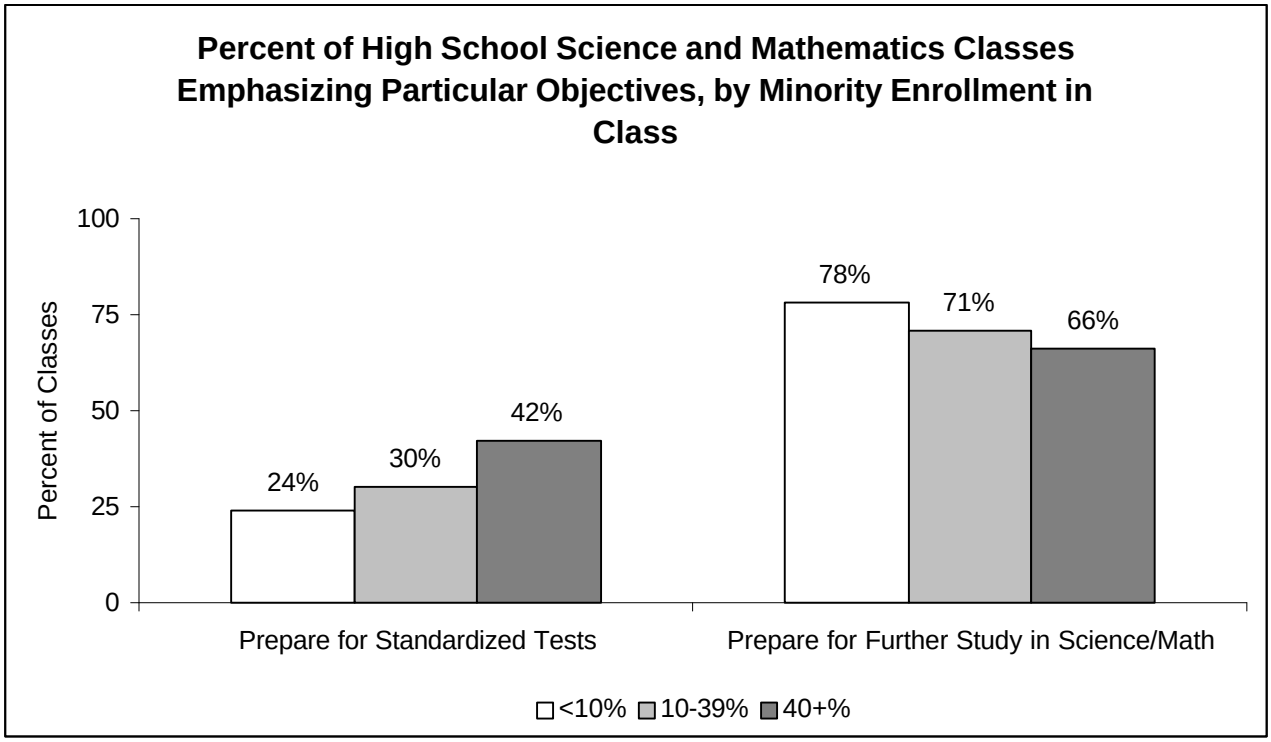

Figure 14

Approximately, one in three students enrolled in review mathematics, but only one in ten enrolled in physics or advanced mathematics, is a minority.

Whatever the reasons, many students who have completed the science and mathematics courses required for high school graduation elect not to take additional courses in these fields. As can be seen in Figure 15, non-Asian minority students are particularly likely to "drop out" of science and mathematics coursetaking. For example, 20 percent of the high school biology enrollment, but only 10 percent of the high school physics enrollment is comprised of members of non-Asian minority groups. Similarly, 34 percent of the students in review mathematics classes, but only 8 percent of those in Algebra II and more advanced mathematics classes, are members of minority groups other than Asian American.

Finally, the percent of science and mathematics teachers who are themselves members of minority groups is very low—only about 11 percent in the elementary/middle grades and 7 percent at the high school level at a time when roughly 30 percent of students are minorities.

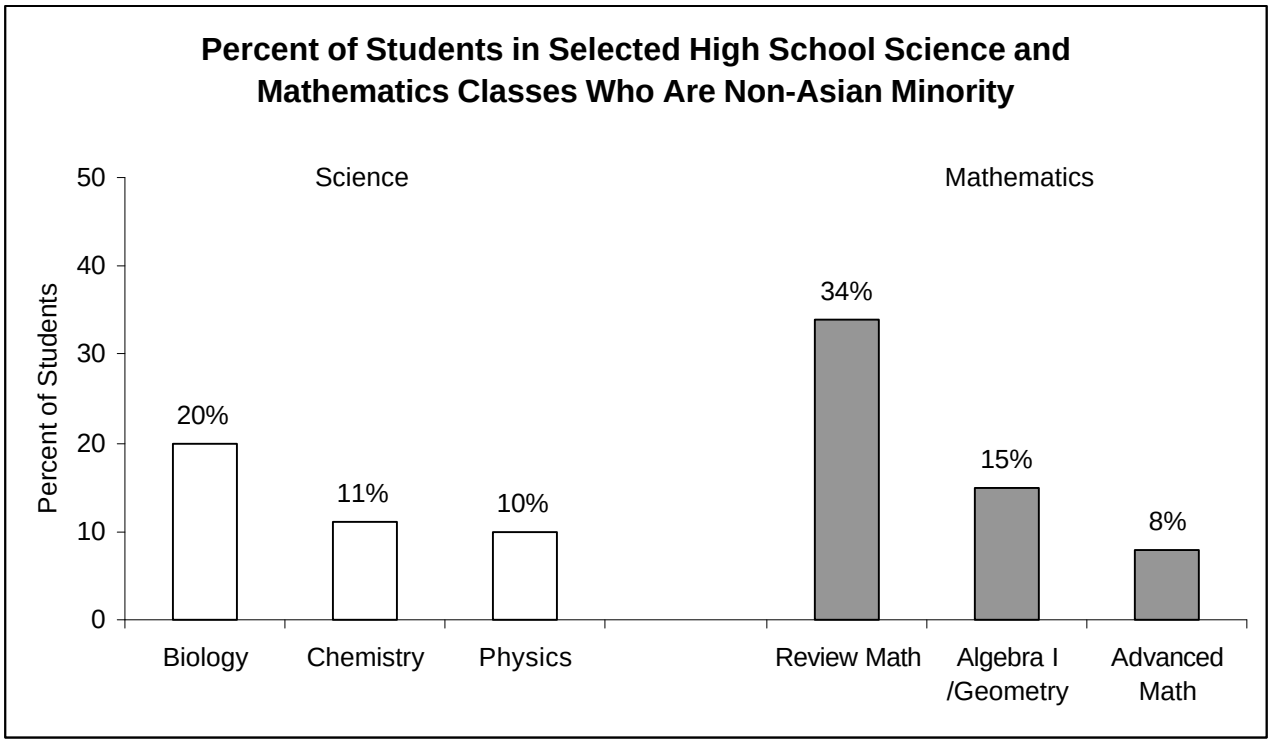

Figure 15

Conclusion

The results of the 1993 National Survey of Science and Mathematics Education indicate quite different patterns of strengths and weaknesses at different levels of schooling. While elementary teachers tend to be confident in their ability to use reform-oriented strategies such as cooperative learning, even those who have had the minimum recommended college coursework in science and mathematics do not feel confident in their ability to teach a number of elementary science and mathematics content areas. In contrast, high school teachers are more likely to have extensive preparation in their subjects, but are less supportive of the use of reform-oriented instructional techniques, less confident of their ability to do so, and less likely to use them in their classes.

Most science and mathematics teachers feel supported by their colleagues to try out new ideas, and indicate that they regularly share ideas and materials with other teachers. But schools are not organized in ways that facilitate collaboration among teachers; few teachers have time during the regular school week to work with their colleagues on science and mathematics curriculum and instruction, and even fewer have opportunities to observe each other teaching.

One of the areas of science and mathematics education that has become increasingly aligned with national standards is the use of hands-on/manipulative activities, especially in elementary mathematics. However, the 1993 National Survey of Science and Mathematics Education found that there continue to be many barriers to the use of these techniques, including inadequate laboratory facilities and science equipment, lack of computers and appropriate software, and lack of money to purchase consumable science and mathematics supplies.

There is also considerable evidence that the goal of quality education for *all* students has not yet been achieved. While there has been a decrease in the use of tracking since the mid-1980s, classes with large numbers of minority students are less likely to have access to well-qualified teachers and other resources. In addition, many science and mathematics teachers noted their lack of preparation for teaching students with learning disabilities and those with limited English proficiency.

Bibliography

American Association for the Advancement of Science. *Benchmarks for Science Literacy: Project 2061*. New York, NY: Oxford University Press, 1993.

American Association for the Advancement of Science. *Science for All Americans: A Project 2061 Report on Literacy Goals in Science, Mathematics, and Technology*. Washington, DC: American Association for the Advancement of Science, 1989.

Madaus, G.F., West, M.M., Harmon, M.C., Lomax, R.G., and Viator, K.A. *The Impact of Mandated Standardized Testing on Minority Students*. Chestnut Hill, MA: Center for the Study of Testing, Evaluation, and Educational Policy, Boston College, 1992.

National Council of Teachers of Mathematics. *Curriculum and Evaluation Standards for School Mathematics*. Reston, VA: National Council of Teachers of Mathematics, 1989.

National Council of Teachers of Mathematics. *Professional Standards for Teaching Mathematics*. Reston, VA: National Council of Teachers of Mathematics, 1991.

National Research Council. "National Science Education Standards: Progress Report." Washington, DC: National Research Council, 1993.

National Research Council. "National Science Education Standards: Discussion Summary." Washington, DC: National Research Council, 1994.

National Research Council. *National Science Education Standards*. Washington, DC: National Research Council, Draft, November 1994.

National Science Teachers Association. *Scope, Sequence and Coordination of Secondary School Science: The Content Core, A Guide for Curriculum Designers, Volume I*. Washington, DC: National Science Teachers Association, 1992.

Oakes, J., Ormseth, T., Bell, R., and Camp, P. *Multiplying Inequalities: The Effects of Race, Social Class, and Tracking on Opportunities to Learn Mathematics and Science*. Santa Monica, CA: RAND Corporation, 1990.

Weiss, I.R. *Report of the 1985–86 National Survey of Science and Mathematics Education*. Research Triangle Park, NC: Research Triangle Institute, 1987.

Description of Data Collection Procedures

The 1993 National Survey of Science and Mathematics Education was designed so that national estimates of teacher preparation, course offerings and enrollments, and classroom practices could be made from the sample data. The sample design also ensured that comparisons could be made with results of two earlier surveys of science and mathematics education, conducted in 1977 and 1985–86.

Considerable effort went into achieving as high a response rate as possible. First, the study requested and received endorsements from the American Federation of Teachers, the National Catholic Education Association, the National Council of Teachers of Mathematics, the National Education Association, and the National Science Teachers Association. Second, a description of the study design and drafts of the survey questionnaires were submitted to the Education Information Advisory Committee of the Council of Chief State School Officers. Following a favorable review by this committee, contacts were made with the responsible authorities at each level of the educational system, and any concerns were resolved before proceeding to the next level: the Chief State School Officer in each state, the district superintendent (or head of the Diocese for Catholic schools), and the principal of each school included in the sample.

Principals were asked to provide demographic information about the students in the school; the names of the science and mathematics department heads or other individuals who would be able to provide information about the science and mathematics program in the school; and a list of all teachers responsible for teaching science and/or mathematics to one or more classes. The response rate at the school level was 89 percent. The teacher lists were used to select a national probability sample of science and mathematics teachers to be asked to provide information about their background, pedagogical beliefs, and instruction in a single, randomly selected class.

An incentive system was developed to encourage school and teacher participation in the survey. Each school was given a credit of $25 towards the purchase of science and mathematics education materials; the amount was augmented by $10 for each responding teacher. At the completion of the data collection phase, schools were sent vouchers that they could use for purchasing NCTM publications, calculators, science activity books, kits, etc. from a catalogue developed for this study. Postcard reminders, phone calls, and additional mailings of survey materials were also used to encourage non-respondents to complete the questionnaires; the final questionnaire response rates were 88 percent for school program representatives and 84 percent for science and mathematics teachers.

Completed questionnaires were edited manually to identify missing or inconsistent information, and respondents were re-contacted to resolve problems with the items considered most essential. Codes were then created for open-ended items and the data were keyed, verified, and run through a machine edit to check for out-of-range responses and adherence to skip patterns. The final step in file preparation was the addition of weights to the file, calculated as the inverse of the probability of selecting the individual into the sample multiplied by a non-response adjustment factor designed to reduce possible bias caused by differential non-response among subgroups of schools.

All results presented in this report are population estimates, computed using weighted data. Detailed information about the sample design and a more complete presentation of the survey results are included in the Technical Report available from Horizon Research, Inc.