Achievement Test Scores in Mathematics and Science

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Summary. Average achievement test scores of the nation's youth in mathematics and science have declined rather steadily since the early 1960's, and this decline is more marked in the higher grades. The average test scores in mathematics and science of high school seniors who have intended to go to college and major in those fields, however, have been quite stable. These findings may have implications for educational policy.

Between 1973 and 1977, the national media periodically reported on the declining average achievement test scores of U.S. students. This publicity stimulated public concern and probably helped contribute to the adoption by some states of "competency examinations" for high school seniors. Since 1977, national media attention has waned, but test scores have continued to decline. In this article, I summarize evidence of changes in achievement test scores from records of national testing and assessment programs and compare differential rates of change in mathematics and science with other fields.

College Admissions Tests

The Scholastic Aptitude Test (SAT). The SAT, designed by the Educational Testing Service, has been offered by the College Entrance Examination Board since 1948. The SAT scores are widely used for college admission decisions. Although called an aptitude test, the SAT assesses verbal (SAT-V) and mathematical (SAT-M) achievement. The two parts are administered separately, and separate scores are presented, each on a scale of 200 to 800. The scales were established on the basis of the performance of nearly 11,000 students who took the SAT in April 1941; a mean score of 500 and a standard deviation of 100 were set for that group. Successive editions and alternate forms of each part of the test are equated by including in every new form some questions from earlier forms; raw scores are then scaled according to performance on these questions.

The verbal portion, designed to assess reading skills and understanding of word relations, covers antonyms, analogies, sentence completion, and reading comprehension. The mathematical portion, based on mathematics typically taught in grades 1 through 9, includes problems in arithmetic reasoning, elementary algebra, and elementary geometry. All items on each test are presented in a multiple-choice format.

The SAT, given in the 11th and 12th grades, has been taken by more than 1.4 million students annually in recent years. About one-third of the nation's high school seniors take the test. Mean SAT-V and SAT-M scores, averaged over 2-year periods from 1952 to 1980 (Fig. 1) show a steady and appreciable decline from 1962–1964 to the present. The decline in scaled scores appears somewhat greater for SAT-V than for SAT-M, but differential drift in the scale may account for this apparent difference.

The question naturally arises whether this apparent decline in SAT scores is the result of changes in content or in the scoring scale of the SAT. Although changes in item content are considered to have at most a minor effect, there is evidence that the equating of test forms, over the years, has not been totally successful. When 1963, 1966, and 1973 test editions were administered to more than 3000 high school students in 1973, an upward drift in the scaling on the scores was detected; the mean scores of these same students were higher on the 1973 tests than on the earlier editions, and the differences were greater on the SAT-M than on the SAT-V. Thus, under constant scale conditions, the decline in mean scores, at least for 1963 to 1973, would have exceeded the reported declines, probably by a larger margin for SAT-M than for SAT-V (*1*).

An important study designed to aid in understanding the decline in mean SAT-V scores is that of Beaton, Hilton, and Schrader (*2*). They used scores on two reading comprehension tests, one given to about 20,000 high school seniors in 1960 in Project Talent, the other to about 17,000 high school seniors in 1972 in the National Longitudinal Study (NLS). To equate the scores on these two tests, both were given in 1976 to a sample of about 1700 high school seniors selected to be representative of all seniors. It was then possible to compare the 1960 test scores with those from 1972, and comparisons were made separately of scores of all high school seniors, of those seniors who took the SAT, and of those who later entered a 2-year or 4-year college. The results suggest that the decline in mean SAT-V scores between 1960 and 1972 is related to a corresponding decline in reading comprehension.

The average reading comprehension score for high school seniors declined about 16 percent of one standard deviation between 1960 and 1972 (*2*). Had those who took the SAT's been random samples from high school classes, then the expected corresponding decline in average SAT-V scores would have been about 16 points on the SAT score scale. It should be noted that from 1960 to 1972 the number of high school graduates as a proportion of students who 8 years earlier had entered the fifth grade increased from 62 to 75 percent (*3*). The decline in the drop-out rate of students between 1960 and 1972 might help explain the decline in average reading skill, if a higher rate of dropout is assumed for poor readers.

Of even greater importance in accounting for the drop in mean SAT-V scores, was the change between 1960 and 1972 in the population taking the tests. In 1972, a larger proportion of high school seniors took SAT's than in 1960, with a higher representation of students below the top quartile in grade-point average, and presumably a greater number of relatively poor readers.

The study by Beaton *et al.* (*2*) also presents provocative results on the change in the mean reading scores be-

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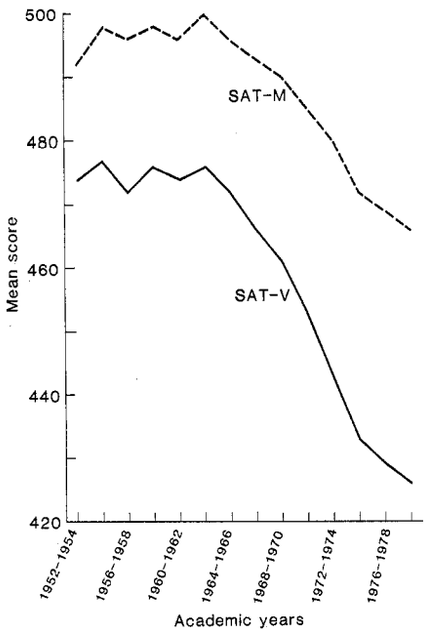

Fig. 1. The SAT scaled mean scores from 1952 to 1980. [Data from 1952 through 1977 are from the College Entrance Examination Board (*6*), and mean scores for 1978 through 1980 are from Marco (*18*)]

tween 1960 (Project Talent) and 1972 (NLS) of high school seniors who planned to go to college and major in science or mathematics (Fig. 2). The percentage of these seniors declined between 1960 and 1972 from 8.6 percent to 7.0 percent, but the average reading comprehension scores of this group increased 0.3 score units on the equated reading comprehension tests, an increase that contrasts sharply with an average decline of 0.8 score units for all high school seniors. Also, mean SAT scores of high school seniors who planned to enter college and major in science or mathematics were slightly higher in 1972 among NLS students than in 1960 among Project Talent students: 503 and 499, respectively, for SAT-V and 560 and 544 for SAT-M. [In the 1979–1980 school year, the mean SAT scores for all high school seniors intending to go to college and major in science or mathematics were 475 for SAT-V and 535 for SAT-M; mean scores for all high school seniors were 424 for SAT-V and 466 for SAT-M (*4*).]

It is of incidental interest to note that between 1960 and 1972 the mean reading scores of intended majors in "other fields" (Fig. 2), which include business administration, education, agriculture, nursing, home economics, journalism, and computer science, increased slightly. (Computer science was included with other fields rather than with the sciences because it appeared in the 1972 survey but not in the 1960 survey.) The greatest decline in reading comprehension scores was among students who indicated no intention to go to college, 50 percent of seniors in 1972 and 44 percent in 1960.

When declines in mean SAT scores are being considered, changes at the extremes of the score distribution are of special interest. From 1966–1967 to 1974–1975, the proportion of SAT-V scores above 700 declined 52 percent, and the proportion of SAT-M scores above 700 declined 15 percent. Proportions of scores below 300 increased 30 percent for SAT-V and 38 percent for SAT-M (*5*).

The greater part of the decline in SAT-V mean scores up to 1972 may be attributed to changes in the population of SAT test-takers, but the same cannot be said of the further substantial decline after 1972. The Advisory Panel on the SAT Score Decline (*6*) concluded that as much as three-fourths of the decline between 1963 and 1970 could be attributed to "compositional" changes in the group of students taking the test, but no more than one-fourth of the decline since 1970 could be attributed to that factor, since the composition of the SAT-taking population has been more stable since 1970. Other factors deemed important by the panel include: (i) changes in school curricula, especially a reduction in numbers of required courses; (ii) less attention to mastery of skills and knowledge in the learning process, in the schools, the home, and society; (iii) the impact of television in encouraging children to learn more by viewing and listening rather than by actively participating; (iv) changes in family structure, such as the increasing percentage of children in single-parent families; (v) disruption in the life of the country during the time when the high school students of the early 1970's were getting ready for their college entrance examinations; and (vi) diminution in young people's motivation for learning.

It should be pointed out that the number of 18-year-olds in the nation increased more than 50 percent between 1960 and 1972, to nearly 4 million. This increase was appreciably greater than the increase in the total population. The sheer numbers of young people leaving high school together and the perceptions of limited opportunities for assimilation into society might be viewed as factors that had an impact on both motivation and achievement and thereby contributed to lower average SAT scores.

The Preliminary Scholastic Aptitude Test (PSAT). This test, which is a short version of an earlier-used edition of the

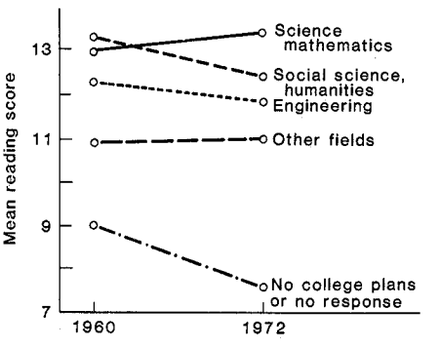

Fig. 2. Mean reading comprehension scores of high school seniors in 1960 (Project Talent) and 1972 (NLS) by intended college major (*2*).

SAT, is given by local school districts, primarily to high school juniors. Analysis of trends in mean PSAT scores is complicated by likely changes in the composition of the test-takers, particularly since 1971, when the PSAT began to be used for National Merit Scholarship competition. At that time, the number of schools that gave the test increased while the number of examinees per school decreased, suggesting that a more select group of students was taking the test. A study of national mean PSAT scores for the period 1959 to 1974 shows no consistent pattern of change but concludes that declines in PSAT scores would have been similar to those of the SAT scores were it not for scale drift and changes in the composition of PSAT test-takers (*5*).

The American College Testing Program. The second most widely used college admissions tests, taken by about 900,000 students a year, are those of this program, which has separate tests in English, mathematics, natural sciences, and social sciences. Summary data of annual results from these tests between 1965–1966 and 1973–1974 show the decline in mean scores to be roughly comparable to the decline in mean SAT scores (*5*). One exception is the mean scores on the natural science test, which are stable over that decade.

Other Assessment Programs

The Iowa Tests of Educational Development. These tests, developed by the Iowa Testing Programs of the University of Iowa and first used in 1942, are given by many school systems throughout the country to assess achievement of high school students in seven areas. Most high school students in Iowa take them, and mean scores for these students are available for the period 1962 to 1977 (*7*). From the mid-1960's to 1977, mean

scores in quantitative thinking and natural science declined steadily for Iowa students in each high school grade, 9 through 12.

The Iowa Tests of Basic Skills. These tests, also developed by the Iowa Testing Programs, assess achievement in the elementary grades and are widely used nationally. Between 1965 and 1977, mean scores of students from Iowa on mathematical concepts and mathematical problems (*8*) showed a steady decline at the higher grades, although very little in 1975, 1976, and 1977. Mean scores on both tests changed little at grades 3 and 4 between 1965 and 1977.

The National Assessment of Educational Progress (NAEP). Administered by the Education Commission of the States, with federal funding since 1969, the NAEP is intended to assess changes in achievement of the nation's youth in various areas of learning. Exercises in science, as in other subjects, represent objectives of science teaching, as agreed upon by panels of scholars, educators, and citizens. A booklet of exercises, requiring about 50 minutes to complete, was administered to each of about 2500 students at a given age, who constituted a national probability sample of that age group. Science exercises were distributed over about ten booklets, so that different samples of individuals answered different exercises. All exercises were presented on tape recordings as well as in writing to reduce the effects of reading disabilities and to ensure uniform time for responding.

Science exercises were given in 1969–1970, 1972–1973, and 1976–1977 to comparable samples of 9-, 13-, and 17-year-olds. Many of the same exercises were administered in 1969–1970 and 1972–1973, and many exercises were given both in 1972–1973 and 1976–1977, allowing comparisons of performance over time for each age group. The mean changes in the percentages of correct responses to the science exercises (Fig. 3) (*9*) indicate that, at each age, science achievement declined more during the first 3 years of the 1970's than during the next 4 years, and the decline is greatest among 17-year-olds and least among 9-year-olds. At all three ages, the decline in achievement is more marked in physical science than in biology (Figs. 4 and 5). Indeed, performance in biology increased among the 9-year-olds, and perhaps among the 13-year-olds.

The same methods used to assess achievement in science were applied to mathematics in 1972–1973 and 1977–1978. The average change in the percentage of correct responses to exercises

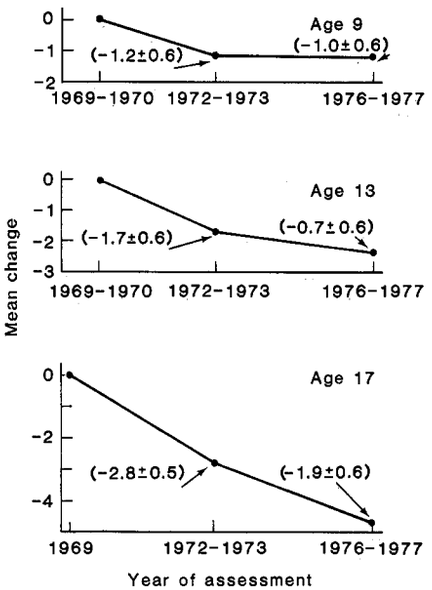

Fig. 3. Changes in the percentage of correct responses to NAEP science exercises at ages 9, 13, and 17 (*9*). Numbers in parentheses represent the mean change from one assessment year to the next ± the standard error of the mean change.

given in both years is shown in Table 1 (*10*). In overall performance, 9-year-olds show a negligible decline, 13-year-olds a 2 percent decrement, and 17-year-olds a 4 percent decrement. At ages 13 and 17, the performance decline is relatively uniform, but at age 9, a mean performance decline is seen in exercises designed to assess applications of mathematics, typically exercises involving word problems or story problems, but essentially no change is found in mathematical skills or knowledge.

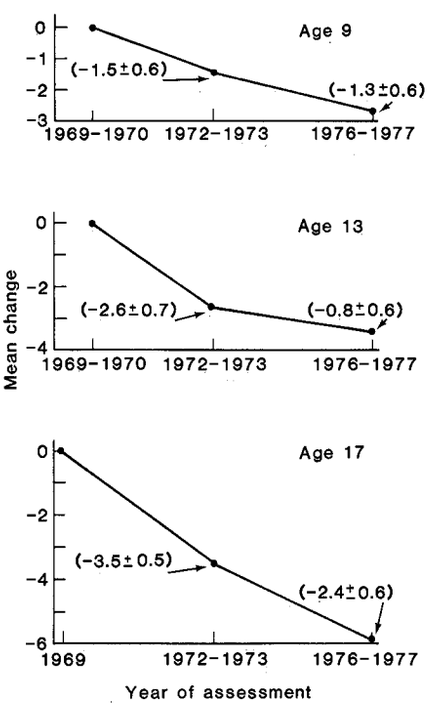

Fig. 4. Changes in the percentage of correct responses to NAEP physical science exercises at ages 9, 13, and 17. Numbers in parentheses represent the mean changes from one assessment year to the next ± the standard error.

It is of interest to compare the changes in performance on the science and mathematics exercises with NAEP results in reading, writing, and social studies for years in which the same exercises were given two or more times between 1969–1970 and 1979–1980 (*11*). For 9-year-olds, mean reading achievement improved slightly between 1970–1971 and 1974–1975 and more substantially by 1979–1980; mean performance in social studies improved slightly between 1971–1972 and 1975–1976, but writing achievement changed little. For 13-year-olds, reading achievement was unchanged to 1974 but improved slightly by 1979; performance in writing and social studies showed a small decline. For 17-year-olds, neither reading nor writing achievement showed appreciable change; in social studies, performance declines were more prominent than at the younger ages. Generally, the decline in mathematics and science performance during the 1970's appears to be slightly greater than that reported by NAEP in social studies and is considerably more pronounced than the decline in reading or writing.

Advanced placement tests. The College Entrance Examinations Board has offered advanced placement examinations in various academic subjects since 1955. The scores are used by colleges in placing or sectioning students, particularly in the freshman year. In science and mathematics, seven distinct tests are offered: biology, calculus AB (elementary), calculus BC (more advanced), chemistry, physics B (without a calculus requirement), physics C (mechanics), and physics C (electricity and magnetism). Since most students who take these tests probably intend to major in science or mathematics, it is of special interest to look at both the number of students who took the tests and the pattern of changes in average test scores in recent years. The total number of advanced placement tests taken more than doubled from about 24,300 in 1969 to 49,600 in 1979 (*12*). The increase is evident for each test and is especially prominent since 1973, when about 26,000 tests were administered.

The grades for advanced placement tests are reported on an integer scale from 1 (low) to 5 (high) and represent a composite of results from a multiple-

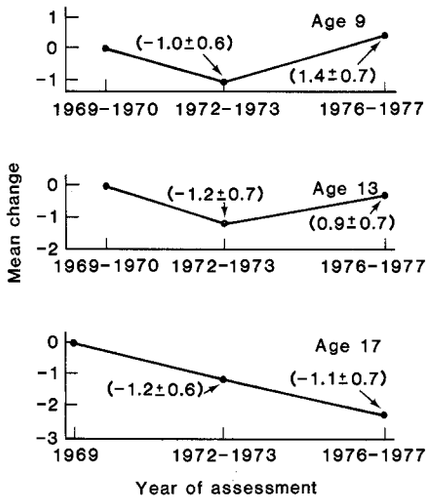

Fig. 5. Changes in the percentage of correct responses to NAEP biology exercises at ages 9, 13, and 17. Numbers in parentheses represent mean changes from one assessment year to the next ± the standard error.

choice portion of the test and a subjectively scored essay portion. From 1969 to 1972, efforts were made to equate the composite scores from year to year so that the reported grades would be approximately comparable. From 1973 to 1979, only the multiple-choice scores were equated, on a scale from 20 to 80, with an initial mean of 50 and a standard deviation of 10.

Without exception, the mean reported grades in science and mathematics increased from 1969 to 1979. The mean scaled scores from 1973 to 1979 increased slightly for calculus AB, calculus BC, and physics C (electricity and magnetism); decreased slightly for biology, physics B, and physics C (mechanics); and first increased and then decreased for chemistry, with the same value in 1979 as in 1973. These results show that, even with the increasing numbers of test-takers, the high school students who took advanced placement tests in science or mathematics in 1979 performed about the same as those who had taken the tests 6 years earlier.

A Summary of the Evidence

Enrollment patterns. Between 1960–1961 and 1976–1977, the proportion of public high school students (grades 9 to 12) enrolled in science courses declined from 60 to 48 percent (*13*), and enrollments in high school mathematics courses also declined (*5, 14*). In the elementary grades, a 1977 national survey conducted for the National Science Foundation (NSF) (*15*) found that instruction in science was limited to an average of less than 20 minutes a day for children in kindergarten through grade 3, and to an average of about 30 minutes a day in grades 4 to 6 (Fig. 6).

Although changes in enrollment in science and mathematics classes would be expected to influence general levels of student achievement in these subjects, the NSF report (*15*) suggests that the qualifications of science and mathematics teachers, the content of the curriculum, and the climate for learning in the schools may be even more important factors in accounting for changes in achievement.

Declining achievement. The cited evidence of changes in mathematics and science achievement may be summarized as follows.

1) Nationally, mean SAT scores have shown a monotonic decline since 1962–1964. However, a comparison of scores of high school seniors intending to select a college major of science or mathematics from 1960, 1972, and 1980 shows little change in mean SAT-V and SAT-M scores from 1960 to 1972 but a modest decline in both by 1980.

2) For college-bound students who took the American College tests, the mean scores on the natural science part were quite stable from 1964–1965 to 1973–1974. For the same group, the mean score on the mathematics test was lower in 1973–1974 than in any year in the preceding decade.

3) For high school students in Iowa who took the Iowa Tests of Educational Development, mean scores on quantitative thinking declined from the mid-1960's to 1977; the decline was greatest for grade 12 and less in the lower grades. For the same high school students, mean scores on the natural science test declined from the mid-1960's to 1977 in all four high school grades.

4) For grade school students in Iowa who took the Iowa Tests of Basic Skills between 1965 and 1975, mean scores on mathematical concepts and on mathematical problems declined sharply at the higher grades, less at grade 4, and not at all at grade 3. From 1975 to 1977, mean scores on both tests were relatively unchanged for grades 3 through 8.

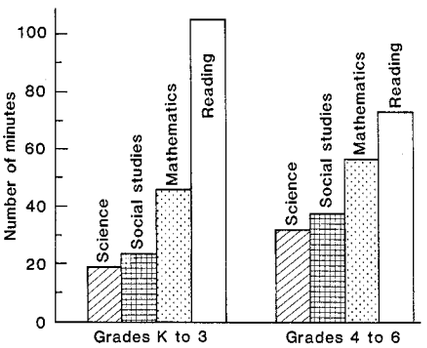

Fig. 6. Average number of minutes a day spent by teachers on science, social studies, mathematics, and reading in kindergarten (*K*) through grade 3 and in grades 4 to 6.

5) For national samples from the National Assessment of Educational Progress, mean performance declines were seen during the 1970's on mathematics and science achievement exercises. There were exceptions: the performance of 9-year-olds in mathematics was stable, and on the biology exercises, the mean performance of 9- and 13-year-olds increased between 1973 and 1977 to about that of 1969.

6) Mean grades increased between 1969 and 1979 on all College Entrance Examination Board advanced placement tests in science and mathematics as did the number of students who took each test. However, the equated mean scores, based on the multiple-choice portions of these tests, show neither a systematic increase nor decrease between 1973 and 1979. This evidence suggests little average change in science or mathematics achievement during recent years for the high school students who took these tests, many of whom expected to major in science or mathematics in college.

7) Some evidence suggests that high

Table 1. Five-year mean changes in percentage of correct responses to NAEP mathematics exercises (the mean correct responses in 1977–1978 minus the mean correct in 1972–1973 on those exercises given in both school years). [Data from (*10*)]

Exercise	Age 9		Age 13		Age 17	
	N	Change (%)	*N*	Change (%)	*N*	Change (%)
Mathematics knowledge*	17	−1	15	−2†	16	−2†
Mathematics skills	21	0	37	−2†	46	−5†
Mathematics understanding‡			12	−2	13	−4
Mathematics applications	9	−6†	12	−3†	25	−4†
All mathematics items	55	−1	77	−2†	102	−4†

*Items assessing knowledge of the metric system, one at age 13 and two at age 17, are excluded; the mean change without removal of these items is 0 at both ages. †Change is statistically significant at the .05 significance level. ‡Results not reported at age 9 because of the small number of exercises (*N*).

school courses in mathematics and physical science attracted smaller percentages of students in the mid-1970's in comparison with the early 1960's.

The general picture is one of a modest decline in average science and mathematics achievement for the nation's youth from the mid-1960's to the late 1970's with exceptions among 9-year-olds and high school seniors who plan to attend college and major in science or mathematics. Thus, during a time when science and technology have had an increasing impact on the lives of the nation's citizens, the average mathematics and science achievement of all high school students has declined.

Implications for Policy

The NSF asked a number of organizations to review and interpret findings from the NSF reports on science, mathematics, and social studies educational practices in the secondary schools (*15*). Several organizations responded with specific recommendations (*16*).

The American Association for the Advancement of Science (AAAS) noted that many problems of education in science and mathematics—lack of student motivation, lack of discipline, assignment of teachers to subjects for which they are ill-prepared, or financial constraints—are common to education in other subjects as well. The AAAS recommended that a national commission be established to examine the goals and purposes of pre-college education and that major research efforts be undertaken in areas relating to school learning (*16*, p. 75).

The National Research Council (NRC) of the National Academy of Sciences offered six recommendations (*16*, pp. 103–115): (i) the establishment of science and mathematics teaching resource centers to provide teacher training, to distribute science instruction kits, and to offer expert advice on the teaching of science and mathematics; (ii) an increase in funding for NSF programs to design, test, and revise science and mathematics courses; (iii) support of an NSF program of institutes for teachers of science and mathematics; (iv) development of additional community science and technology centers; (v) special efforts to provide greater opportunities for women and minority group members to become interested in and prepare for careers in science and technology; and (vi) vigorous efforts to combat an overemphasis on standardized achievement tests, which generally assess "minimum competency" and may create a climate in which less attention is given to more capable students, and the creation of banks of test items in the major subjects that cover a wide range of skills and knowledge, and that are openly available to teachers, parents, and children. Concerns about the effects of competency testing were also raised by the National Congress of Parents and Teachers: "Another problem, with an overemphasis on basics, is a tendency to teach children only those things for which they will be tested, a tendency that leads to mediocrity" (*16*, p. 187). The NRC reviewers conclude that the leadership in this effort "must come from scientists and scientific organizations, since it is quite unlikely to come from . . . within the educational system" (*16*, p. 115).

Not only must a quality education in science and mathematics be extended to more high school students, but also a better introduction to the methods of science in the elementary schools must be effected to ensure a continuing flow of talented youth into careers in engineering, mathematics, and science, and to enhance the understanding of science by the people of this country. By the end of the 1970's, only high school students who were already attracted to careers in mathematics and science, or had at least elected a college major in these areas, performed on science and mathematics achievement tests as well as similar students early in the decade. For the bulk of students of high school age, knowledge and skills in science and mathematics clearly have declined. Science may well be the subject "best adapted to help younger children develop critical thinking abilities, positive attitudes toward their environment, and an understanding of the world they live in" (*17*). If this is so, then additional classroom time should be devoted to science in elementary schools, with relatively less emphasis on reading or listening and more on doing. Also, the science content of materials used in reading instruction could be increased to expose young children to the methods of science. As Hausman has stated, "The basic processes used in science—observing, describing, comparing, classifying, measuring, using numbers, interpreting evidence, inferring, predicting, experimenting—are such fundamental skills that they should be developed during the formative years in an activity-based science program" (*17*, p. 44).

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