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ABSTRACT

The Second International IEA Science Study (SISS) had participants from 24 countries. In this report the data collected in 17 countries are analyzed and reported. Students from the 5th, 9th, and 12th grades were tested. The results from achievement tests, student questionnaires, opinionnaires, a science teaching and learning inventory, a word knowledge test, a mathematics test, and science process laboratory tests were analyzed. In addition, teachers were asked to indicate the extent to which their students had an opportunity to learn the concepts tested by each question, and these opportunities to learn (OTL) results are given in this report. There also are summaries of the responses to a short teacher questionnaire and a school questionnaire completed by a principal or some other person who could provide data about the school. Countries include Australia, Canada, England, Finland, Hong Kong, Hungary, Italy, Japan, Korea, Netherlands, Norway, Philippines, Poland, Singapore, Sweden, Thailand, and the United States. Chapters include: (1) "Introduction"; (2) "How the Study Was Conducted"; (3) "Science Achievement in the Fifth Grade"; (4) "Science Achievement in the Ninth Grade"; (5) "Achievement in Biology"; (6) "Achievement in Chemistry"; (7) "Achievement in Physics"; (8) "Science Achievement in the 1970s and 1980s"; (9) "Sex and Science Achievement"; (10) "Science Process Laboratory Skills"; (11) "The Influences of School and Home"; (12) "Teachers and Teaching"; (13) "Teaching and Learning of Science"; (14) "The Opportunity to Learn"; (15) "Student Attitudes Toward Science and School"; and (16) "Toward a Better Science Education." (KR)

SCIENCE ACHIEVEMENT IN THE UNITED STATES AND SIXTEEN COUNTRIES

A REPORT TO THE PUBLIC

BY

WILLIARD J. JACOBSON

AND

RODNEY L. DORAN

The International Association for the Evaluation of Educational Achievement (IEA)

USA

Second IEA Science Study
(SISS)
UNITED STATES

IEA

TEACHERS COLLEGE, COLUMBIA UNIVERSITY

SCIENCE ACHIEVEMENT IN THE UNITED STATES AND SIXTEEN COUNTRIES

A REPORT TO THE PUBLIC

BY

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SECOND INTERNATIONAL SCIENCE STUDY
TEACHERS COLLEGE, COLUMBIA UNIVERSITY
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Our Department. There were advantages to being located in The Department of Mathematics and Science Education. When problems arose, there often were people "in the Department" who could give us a helping hand.

Research Associates. The research associates, who are listed elsewhere, could be irritatingly critical, but we were the better for it. Their ideas and suggestions are spread throughout this monograph.

The National Committee. We had the advice of a distinguished National Committee. They helped us with technical problems and provided a broader perspective of the Study. They are listed elsewhere.

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Our Office Associates. Drena Elfrink-Hetzel did many things we had thought of, and, we suspect, many more things that she detected before we had a chance to think of them. A study such as this requires more skills than can be found in one person, and Gene Muller and Mark Rinkerman gave us access to complicated statistics and the ubiquitous computer. There always are a myriad of things to be done, and Arthur Schneider always found ways to do them.

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W.J.J.
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INTRODUCTION

This is a study of science education in the U.S. and 16 other countries.

This is a report of the Second IEA Science Study--U.S. It is a report on science in the schools of the United States and 16 other countries. In the United States and in other countries, testing was carried out mostly with students in the 5th grade, 9th grade, and 12th grade. A major feature of this Study is the international dimension which makes it possible for countries to learn from each other and to develop better science programs for their children and young people.*

Participating Countries**

Australia	Italy	Poland
Canada (Eng)	Japan	Singapore
England	Korea	Sweden
Finland	Netherlands	Thailand
Hong Kong	Norway	U.S.A.
Hungary	Philippines	

Who Can Use This Report?

-- Teachers can glean ideas that may help them improve their science courses and their teaching.

-- Science supervisors and science department chairs can examine their science programs and gain suggestions for improvement of science facilities, materials, and ways that science instruction can be organized.

-- Boards of Education and Superintendents of Schools can use the findings in this Report and ancillary monographs to raise questions about science programs and resources for science instruction in their schools and to help find ways to improve science programs.

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* A more extensive discussion of the international dimension is in: International Association for the Evaluation of Educational Achievement (IEA), Science Education in Seventeen Countries: A Preliminary Report, New York: Pergamon Press, 1988.

** These are the countries from which data were available in the spring of 1988.

- -- State and Federal Officials with responsibilities for the development and implementation of science education policy can get some indication about the status of science education in the U.S. and gain ideas from other countries that can be used to improve science education. The results of this Study can provide an empirical and international base for policymaking.

- -- Local, state, and federal legislators can use the findings of this study as they develop broad policies for education and, particularly, science education.

- -- Children and young people are the ultimate benefactors, and may experience better science programs in which they will learn more science.

What Does This Report Contain?

The Second IEA Science Study (SISS) was an international study in which 24 countries participated. In this report the data collected in 17 countries are analyzed and reported. Later, it is expected that the reports will be amended to include data from all countries that participated in the Study.

In the Second IEA Science Study, intact classes in three age groups or populations were tested*:

5th grade

9th grade

12th grade

In this Report, the results from achievement tests, student questionnaires, opinionnaires, a science teaching and learning inventory, a word knowledge test, a mathematics test, and science process laboratory tests are presented. In addition, teachers were asked to indicate the extent to which their students had had an opportunity to learn the concepts tested by each question, and these opportunities to learn (OTL) results are given in this Report. There also are summaries of the responses to a short teacher questionnaire and a school questionnaire completed by a principal or some other person who could provide data about the school.

Of special interest are findings related to such issues as the following:

How did the science achievement of U.S. students compare with the science achievement of students in other countries?

How did the science achievement of advanced science students who had studied a science for two or more years compare with advanced science students in selected other countries?

---

* In Australia, 10-, 14-, and 17-year-olds were tested.

To what extent was there growth in science achievement from Grade 5 through Grade 12?

How did science achievement in the 1980s compare with science achievement in the 1970s?

How did the science achievement of girls compare with that of boys?

What factors in the home, school, and community were associated with science achievement?

What approaches to teaching and learning were associated with science achievement?

International Association for the Evaluation of Educational Achievement (IEA). The First International Science Study (FISS). The first international science study was carried out in 1970-71 and involved 19 countries. The major report of this Study is Science Education in Nineteen Countries (Comber & Keeves, 1973). The following were among the major findings of the Study:

1. Home background was a good predictor of science achievement.

2. Boys did better in science than girls, especially in the physical sciences. Boys also showed a consistently more favorable attitude toward science.

3. In Grades 9 and 12 there was a relationship between the opportunity to learn and science achievement.

4. Countries that had a high percentage of an age group remaining in school had lower average science achievement.

5. The amount of growth in science achievement between 9th grade and 12th grade was less in countries where a high percentage of students was retained in schools.

6. In science, schools do make an important contribution to learning.

Summary. In 1983 (and in the United States in 1986), The Second International Science Study (SISS) was undertaken by 24 countries. The major results from U.S. participation in the Second International Science Study are reported in this volume.

About 221 thousand students in 9,808 schools in 17 countries took part in the Study.

Chapter II

HOW THE STUDY WAS CONDUCTED

Random samples of intact classes in stratified probability samples of schools were invited to take part in the Study. There was a mean school response rate of 85.3%.

A basic assumption in the Second International Science Study (SISS) was that countries could learn from each other and that, as a result of this international study, the science education of children and young people around the world could be improved. However, to achieve this, certain conditions had to be met:

-- The testing instruments used had to reflect elements of science curricula that are common to science curricula in the countries that participated in the Study.

-- The instruments had to be understandable to the students who took part.

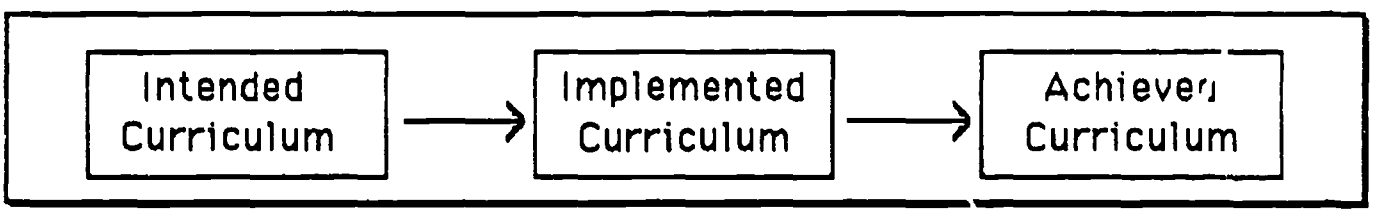
-- Descriptions of various aspects of science education in each of the countries were needed for the interpretation of results.

Instruments were developed that were deemed suitable for use in each of the participating countries.

-- The students involved in the Study should be representative of the total population of students.

In this chapter there are descriptions of how these conditions were met in the United States.

Science Curricula Studies.* The curricular analyses had three stages:



The "Intended Curriculum" consists of aims, objectives, coverage in textbooks and new science programs, syllabi and reference materials. State guidelines and science curricula research studies were examined. The intended curricula indicates what we plan to achieve in our science programs.

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* For a much more extensive description of the science curricula in the United States see Miller, J.K. 1986: An Analysis of Science Curricula in the United States. New York: Second IEA Science Study--U.S., Teachers College, Columbia University.

The "Implemented Curriculum" is the composite of content topics that are actually taught. It is the opportunity the students had to learn the concepts. In this Study, the implemented curriculum was largely the indication by the teachers as to whether students had had a chance to study the concepts related to the questions on the test instruments.

The "Achieved Curriculum" indicates what students have learned. In this Study the achieved curriculum is represented by the scores on the achievement tests.

In the investigations of the "Intended Curriculum" a roster of science curriculum concepts was developed. The concepts were rated by expert science educators in universities, state departments of education, and school systems. Among the findings were the following:

1. Coverage of science content and use of science-related skills in planned curricula increased with age of students.

2. The proportion of physics and chemistry content increased from elementary to high school.

3. Of the major sciences, chemistry received the least attention in the elementary school years.

4. There appeared to be considerable attention to environmental science in Grades Five and Nine. Apparently, in Grades Five and Nine, there was greater attention to environmental science than to the physical sciences.

5. There appeared to be about equal emphasis on learning subject matter and investigative skills.

6. Considerable attention is being devoted to technology and preparing students to live in a technological society.

The SISS science achievement tests were based on science curriculum case studies carried out in each of the countries.

Many factors may affect science achievement and an attempt was made to identify some of them in a science curricula case study (Miller, 1986). Such a case study was prepared in each country. The case study contains: descriptions of how education is organized and funded in each country, types of schools and examinations, aims and objectives of science education, approaches to curricula development, content of teacher education, examples of professional associations, types of laboratories, provisions for talented students, and arrangements for out-of-school science. The science curricula case study provided a framework within which the results of a country could be interpreted and some explanation for results could be found.

FIGURE 1

Common Patterns of Science Curricula in the U.S.A.

Age	I	II	Grade	
17	Physics I	Advanced Placement: Biology, Chemistry, Physics	12	- SECONDARY LEVEL -
16	Chemistry I	Physics I	11	
15	Biology I	Chemistry I	10	
14	Physical Science	Earth Science or Biology I	9	
13	Earth and Space	General or Integrated Science	8	
12	Life Science		7	
11	Elementary School Science		6	- ELEMENTARY LEVEL -
10			5	
9			4	
8			3	
7			2	
6			1	
5			K	

Optional Secondary Courses: Astronomy, Ecology, Environmental Science, Marine Biology, Oceanography, Genetics, Zoology, Physiology, Laboratory Techniques...

An important difference between science programs in the U.S. and in many other countries is the way science is studied and learned in the secondary school. In most European countries, sciences such as biology, chemistry, and physics are taught each year of the secondary school. In the United States, students study a different science each year. The usual pattern is to study biology in the 10th grade, chemistry in the 11th, and physics in the 12th. A few advanced science students study a science for two years. This pattern of studying a different science each year is sometimes called a "layer cake" approach by our European critics. The findings in this Study raise serious questions about the effectiveness of this usual way of organizing science instruction in the United States.

The instruments were field tested in the participating countries.

Field Testing of Items and Procedures.* Before the international instruments were assembled, items and procedures were field tested. The items were checked for difficulty. If 85% or more of the students answered the item correctly, it was considered too easy. If less than 35% answered it correctly, the item was considered too difficult. The items were also checked for discrimination, which is the extent to which an item discriminates between stronger and weaker students. The discrimination index was reported to the International Coordinator of the Study. The content validity was checked by science educators on the National Committee of the Study and members of the Department of Mathematics and Science Education at Teachers College, Columbia University.

The final instruments were agreed upon and assembled by the National Research Coordinator from each of the countries under the leadership of the International Research Coordinator.

The Instruments. The tests contained international items that were used in all countries. Each country also could include unique national items that were judged to be important in the country. Bridge items were items that also were used in the 1970 Study (FISS) which made it possible to compare scores on the same items in 1986 and 1970. An attempt was made to retain as many bridge items as possible. Anchor items were items used at more than one grade level. With the anchor items, it was possible to study growth in science achievement from one population to the next.

In addition to the achievement tests; students responded to a science learning questionnaire which solicited information about how the students were taught and studied science. They also responded to an opinionnaire asking for their opinions of science and school. A word knowledge test assessed high school student verbal ability. Upper secondary science students

* For a much more extensive description of the field trials see Clive, T.A., 1983: The Trial Testing of Items and Instruments for the Second IEA Science Study: An Analysis of Results to Verify the Cumulative Hierarchical Nature of Bloom's Taxonomy of Educational Objectives (Cognitive Domain) New York: Ed.D. dissertation, Teachers College, Columbia University, 1983.

responded to a mathematics test which contained mathematics items important in the study of science. For a listing of the instruments used in the United States, see Figure 2.

A feature of the testing in SISS (1986) was the Science Process Laboratory Skills tests. In these tests, students had to carry out observations and manipulations in order to answer the questions asked. For example, in one exercise, students found the mass and volume of a sinker and calculated its density.*

FIGURE 2

Student Instruments**
Second IEA Science Study
Phase II, 1986

GRADE	SESSION 1	SESSION 2
5	Achievement Test Background Questions	Process (Lab) Test
9	Achievement Test Background Questions	Process (Lab) Test
10 First Year Biology	Achievement Test	High School Science Booklet 2 Student Questionnaire Opinionnaire Word Knowledge Test** Mathematics Test***
11 First Year Chemistry	Achievement Test	
12 Advanced/ Second Year Science	Achievement Test (Biology, Chemistry, OR Physics)	

* For a further discussion of the Science Process Laboratory Skills Tests and results see Chapter VII.

** All tests and questionnaires were internationally developed and trial tested for validity with U.S. students.

*** Separate versions of these tests were developed to accommodate the different levels of expertise among these groups of students.

In addition to the instruments to which students responded, there were school and teacher questionnaires. With the school questionnaire, school principals or science department chairs provided data about the schools. Teachers responding to a questionnaire provided information about themselves.

The teachers also were asked to indicate whether all or most of the students in their class may have had the opportunity to learn the concepts tested by each question:

A during a previous year's science course

B during this year's science course

C in a future science course in this school

D not in any part of the science program at this school

E I don't know

Sampling. The eligible student universe was all students in the 50 states in public and private schools that included the specified grades. The sample design for the Second International Science Study (SISS) was characterized as a three-stage probability sample of public and private school students in Grades 5, 9, 10, 11, and 12. The first stage or primary sampling units were counties or groups of counties. The secondary sampling units were schools within sampled counties, and the tertiary sampling units were intact classes within sampled schools. The basic unit selected was an intact class. Classes were selected with equal probability within sampled schools. Within the schools selected, if there was more than one eligible class, a random selection of one intact class was made.

The data collection was carried out in the spring of 1986. An attempt was made to have a sample of 125 intact classes of each population tested. The sampling and data collection were carried out by the Research Triangle Institute (RTI). There were two testing sessions, each about 40 minutes long.

Table 1 on the next page shows the number of schools and students that participated and the response rates in percent:

TAPLE 1

Students and Schools in U.S. Study

Grade	Number of Schools	Number of Eligible Students	Response Rate of Schools in Percent
5	123	3220	88.5
9	119	3117	87.5
Biology	118	3112	85.5
Chemistry	119	2804	86.9
Advanced Biology	43	785	91.5
Advanced Chemistry	40	656	88.9
Advanced Physics	35	580	87.5

A special feature of the Study was the selection and testing of advanced science students, i.e., high school students who had essentially completed a second year of biology, chemistry, or physics. It was of special interest to compare their scores with students in other countries who may have studied a science for two or three years.

In the U.S., over 14 thousand students in almost 600 schools took part in the Study.

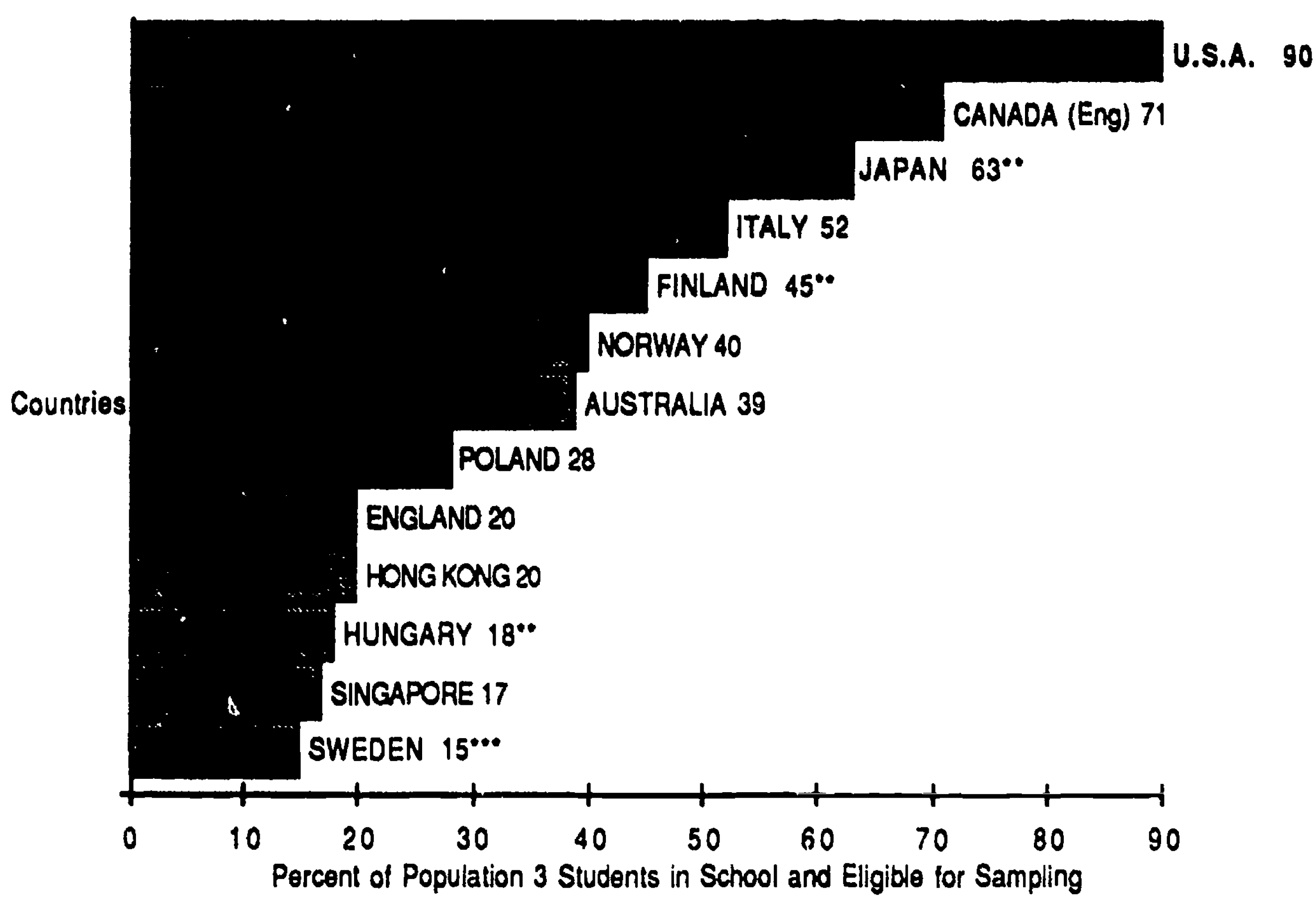
Populations eligible for sampling. In all 17 countries where data have been analyzed, about 99% of the Population 1 (Grade Five) age group was in school and eligible for sampling.

Except for the Philippines (60.7%) and Thailand (32%), in all countries 90% or more of the Population 2 (Grade Nine) age group was in school and eligible for sampling. Thus, the United States cannot claim to be unique with regard to enrollments in Grades Five and Nine or comparable age groups.

At the Population 3 level (the last year of secondary school), the United States, with 90% enrolled, had by far the largest percentage of the age group enrolled in school. England, Hong Kong, and Singapore, which did comparably well on the Population 3 science achievement tests, all had less than 20% of the population in school. Of this 20% of the population in school, perhaps about one-half specialized early in subjects other than science and mathematics. Since these students had little opportunity to study science and mathematics, it may be that 10% or less of the Population 3 age group in England, Hong Kong, and Singapore was studying advanced science.

FIGURE 3

Percent of Population 3* Students in School



(IEA, 1988, p. 14)

Data Collection. Professional test administrators were used. It was especially important to have this expertise for the administration of the Science Process Laboratory Skills Tests. The professional test administrators had been specially trained in the administration of the tests including the use of science equipment and materials. The answer sheets and process test booklets were returned to the Research Triangle Institute, where the data were processed and then sent to the National Research Center at Teachers College, Columbia University for analysis and interpretation.

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*Population 3 are students in the final year of secondary school.
**Students in vocational schools were not sampled.
***Students in nonscience, vocational, and general tracks were not sampled.

Summary. The results that are discussed in this book are based upon the sampling and data collection that have been carried out in intact classes in a representative sample of schools. As you read this book, you may wish to pause occasionally to think of the more than 14 thousand students in the U.S. and 221 thousand around the world who took part in this Study. Also give a thought for the 600 teachers in the U.S. and about 10 thousand teachers in all 17 countries that made the Study possible. It is our hope that the efforts of all countries will make possible better science education for children and young people around the world.

Chapter III

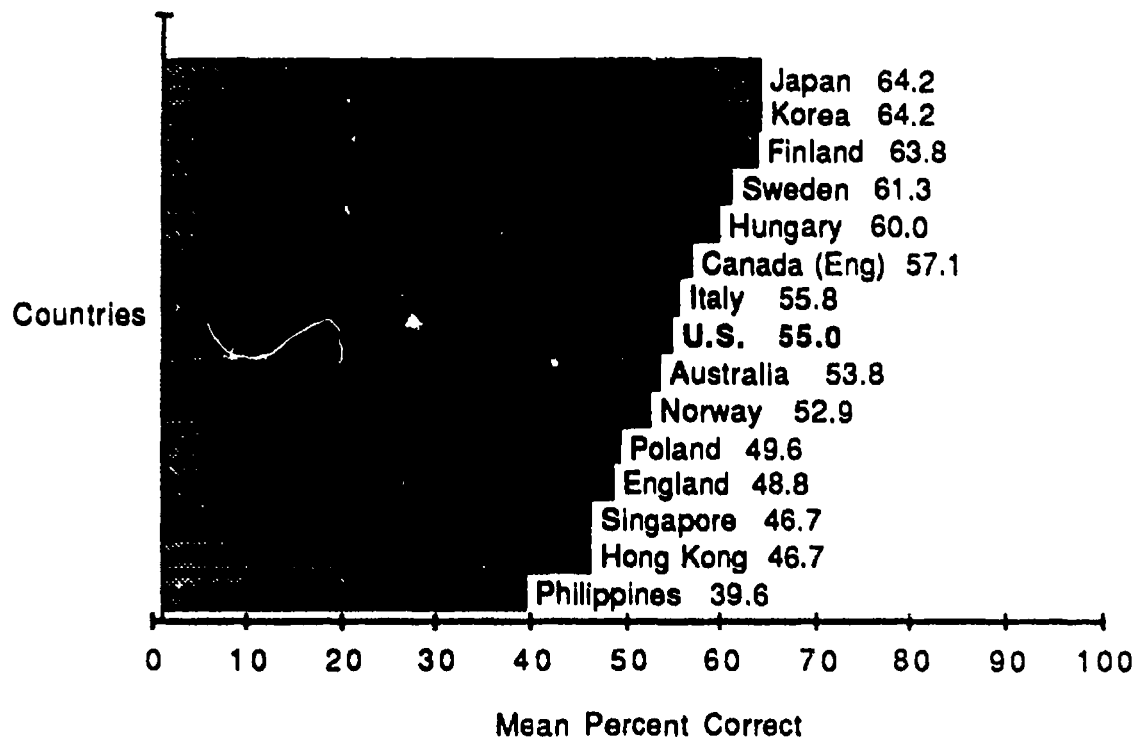
SCIENCE ACHIEVEMENT IN THE FIFTH GRADE*

When ranked with 15 other countries on science achievement scores, U.S. fifth grade students were at the median.

There was a strong rationale for the fifth grade as a level for testing. The fifth grade was chosen because, in most countries, it represents the upper elementary level where most of the students are taught by a general classroom teacher.

Science programs in the elementary school in the United States are not as standardized as the science courses in the high school. Content may be drawn from the life, physical, earth, and space sciences. The content may be organized around conceptual themes. Some attention is given to such process skills as observation, classification and measurement. "Hands-on" activities are advocated. The teaching of science is usually carried out by the general classroom teacher.

FIGURE 4
Grade Five Science Achievement in 15 Countries



* For a much more extensive description of science achievement in the fifth grade see Meng, E. A. The Teaching and Learning of Elementary School Science. New York: Second IEA Science Study--U.S., Teachers College, Columbia University (Work in Progress) and Ekeocha, E. Correlates of Science Achievement: A U.S. Study of Fifth Grade Students. Ph.D. dissertation, State University of New York at Buffalo, 1986.

Science achievement of fifth grade students was studied in 15 countries. In the United States, 2,582 fifth grade students in 123 schools took part in the Study. In the 15 countries where fifth grade results were analyzed, there were 2,617 schools and 71,576 students who took part. The mean age of the U.S. students in the spring of 1986 was 11.3 years. When the achievement scores of students in the fifth grade in each country were ranked, the science achievement of U.S. students was at the median. See Figure 4 on the previous page.

The achievement scores were based on international core tests containing 24 items responded to by fifth grade students in 15 countries. Many of the same items also were used in the First IEA Science Study (FISS) in 1970.

Japan, Korea, and Finland had the highest science achievement scores in Grade Five.

Among the countries using the fifth grade international core test, Japan, Korea, and Finland ranked highest. The U.S. students had a mean of 55% of items correct and the U.S. ranked 8th. In the U.S., about 28% of the schools scored lower than the lowest scoring school in Japan. In part, this is due to the homogeneity of schools in Japan. Of course, it also is due to the low mean score of many elementary schools in the U.S. However, six countries, including England, Poland, and the Philippines had a higher percentage of schools than the U.S. having mean scores lower than the lowest scoring Japanese school.

Note that the differences between many countries are small. Mean scores for four countries [Canada (Eng), Italy, Australia, and Norway] are less than 2.1% from the U.S. score.

In countries such as Japan and Sweden, there was very little difference in science achievement between schools. In the United States, the differences in science achievement between schools was 14% of the total between student variance. The between school difference was greater in 10 countries than in the U.S.

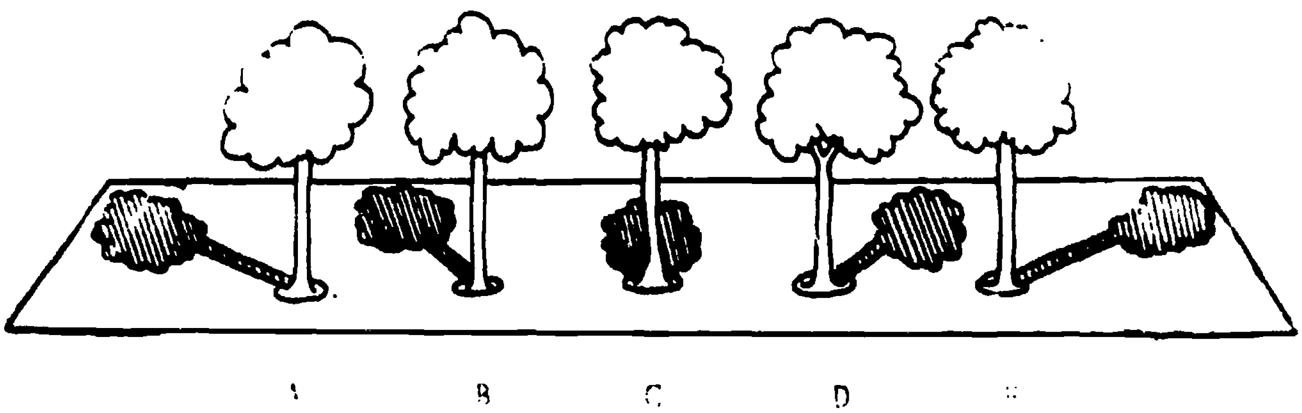
In the U.S., the item on which the pupils had the highest percentage correct is one in which students were asked to identify the shadow of the tree at noon (see Figure 5). The concept on which this question is based is in many elementary school science programs. The observation can be made in everyday life.

The most difficult item which only 26.1% answered correctly involved reading a table of temperatures and identifying the time a chilling wind began to blow (see Figure 6 on Page 18).

FIGURE 5

Item on Which U.S. Fifth Grade Students Had the Highest Score

At different times during a sunny day a tree was seen to cast shadows of different lengths as shown in the diagram below. Which diagram shows the shadow at mid-day (12 noon)?



Percent Responding		
8.5%	A	diagram A
5.8%	B	diagram B
79.3%	*C	diagram C
4.2%	D	diagram D
5.8%	E	diagram E

FIGURE 6

Item on Which U.S. Fifth Graders Had the Greatest Difficulty

	6 a.m.	9 a.m.	12 noon	3 p.m.	6 p.m.
Monday	15 °C	17 °C	20 °C	21 °C	19 °C
Tuesday	15 °C	15 °C	15 °C	10 °C	9 °C
Wednesday	8 °C	10 °C	14 °C	14 °C	13 °C

On one day a cool wind began to blow. When do you think this happened?

Percent Responding		
24.5%	A	Monday morning
14.7%	B	Monday afternoon
10.7%	C	Tuesday morning
26.1%	*D	Tuesday afternoon
23.9%	E	Wednesday afternoon

U.S. students had difficulty in reading a table and identifying a change over time.

Not only does this item require the student to read a table, but it also requires students to identify change in temperature associated with "a cold wind began to blow." Apparently, this is an intellectual task that is difficult for fifth graders.

Eleven of the twenty-one items used in both 1970 and 1986 were classified as science process items and ten were considered to be science non-process items. Science process items require the students to carry out such operations as description, classification, measurement, stating hypotheses, controlling the variables, operational definition, and designing experiments. Many of the science curricula development projects of the 1960s and 1970s emphasized the development of science process skills. Have there been gains in science process skills? See Table 2.

TABLE 2

Gains on Process and NonProcess Scores

	Gains from 1970 to 1986
Process Items (N = 11)	+1.8%
NonProcess Items (N = 10)	-1.2%

Thus, there was a small gain in achievement on the process items and a drop in achievement on nonprocess items. Perhaps, this indicates that students have improved slightly in carrying out the mental and physical operations called for in science processes.

There was a small gain from 1970 on items that were classified as "process" items and a small decline on "nonprocess" items.

The following is an item considered to be a process item. It involves the designing of an experiment to find out which of two balls bounces better. Of U.S. students, 66.3% answered the question correctly. See Figure 7.

FIGURE 7

Example of a Process Item

Mary and Jane each bought the same kind of rubber ball. Mary said, "My ball bounces better than yours." Jane replied, "I'd like to see you prove that." What should Mary do?

Percent <u>Responding</u>		
66.3%	*A	Drop both balls from the same height and notice which bounces higher.
3.9%	B	Throw both balls against a wall and see how far each ball bounces off the wall.
4.5%	C	Drop the two balls from different heights and notice which bounces higher.
14.0%	D	Throw the balls down against the floor and see how high they bounce.
10.4%	E	Feel the balls by hand to find which is the harder.

To answer this item correctly, the student must have some understanding of the need to control variables. It is worth noting that two-thirds of the students indicated that the height variable had to be controlled if they were to find out which ball "bounces better."

Of the 21 items administered to the fifth graders in 1970 and 1986, 13 were classified as being physical science items and 8 as being life science. On both life science (+0.9%) and physical science (0.0%) there were no changes in mean percent items correct from 1970 to 1986. See Table 3. The comparison of scores on the total set of items common to 1970 and 1986 is located on Page 52.

TABLE 3

Comparison of Achievement Scores on
Life Science and Physical Science Items
Mean Percent Correct

	1970	1986	1986 minus 1970
Life Science (8 items)	50.4	51.5	+0.9
Physical Science (13 items)	59.3	59.3	0.0

<u>Summary</u>. U.S. fifth graders were about at the median among the 15 countries whose results have been analyzed. While the 5th grade results leave little room for rejoicing, the ranking is higher than those for 9th grade and 12th grade. There have been small gains on science process items, and this may be due to the emphasis on science processes in the elementary science program developed in the 1960s and 1970s. However, on both life science and physical science items that were used in 1970 and 1986, there were no significant changes when 1986 scores were compared to 1970. While there may be a "pursuit of excellence," American fifth graders seem to be struggling to hold their own.

Chapter IV

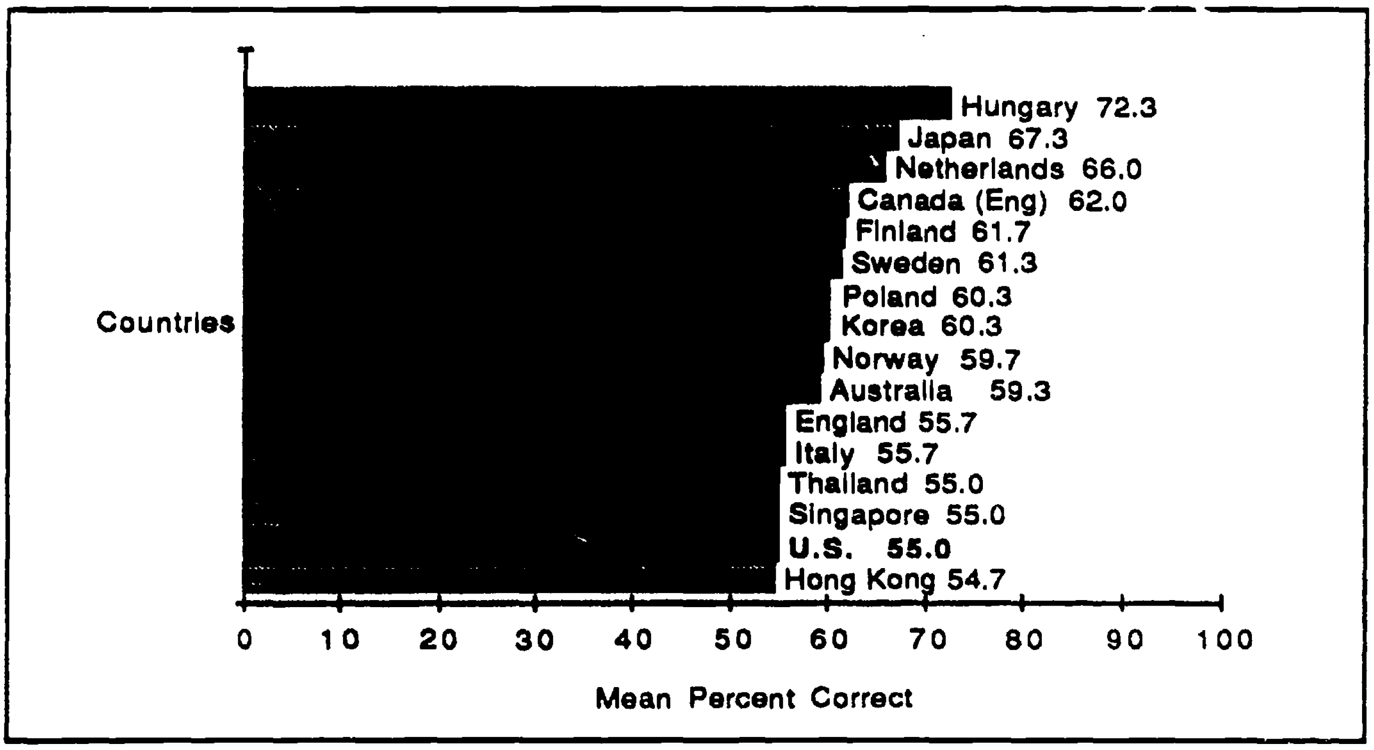
SCIENCE ACHIEVEMENT IN THE NINTH GRADE*

The U.S. ninth grade students joined students from England, Italy, Thailand, Singapore, and Hong Kong at the bottom of the ranking for science achievement for 16 countries.

Ninth grade students in 16 countries were tested with a core test consisting of 30 items. Some of the items were used in the First IEA Science Study (FISS), and a few of the items were also used at the 5th and the 12th grade levels. When compared to the science achievement scores of ninth grade students in 15 other countries, the scores of the U.S. ninth grade students ranked last along with England, Italy, Thailand, Singapore and Hong Kong.

The ninth grade level was chosen for testing because in many industrialized countries, the ninth grade is the last grade for compulsory education and about 100% of the age group in the U.S. and other industrialized countries are still in school. In most systems of education and in many countries, science in the ninth grade is taught by specialist science teachers.

FIGURE 8
Grade Nine Science Achievement in 16 Countries



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* More extensive discussions of achievement in the ninth grade are in Micik, J. M. The Teaching and Learning of Science at the Ninth Grade Level. New York: Second IEA Science Study--U.S., Teachers College, Columbia University (Work in Progress) and Dryden, M. A. Modeling Classroom Environments: An Analysis of Achievement at the Ninth Grade Level. Ph.D. dissertation, State University of New York at Buffalo. 1986.

Science in the ninth grade may be offered as general or integrated science or as a discrete science, such as physical science, earth science, or biological science. Laboratory skills are stressed in planned science curricula at this level. Science process skills also are usually included at this level.

In the U.S., 2,519 students in 119 randomly selected schools responded to the instruments. In the 16 countries where ninth grade results have been analyzed, 2,819 schools and 73,001 students took part. In the U.S. and most industrialized countries about 99% of the population are in school. The mean age of the ninth graders in the U.S. in the spring of 1986 was 15.4 years.

The international core test consisted of 30 items. Ten of the items were classified as life science items, six were earth science items, four were chemistry, and ten were physics items. Seventeen of the items were classified as "process items." Nineteen of the items administered in 1986 had also been used in 1970.

Of the 16 countries that administered the ninth grade international core test, students in Hungary had 72.3% correct, which was the highest mean percent correct. Japan and the Netherlands also scored high. The U.S. students had 55% correct. England, Italy, Thailand, Singapore, the U.S., and Hong Kong had about the same mean score and ranked lowest on the Grade Nine achievement test. About 30% of U.S. schools scored lower than the lowest school in Hungary, which was the highest scoring country.

One of the aims in science education is to make all citizens scientifically literate. Therefore, there is a concern for the education of the bottom 25%. In the U.S., the bottom 25% had a mean of 34.3% correct. Hong Kong and Singapore had very nearly the same mean as the U.S. Only the bottom 25% in the Philippines had a lower score. There is reason for concern. On a 30 item, five-option test, an average score of six item correct (20%) could be achieved by guessing. Some of these students will study little science beyond the ninth grade. The bottom 25% of U.S. ninth grade students can hardly be considered scientifically literate.

Hungary had the highest Grade Nine mean science achievement score.

Note that the differences between many countries are small. Mean scores for six countries (England, Italy, Thailand, Singapore, Hong Kong, and the U.S.) vary by less than 1%.

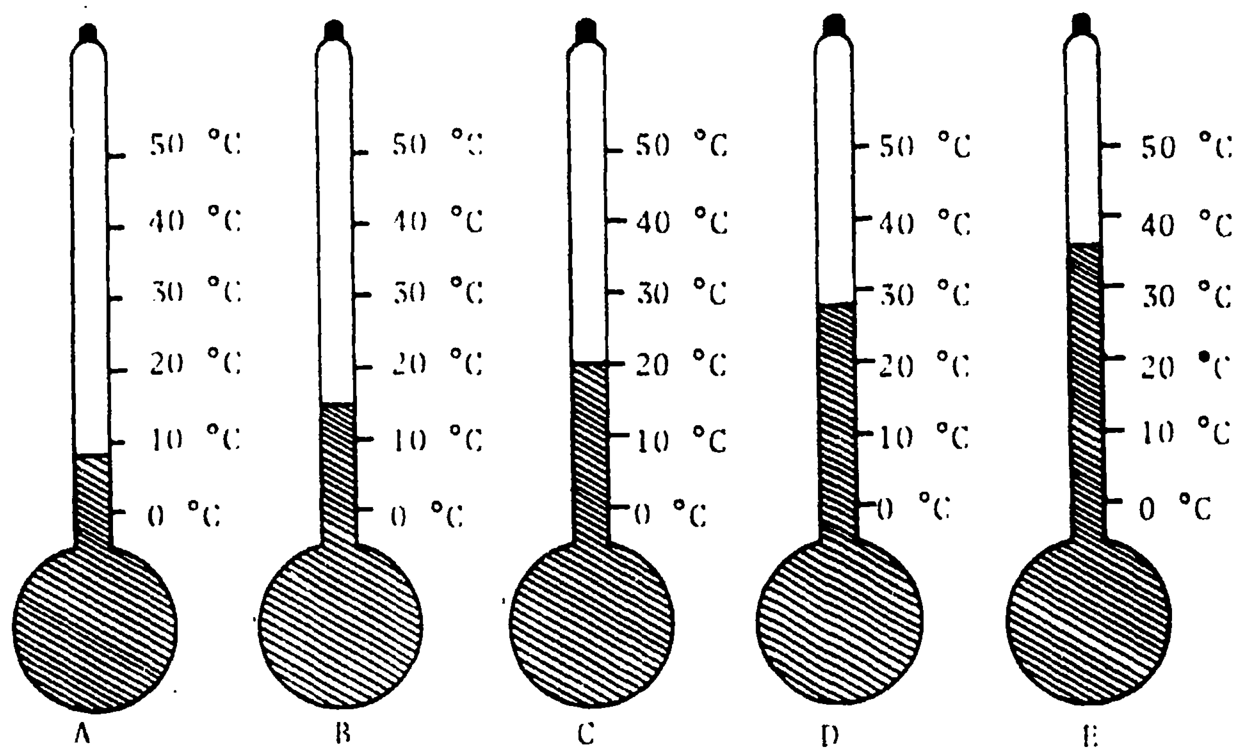
Many countries aim to provide equal opportunities for all to study, learn, and achieve in science. For this aim to be met, almost all the variance should be between students in schools and there should be little variance between schools. The students should have equal opportunity to learn science. In the United States, the difference in science achievement between schools was 29% of the total between student variance. In contrast, Norway, Japan, and Finland had less than 5%. Singapore, on the other hand, had 56% of the total student variance which was due to the school. The between school variance was less in 13 countries than it was in the United States. All students in ninth grade science in the U.S. do not have equal chances to learn science.

Some insight into what science seems to be known by students and not known can be derived by an examination of the questions most students responded to correctly. The item in Figure 9 is classified as a process item. To answer it correctly, students must be able to locate a number in a table and identify a number on a thermometer scale that indicates the temperature; 88% of the ninth grade students were able to do this. Certainly, these are skills that are often used in elementary and middle/junior high school science. These skills probably also are often used in everyday life.

FIGURE 9
Item on Which U.S. Ninth Grade Students Had the Highest Scores

	6 a.m.	9 a.m.	12 noon	3 p.m.	6 p.m.
Monday	15 °C	17 °C	20 °C	21 °C	19 °C
Tuesday	15 °C	15 °C	15 °C	10 °C	9 °C
Wednesday	8 °C	10 °C	14 °C	14 °C	13 °C

Which of the following shows the temperature at 6 a.m. on Wednesday?



Percent Responding	
88.0	*A
9.4	B
1.4	C
0.4	D
0.5	E

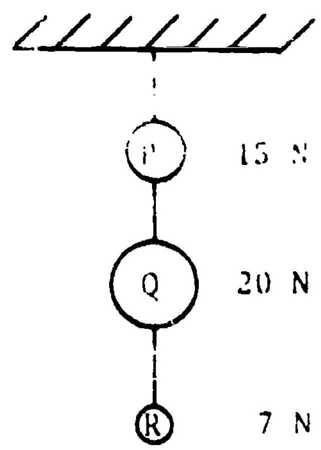
The associated question that asks students to indicate when "a cool wind began to blow" was the most difficult for fifth graders. It was answered correctly by only 26.1% of the fifth graders (see Figure 6 on Page 18). However, this item was answered correctly by 50.9% of the ninth graders. This indicates substantial growth since the fifth grade.

The item on which U.S. students had the greatest difficulty asked them to indicate the tension on a certain point on a string between two weights (see Figure 10).

FIGURE 10

Item on Which U.S. Ninth Grade Students Had the Greatest Difficulty

The objects P, Q, and R of weight 15 N (newtons), 20 N, and 7 N, are hung with a light thread as shown in the figure.



What is the tension in the thread between P and Q?

Percent Responding		
9.5	A	42 N
46.7	B	35 N
20.3	*C	27 N
11.8	D	15 N
10.4	E	7 N

Twenty percent of the U.S. ninth grade students tested answered the question correctly, and on a five-option item this is not better than chance. This item was difficult for students in other countries as well. Only in Hungary and Japan did more than 50% of the students get the item correct. At one level it would seem that the question could be answered using "common sense" with little necessity for the use of physics. On the other hand, the higher order cognitive skills of application and analysis may be difficult for 15-year-old students.

One of the aims in ninth grade science is to develop science process skills. Seventeen of the thirty international core items were judged to assess various process skills. Process items are those that require some mental or physical operation. The item shown in Figure 11 on the next page was one of the more difficult items with only 32.7% of the respondents answering the question correctly.

The item shown in Figure 11 requires the development of a mental model that will explain the observations that have been made. These are sometimes called "black box" questions. In elementary school science, students sometimes are asked to carry out observations on a box and then try to describe the contents of the box on the basis of these observations. This question is a rather sophisticated example of a "black box." To answer this question, some elementary knowledge of electricity is required, as well as the ability to construct mental models. This proved to be difficult for ninth graders (32.7% correct). However, 71.9% of a sample of 12th grade physics students were able to answer this question correctly.

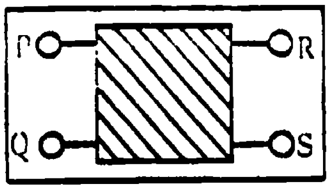
Ninth grade students had difficulty with items that required such higher order logical skills as analysis, application, and mental model building.

FIGURE 11

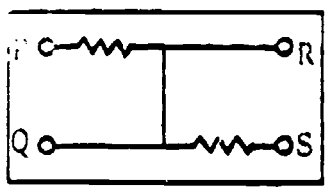
Example of a "Black Box" Question

The figure shows a box with four terminals: P, Q, R, and S. The following observations were made.

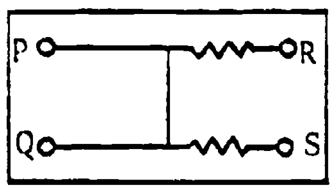
1. There is a certain amount of resistance between P and Q.
2. Resistance between P and R is twice that between P and Q.
3. There is not any appreciable resistance between Q and S.



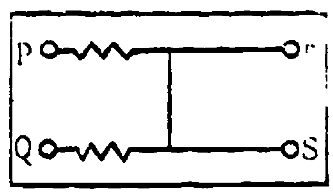
Which of the following circuits is more likely to be within the box? Assume that the resistances shown are equal.



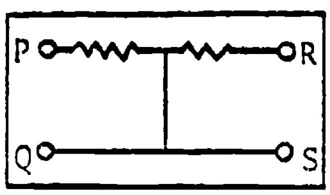
A



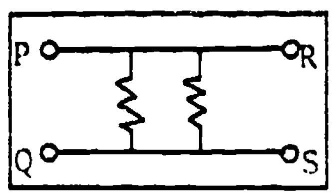
B



C



D



E

Percent Response	
12.4	A
11.6	B
14.6	C
32.7	*D
26.0	E

Of the 30-item core test, 19 items were also used in the 1970 tests. The overall comparisons on these items is found on Page 54. These "bridge" items were categorized into process or nonprocess categories and life science or physical science. The results of comparing 1970 and 1986 performance on these subtests are presented in Table 4. The results generally reflect the overall decline from 1970 to 1986. The decline of the process and nonprocess items was not substantially different (-5.0%, -4.2%). There was a slightly greater decline on the physical science items (-5.5%) than on the life science items (-3.6%). Might these results reflect a shift to nonprocess, life science dominated instruction in the sciences?

TABLE 4

Comparison of Achievement Between 1970 and 1986
by Process and Science Areas
Mean Percent Correct

	1970	1986	1986 minus 1970
Process Items (N = 12)	53.8	48.8	-5.0
NonProcess Items (N = 7)	54.0	49.8	-4.2

Life Science Items (N = 7)	59.6	56.3	-3.6
Physical Science Items (N = 12)	50.5	45.0	-5.5

U.S. ninth grade students joined students in five other countries at the bottom of the ranking for science achievement. With the emphasis on environmental science and earth and space science, it may be that the U.S. students studied areas of science that were not emphasized in the ninth grade science test. But, why is it that ninth grade students score little better than chance on items that require such higher order abilities as application and imagining mental models? Could it be that our ninth grade students do not have sufficient opportunity to learn and use these skills?

Summary. In other chapters, there is discussion of the apparent importance of learning the basic science concepts that will help in further learning in science. The middle/junior high school years are the years when the development of such concepts should begin. If students fail to begin to develop these concepts in middle/junior high school, they will be handicapped in their later studies. So much is at stake. Shouldn't something be done about middle/junior high school science?

Chapter V

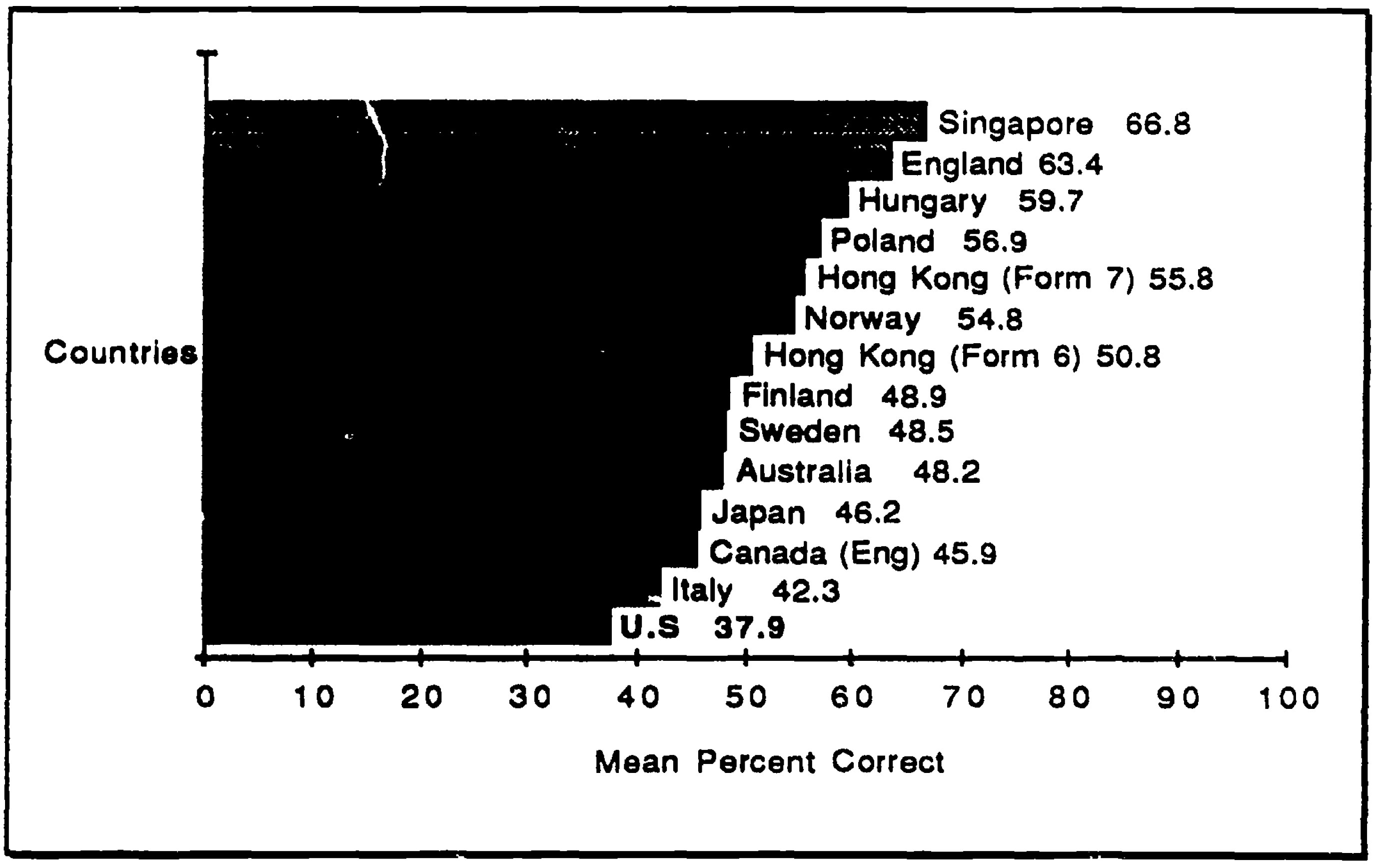
ACHIEVEMENT IN BIOLOGY*

Students in the United States who had studied biology for two years ranked 13th among 13 countries in achievement in biology.

Biology is the most popular of the sciences in the secondary school. Ninety-nine percent of our secondary schools offer biology (Weiss, 1987, p.16). It is estimated that at least two-thirds of our high school graduates will study at least one year of biology (Welch, et al., 1984, p. 16).

In Figure 13, the scores of biology students in 13 countries are compared. Note that there are two populations reported for Hong Kong. One population (Form 7) is somewhat more advanced than the other (Form 6). Of 13 countries, the U.S. second year biology students had the lowest mean percent correct.

FIGURE 12
Biology Specialists (Mean Percent Correct)



* A more extensive discussion of achievement in Biology is in Anderson, O. R., The Teaching and Learning of Biology in the United States. New York: Second IEA Science Study--U.S., Teachers College, Columbia University, (Work in Progress).

Students studying first year biology in the 10th grade and students who were studying a second year biology course were tested in the spring of 1986. The students were tested with one of two biology achievement tests, each consisting of 30 items. Nineteen of these items were common to both the first year biology test and the second year biology test. This made it possible to make some comparisons between the scores of 10th grade, first year biology students and 12th grade students with two or more years of biology. The scores of American second year biology students on common items also could be compared with those in other countries in the Second International Science Study (SISS). Students also responded to an opinionnaire soliciting their opinions about science and school, a questionnaire seeking information about how students study science, a word knowledge test, and a mathematics test.

The first year biology test of 30 items was given to 2,582 students in 118 schools. The advanced science biology test was given to 674 students in 43 secondary schools and who were studying a second year biology course. This reflected a response rate of over 80% of the schools contacted.

Singapore had the highest mean achievement score in biology.

In the graph in Figure 12 on the previous page, the mean percent correct of the biology students who had had two or more years of biology are compared with the scores of students in 13 other countries. The international biology test was composed of 30 items (the U.S. test included 25 international and 5 national option items). The U.S. results are based on 25 of these items that were used in all countries. In this comparison the U.S. ranks last, with a mean score of about 38% correct. Certainly, there are grounds for just concern about the low ranking of the achievement scores of U.S. students.

It should be noted that the U.S. students who were ranked in the graph were a sample of students completing their second year of biology study, many of whom were in the 12th grade. This is a fairly elite group. According to the best data that we have, 6% of American students in the 12th grade are enrolled in a second year of biology. Additionally, some 10th graders and 11th graders in U.S. schools complete a second year course in biology.

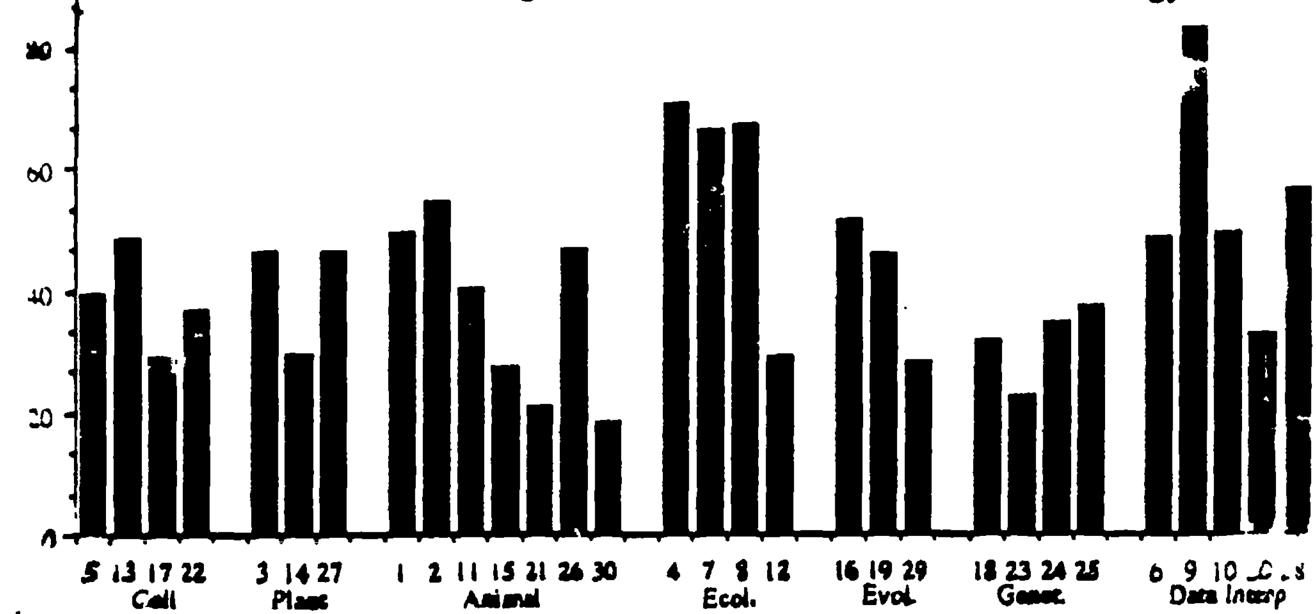
U.S. students with two years of biology scored about 10% higher than students who had had one year of biology.

There were 19 items on the achievement test that were common to the tests for first year biology and second year biology. The first year biology students had 36.7% of the 19 items correct, while the second year biology students had 46.8% of the 19 items correct. This, of course, is a substantial difference. However, the second year biology students were a more elite group and, of course, had studied biology for more than one year It can be noted that neither of the groups, first year biology students or second year biology students, succeeded in answering half the items correctly. Should the second year biology students have scored somewhat better in comparison to the first year biology students? Certainly, there appears to be a need to examine and consider the nature of the instruction that students receive in second year biology.

The biology items in both first year and second year biology tests have been categorized into different biology content areas. These content areas and the items that were classified in each category are shown in Figure 13, which contains a further analysis of the comparative scores on different items and different categories of items:

FIGURE 13A

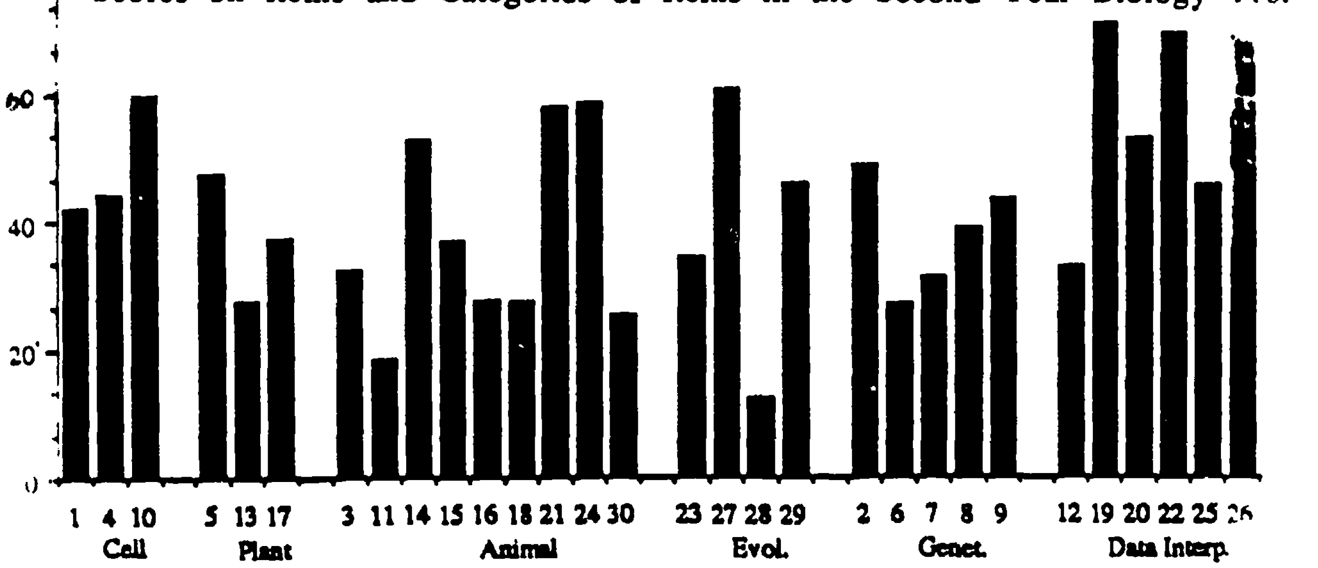
Scores on Items and Categories of Items in the First Year Biology Test*



Histogram: Item percentile distribution grouped accor... o subcateg...

FIGURE 13B

Scores on Items and Categories of Items in the Second Year Biology Test*



Histogram: Item percentile distribution grouped according to subcategories.

Note: The assignment of items to content subcategories is intended only as an aid in identifying individual test items of similar biological content. It is not recommended that comparisons be made between groups or among items in a group since we do not know if they are of comparable difficulty. The histogram plot gives approximate values for the percentiles.

(Anderson, Work in Progress, p. 67)

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* Numbers and bars refer to specific items in biology tests.

In Table 5 the percent correct for both females and males and total scores are shown for the several biology content areas. It is interesting to note that the first year biology students scored highest on the items that were classified as ecology. (There were no ecology items in the second year biology test.) The students who responded to the second year biology test did reasonably well on cellular items. Both the first year biology students and the second year biology students did reasonably well on items that were classified as "data interpretation."

The comparative performance of male versus female students is summarized in Table 5 by subcategories (for comparative enrollment, see Table 10 on Page 60). In general, the percentage of females responding correctly was less than for males, except for items on genetics. With respect to total score, for the first year biology test, the percent of males responding correctly was 44.5% and for females, 41.4%. For the second year biology test, the percent of males scoring correctly was 45.4% and for females, 40.2%. In terms of mean items correct for the first year' biology test, the score for females was 12.4 and for males 13.3, and for the second year biology test, the score for females was 12.1 and for males 13.6. This rather consistent difference points toward a continuing dilemma and the need to encourage female students.

TABLE 5
Comparative Data for Female and Male Respondents on Different Categories of Items in First and Second Year Biology Tests

	First Year Biology Test % Responding Correctly				Second Year Biology Test % Responding Correctly		
Category	Females	Males	Total	Category	Females	Males	Total
Cellular 5, 13, 17, 22	36.3	41.1	38.6	Cellular 1, 4, 10	44.9	54.5	48.7
Plant 3, 14, 27	39.6	42.2	40.8	Plant 5, 13, 17	35.5	39.8	37.4
Animal 1, 2, 11, 15, 21, 26, 30	34.0	38.1	35.9	Animal 3, 11, 14-16, 18, 21, 24, 30	35.1	40.1	37.3
Ecology 4, 7, 8, 12	55.4	[illegible]1.5	58.2	Ecology None	-	-	-
Evolution 16, 19, 29	43.2	40.0	41.5	Evolution 23, 27-29	36.0	41.6	38.3
Genetics 18, 23-25	31.6	31.7	31.5	Genetics 2, 6, 7-9	37.3	37.8	37.7
Data Interp. 6, 9, 10, 28	52.0	56.5	54.1	Data Interp. 12, 19, 20 22, 25, 26	53.2	60.8	56.5
Total	41.4	44.5	42.7		40.2	45.4	42.5

Two items, one from the first year biology test and the other from the second year biology test, give a flavor of the kinds of questions that were asked.

The following item in Figure 14 was in both the first year biology test and the second year biology test. First year biology students had a score of 49.5% correct. The U.S. second year biology students did considerably better with a score of 69.1% correct.

FIGURE 14

Item on Which U.S. Second Year Biology Students Did Well

The following results are from experiments which were made to find how long it took for newborn babies of different mammals to double in weight.

Mammal	Time in days to double the weight of the newborn baby	Percentage protein in the milk of the mother
human	180	1.6
horse	60	2.0
cow	47	3.5
pig	18	5.9
sheep	10	6.5
dog	8	7.1
rabbit	6	10.4

What do the results of these experiments suggest?

Percent Responding First Year	Percent Responding Second Year		
2.8	2.7	A	The larger the mammal, the greater the protein concentration in the milk.
30.7	15.0	B	The smaller the mammal, the greater the protein concentration in the milk.
10.5	8.8	C	The greater the protein concentration in the mammal's milk the slower the newborn baby will double its weight.
49.5	69.1	*D	The greater the protein concentration in the mammal's milk the faster the newborn baby will double its weight.
6.1	4.2	E	There appears to be no relationship between protein concentration in mammal's milk and time taken for a newborn baby to double its birth weight.

The item shown in Figure 15 has been classified as being a "process" item in which students are required to make interpretations of data. It might also be considered a human biology item. For the first year biology students, scores for males and females were essentially the same. Both sexes did quite well on this particular item in the second year biology test. Males in second year biology scored about 7% higher than the female students. In these tests, females tended to achieve quite well on human biology items while scoring about the same as males on biology tests, but in second year biology they did not do as well as males. Why?

One of the items that both first and second year biology students found difficult is in the field of genetics (see Figure 15). This item involves concepts that are ordinarily taught in first year biology. Mastery of technical terms such as "homozygous" and "F_1" may lead to some difficulty in responding to the items. Although the item deals with content that is taught in many biology courses, only 31.2% of the second year biology students were able to answer it correctly.

FIGURE 15

An Item on Genetics Which U.S. First and Second Year Biology Students Found Difficult

Two alternative color characteristics in mice are "hooded" and "white." When homozygous parents of both colors are crossed all the offspring are hooded. If these F_1 hooded rats are mated together and produce litters totalling 50 rats, which of the following proportions is most likely?

Percent Responding 1st Year	Percent Responding 2nd Year				
33.4	27.7	A	50 hooded	:	none white
6.9	5.5	B	50 white	:	none hooded
15.7	17.0	C	38 white	:	12 hooded
20.2	17.4	D	24 white	:	26 hooded
22.4	31.2	*E	10 white	:	40 hooded

The difference between scores of boys and girls holds for most of biology categories. However, it is interesting to note that the differences between boys and girls in the category of genetics is practically non-existent. Is there something unusual about the genetics category which leads to pr. tically no difference between boys and girls?

In biology, boys scored higher than girls, except in genetics where there was practically no difference.

An international comparison of biology student achievement that is sobering is the percentage of schools that score below the lowest school in the highest-scoring country. The highest-scoring country in the biology testing was Singapore. Its lowest-scoring school had a mean of 56.6%. Ninety-eight percent of the schools in the United States had lower means than the lowest scoring school in Singapore.

Another important international comparison is that of comparing the percent of variance that is between schools and that which is between students. In the United States, 40% of the variance was between schools and 60% was between students. The variance between schools in the United States was the highest of that in any country. Thus, in the United States there was considerable difference between schools. Student scores seemed to have depended, to a large extent, on the school students attended.

International comparisons suggest that the advanced biology science scores depend on the number of years of science that have been studied.* For example, if U.S. advanced biology students had had at least four years of science since the eighth grade, they had a mean score of 44.4%. This contrasted with a mean score of 35.2% if the students had had less than four years of science since the eighth grade (see Table 6).

There was a similar improvement in science scores with an increase in the number of years of math studied since the eighth grade. For example, U.S. advanced biology students who had had at least four years of math had a mean score of 45.4%, compared with a mean score of 36.0% for students who had had less than four years of math since the eighth grade.

An analysis of the scores of some of the sub-groups of advanced biology students may help identify other factors that may lead to improved achievement in biology.

These data seem to indicate that it is desirable for advanced biology students to have four years of mathematics and science. It also appears desirable to be involved in advanced placement programs. There are indications that the advanced placement programs may be more structured than the other advanced biology courses.

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* This discussion is based upon Ferko, A.M., Advanced Science Student Achievement in Biology, Chemistry, and Physics, New York, Second IEA Science Study--U.S., Teachers College, Columbia University, (Work in Progress).

TABLE 6

Scores of Some Sub-Groups of Advanced Biology Students Tested

	N	Mean Score in Percent
All Advanced Biology Students	674	39.4
Advanced Placement Biology	102	49.6
NonAdvanced Placement Biology	572	37.6
Students with at Least Four Years of Science	308	44.4
Students with Less Than Four Years of Science	365	35.2
Students with at Least Four Years of Math	226	45.0
Students with Less Than Four Years of Math	419	36.0

Summary. U.S. advanced biology students ranked last of thirteen countries in achievement scores in biology. Singapore had the highest mean score. About 98% of the U.S. schools had lower means than the means of the lowest scoring school in Singapore. In the U.S., students in second year biology had a mean score about 10% higher than first year biology students. In the U.S. there were greater differences between schools in biology achievement than in any other country. Apparently, in the United States, a student's chances of doing well in biology, to a large extent, depended upon the school the student attended. In the U.S., students with strong backgrounds in science and mathematics had higher mean scores in biology.

Chapter VI

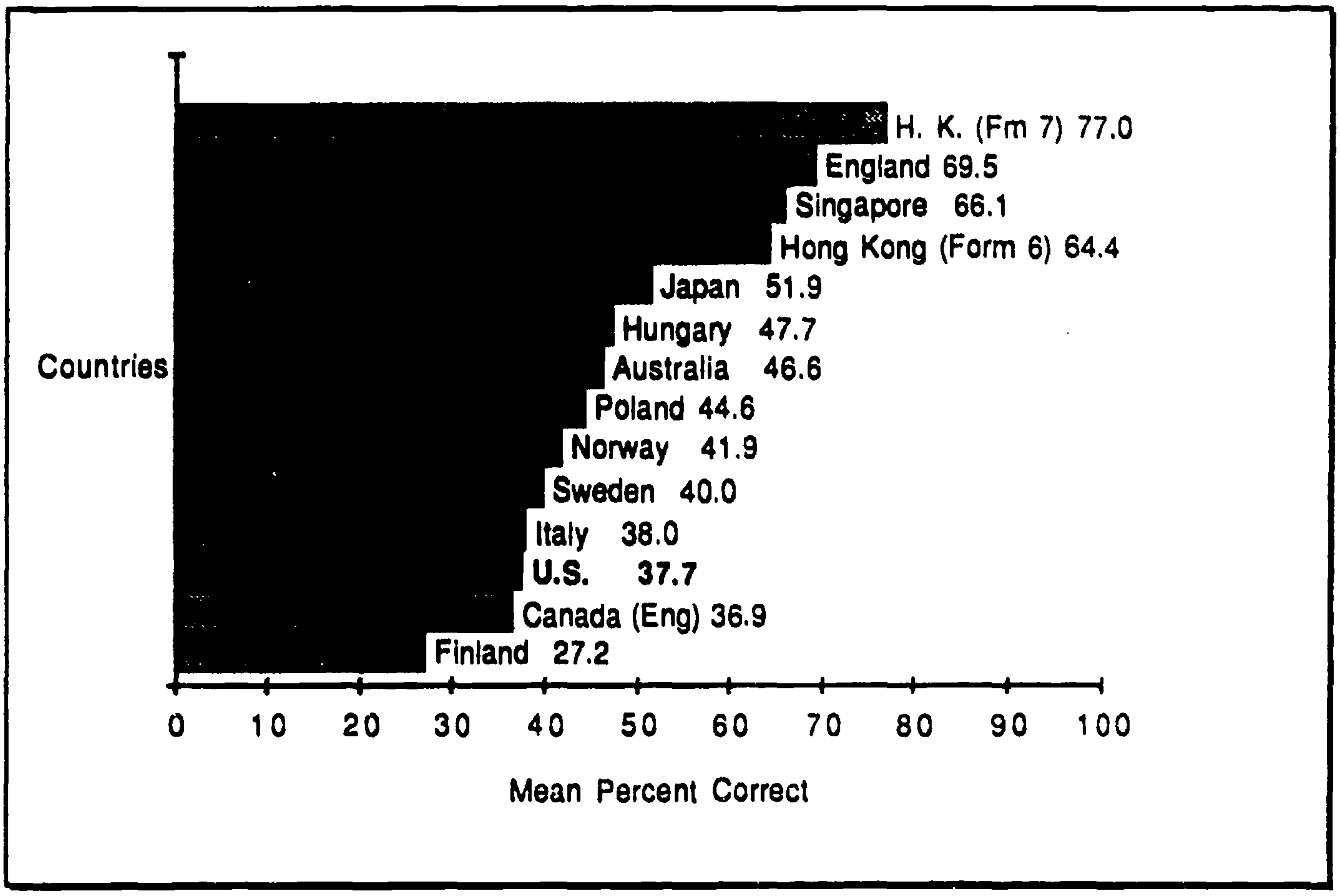
ACHIEVEMENT IN CHEMISTRY*

Students in the U.S. who had studied chemistry for two years ranked 11th among 13 countries in achievement in chemistry.

Of the secondary schools with Grades 10-12, 91% offer first year chemistry and 28% second year chemistry (Weiss, 1987, p. 16). Ordinarily in the United States, chemistry is studied in the 11th grade. In 1981-1982 it was estimated that about 740 thousand 11th grade students studied chemistry (Welch, et al., p. 16). Since some students study chemistry in other grades, it is estimated that about 35% of the U.S. high school graduates have studied first year chemistry in the secondary school. About 4% of the U.S. high school graduates have completed a second year of chemistry.

FIGURE 16

Chemistry Specialists (Mean Percent Correct)



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* A more extensive discussion of achievement in chemistry is in Menis, J., The Teaching and Learning of Chemistry in the United States . New York: Second IEA Science Study--U.S., Teachers College, Columbia University, (Work in Progress).

In Figure 16, the scores of chemistry students in 13 countries are compared. Note that there are two populations listed for Hong Kong. One population (Form 7) is somewhat more advanced than the other (F m 6). The U.S. results shown in Figure 16 are for second year advanced chemistry students and are based upon 25 common items from the 30 item international test. As in advanced biology, the U.S. advanced chemistry test contained 25 international items and 5 U.S. option items.

Hong Kong (Fm7) had the highest mean achievement score in chemistry.

The U.S. students ranked 11th among 13 countries. The U.S. students scored about the same as students in Italy and Canada (English). Students in countries where some students specialize in science and mathematics had the highest scores in chemistry. The three countries that ranked highest (Hong Kong, England and Singapore) have been influenced by the English pattern of early and intensive specialization. At about the age of 15, students in these countries may elect to specialize in science and mathematics and devote most of their academic study to science and mathematics for three years.

In the United States, a first year chemistry achievement test of 30 items was given to 2,205 students in 119 schools for a 78.6% response rate. A second year chemistry achievement test of 30 items was given to 562 students in 40 schools for an 82.3% response rate. As has been mentioned, the total number of students studying chemistry for a second year in the U.S. is quite small, but these second year chemistry students have backgrounds in chemistry that are more like those students in other countries that were tested in chemistry. A second instrument contained a mathematics test, an opinionnaire soliciting opinions about science and school, a questionnaire seeking information about how students study science, and a word knowledge test.

U.S. students with two years of chemistry scored about 13% higher than students who had had one year of chemistry.

In the U.S., chemistry is most often offered as a one year course in Grade 11. How do the scores of the students who have had one year of chemistry compare with those who have had two years? There were 18 common items on the two chemistry tests. As expected, the second year chemistry students had the higher scores on the common items. The first year chemistry students had a mean of 31% correct while the second year chemistry students had 44% correct--a difference of 13%. Should more students have the chance to take a second year of chemistry? Are there ways that first year and second year chemistry can be made more effective? Obviously, both sets of chemistry scores rank low internationally.

An analysis of the scores of different sub-groups of advanced chemistry students may identify factors that could lead to improved achievement in chemistry.*

TABLE 7

Scores of Some Sub-Groups of Advanced Chemistry Students Tested

	N	Mean Score in Percent
All Advanced Chemistry Students	564	34.9
Advanced Placement Chemistry	117	46.9
NonAdvanced Placement Chemistry	445	31.7

In chemistry, as in biology, students in advanced placement programs scored better than the general advanced chemistry students.

Secondary school chemistry items have been classified into eight categories which are shown in Table 8 (Menis, 1988):

TABLE 8

Categories of Secondary School Chemistry Items

Categories	Number of Items in Test	
	First Year	Second Year
Theoretical Chemistry	-	2
Chemical Energy and the Gases	2	4
Solutions	3	4
Acid, Base, and Salts	3	5
Chemical Reaction	6	7
Oxidation - Reduction	-	4
Organic Chemistry	2	2
Nuclear Chemistry	2	2

There were no questions categorized as theoretical chemistry and oxidation-reduction in the first year chemistry test. The greatest number of

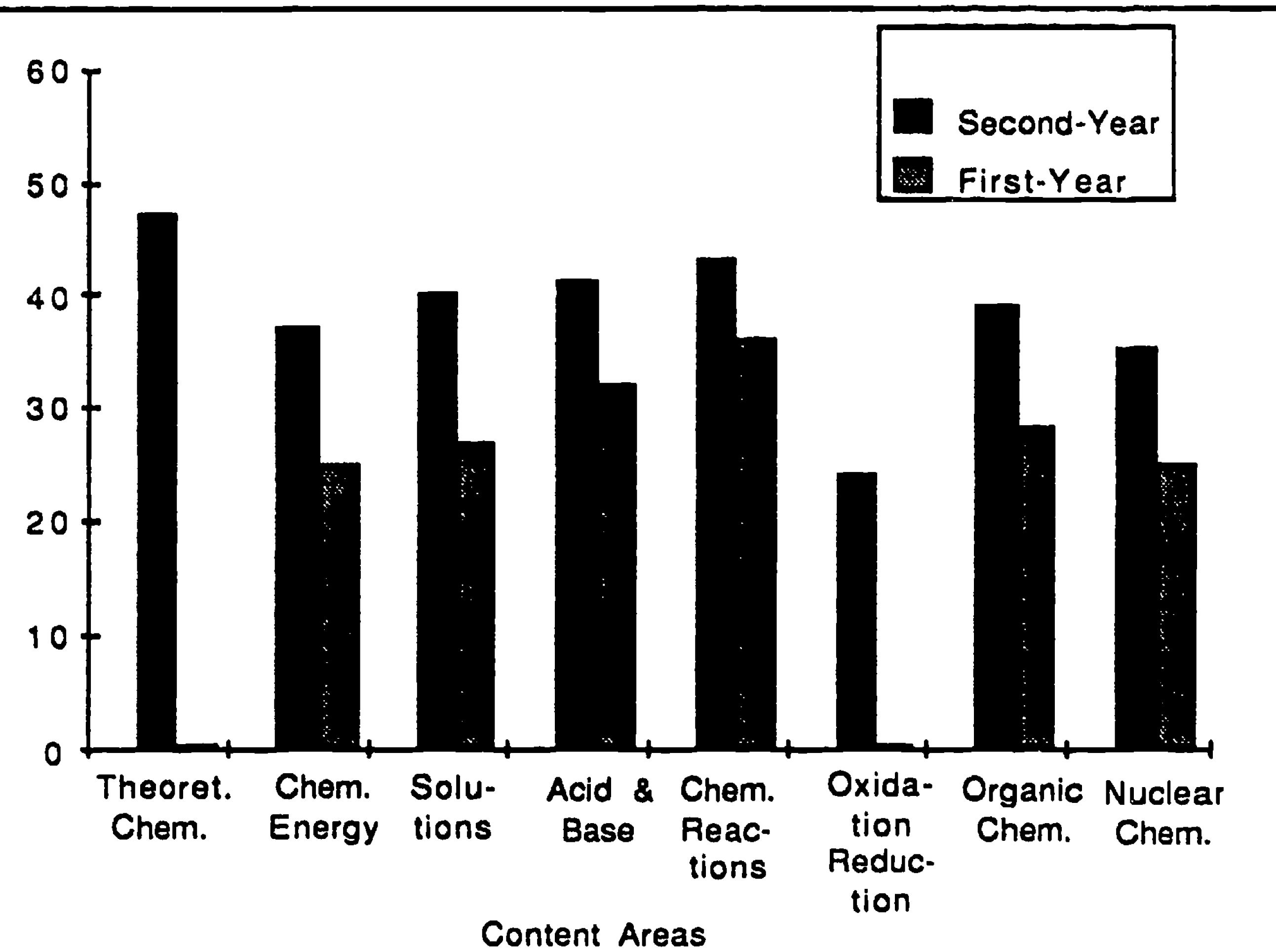
* These analyses are from Ferko, A.M., Advanced Science Student Achievement in Biology, Chemistry, and Physics, New York, Second IEA Science Study--U.S., Teachers College, Columbia University, (Work in Progress).

items in both the first year and second year chemistry tests dealt with the category chemical reactions.

Figure 17 shows that second year chemistry students had a higher mean percent correct than first year chemistry students in each content area.

FIGURE 17

Response to Chemistry Content Areas (1986)
Mean Percent Correct



Note: Since we do not have equally difficult items in different areas of chemistry, comparisons across areas should not be made.

U.S. advanced chemistry students did least well on questions dealing with oxidation-reduction and nuclear chemistry.

While there are relatively small numbers of items for each of the chemistry content categories, it is possible to get a general indication of where U.S. chemistry students do best and worst. The second year students were most successful with items that were categorized "Theoretical Chemistry" and "Chemical Reactions." First year chemistry students also did best with "Chemical Reaction" questions. U.S. advanced students did least well with questions dealing with oxidation-reduction and nuclear chemistry. Curriculum analyses indicate that these two categories have less coverage than categories such as "Chemical Reactions." Should more attention be given to these areas of chemistry?

In the U.S., more boys than girls take chemistry and they tend to score higher than girls (see Table 9 on page 60). In second year chemistry, girls scored higher than boys on two of the 30 items. The items on which girls did better required certain mathematical skills such as use of ratios and proportions. One item required the recognition that the ratio of chromium atoms to iron atoms in stainless steel is a function of the atomic mass of the elements. The other item required the procedures that should be used to make an aqueous solution of given proportions. There were no items in first year chemistry on which girls did better than boys.

In the U.S., the item shown in Figure 18 is the one on which U.S. second year chemistry students did the best with 77.1% of the second year chemistry students answering it correctly, and 56.7% of the first year chemistry students also selecting the right answer.

FIGURE 18

Item on Which U.S. Second Year Chemistry Students Did the Best

A solution of substance X is added to a solution of substance Y. No color change is observed. Which of the following would provide evidence that a chemical reaction had taken place although there was no change in color?

Percent Responding First Year	Percent Responding Second Year		
4.0	1.4	A	Any product is soluble in water.
11.1	6.1	B	The solutions of X and Y can be mixed in all proportions and still give the same result.
56.7	77.1	*C	There was a rise of temperature when the two solutions are mixed.
15.6	10.2	D	The final liquid is shown to be neutral by using an indicator.
9.1	5.0	E	The experiment gives the same result when different concentrations of the two solutions are used.

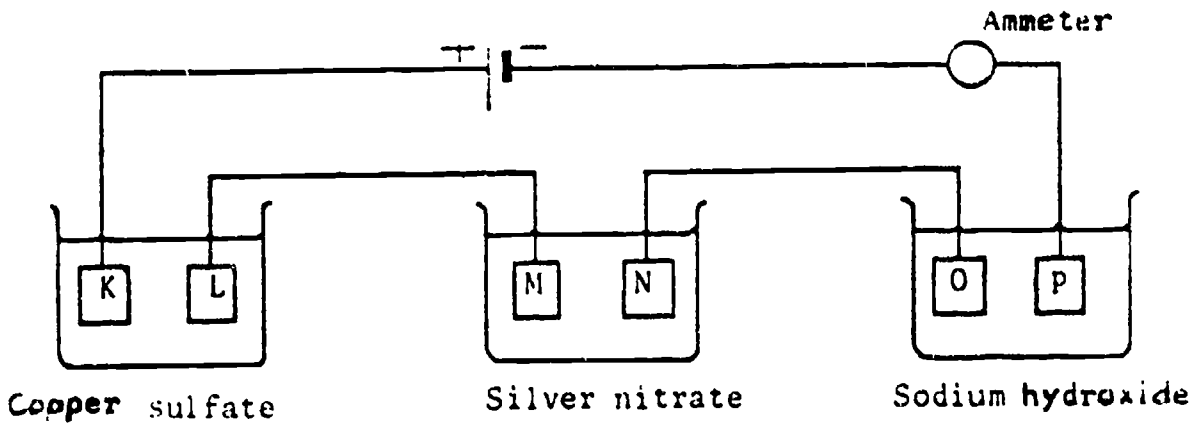
Basically, a correct response called for the recognition that some kind of physical change (change in temperature) indicates that a chemical change has taken place.

U.S. second year chemistry students found an item that involved electrochemistry the most difficult (see Figure 19). Some knowledge of how materials are deposited on electrodes and the importance of relative atomic mass was required. First year chemistry students were not asked to respond to this question.

FIGURE 19

Item on Which U.S. Second Year Chemistry Students Had the Greatest Difficulty

Copper strips K and L, silver strips M and N and platinum strips O and P, which are equal to each other in surface area and mass, are hung opposite each other in aqueous solutions of copper sulfate, silver nitrate and dilute sodium hydroxide respectively. They are connected in series as the figure shows, and a constant current of 0.5 A (amperes) is sent through for several minutes.



Approximate relative atomic masses:

H = 1	N = 14	O = 16	Na = 23
S = 32	Cu = 63.5	Ag = 108	Pt = 195

Which strip gained most weight?

Percent Responding		
21.3	A	copper strip K
11.8	B	copper strip L
15.5	C	silver strip M
15.0	*D	silver strip N
29.3	E	platinum strip P

The comparative popularity of the platinum strip response may have been due to the frequency with which platinum is used in electrodes.

There was a great deal of difference between schools in achievement in chemistry. Almost half of the variance in U.S. chemistry achievement was between schools. In contrast, in Norway and Finland between-school variance was only 12%. In the U.S., achievement in chemistry, as with other populations, depended a lot upon the school attended.

The U.S. had the greatest percentage of schools scoring lower than the lowest-scoring school in the country that had the highest mean score. Hong Kong (Form 7) had the highest mean score of 77.0% as contrasted to the U.S. mean score of 37.7% correct. The lowest-scoring school in Hong Kong (Form 7) had a mean score of 30.0% correct. In the U.S., 48% of the schools had mean scores lower than the lowest-scoring school in Hong Kong (Form 7).

Summary. In chemistry achievement, U.S. students ranked 11th among thirteen countries. Hong Kong (Form 7) had the highest mean score in chemistry; 48% of the schools in the U.S. had mean scores lower than the lowest-scoring school in Hong Kong (Form 7). U.S. second year chemistry students had a score 13% higher than first year chemistry students. In the United States there is a great difference in achievement in chemistry between schools; American students' opportunity to learn depended to a large extent upon the school in which they studied chemistry. Advanced chemistry students who were in advanced placement programs tended to have higher achievement scores in chemistry than did students in other advanced chemistry programs.

Chapter VII

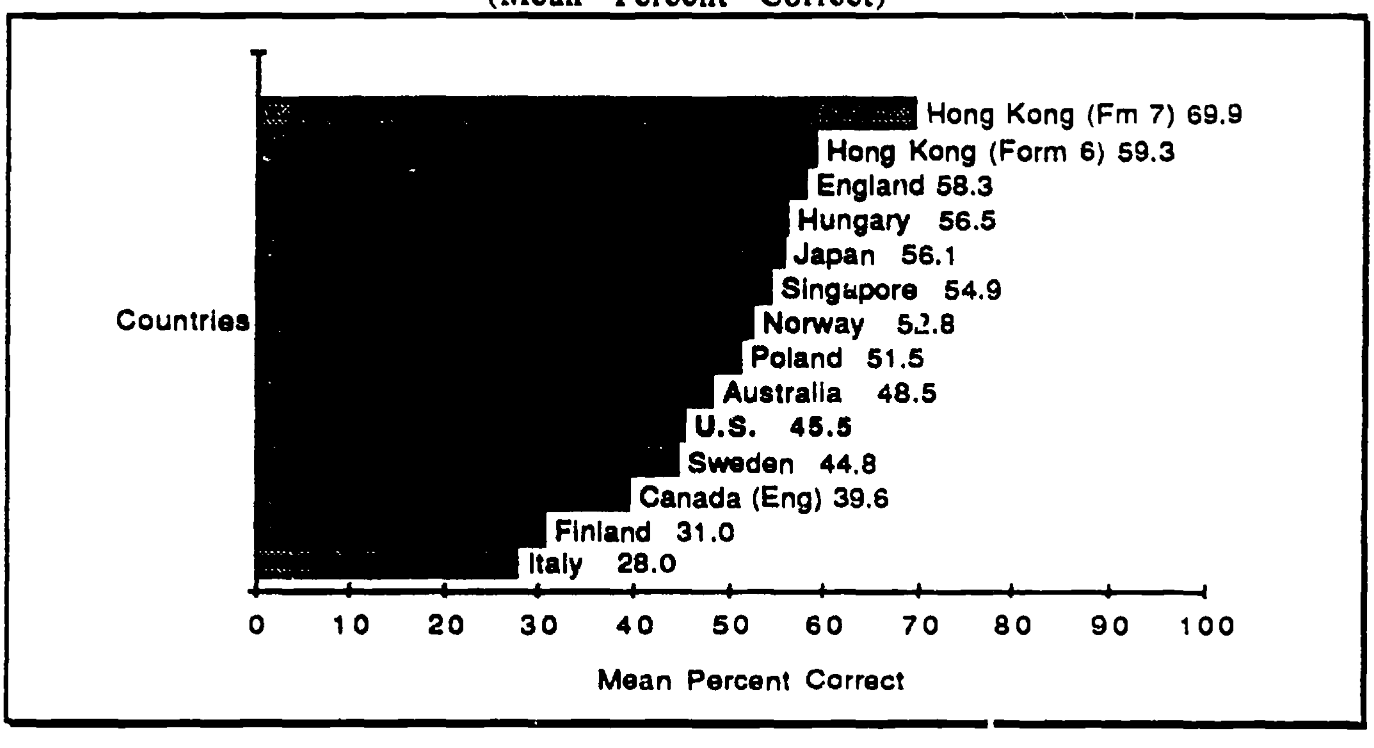
ACHIEVEMENT IN PHYSICS*

> *Prior learning in physics may contribute to learning in earth science, chemistry, and additional learning in physics. (Tamir, 1985, p. 17-18)*

In U.S. schools, physics as a subject usually is studied for one year in the 12th grade. In 1985-1986, about 81% of schools with Grades 10-12 offered a course in physics. A second year of physics was offered in 11% of the schools with Grades 10-12 (Weiss, 1987, p. 16). It was estimated that in the school year 1981-1982, about 504 thousand students studied physics (Welch, et al., 1984, p. 16) in Grade 11 or Grade 12. It was estimated that 16% of American high school students study a year of physics. By contrast, approximately 1.5% of U.S. high school graduates have studied a second year of physics. Comparisons of the second year physics students in the United States with those of other countries are given in Figure 20. (Note that there are two populations reported for Hong Kong.) The U.S. data are based on results from 26 common items from the international test.

FIGURE 20

Physics Specialists
(Mean Percent Correct)



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*For a much more extensive discussion of physics education see Chandavarkar, M. S., Physics in the United States Schools. New York: Second IEA Science Study--U.S., Teachers College, Columbia University, (Work in Progress).

In the spring of 1986, a sample of 474 students who were completing a second year of study of physics responded to two instruments. The first instrument consisted of 30 science achievement items. Twenty-six of these items were international items, and four were U.S. national option items. The second instrument consisted of a mathematics test of 15 items, a student questionnaire, an opin'ɔnnaire seeking opinions about science and schools, and a word knowledge test. Most of the results from the second instrument are discussed in other chapters.

On a set of 26 common items, the second year physics students had a mean score of 46%. Earlier, a first year physics sample of 2,719 was tested with a mean score of 35%. From first year physics to second year there was an improvement of about 11% for second year physics students as compare.. to first year physics students.

Hong Kong (Form 7) had the highest mean achievement score in physics.

The scores of the U.S. second year physics students ranked 9th of 13 countries. The scores of the U.S. students were about the same as those of Sweden, better than those of Canada (Eng.), Finland, and Italy. However, it should be noted that, with the possible exception of Hungary, all of the highest-scoring countries have early specialization. In countries such as Hong Kong, England, and Singapore, students can choose to specialize at about the age of 15. They then study largely science and mathematics for three years. These early science specialists devote more time to science and mathematics than do students in some other countries, including the U.S.

In physics in the United States, about 38% of the variance was between schools. In having such a high between school variance, the United States was joined by Hungary, Japan, and Poland. A student's chance to achieve in physics depended to a considerable extent upon the school attended.

The results also were analyzed to find the percent of schools that scored below the lowest scoring school in the country that had the highest scores (Hong Kong, Form 7). About 89% of the U.S. schools scored lower than the lowest school in Hong Kong (Form 7).

Physics is the science most often taught in the 12th grade, and all of the students in second year physics usually have had a previous year of physics and at least one year of chemistry. Most advanced physics students have strong back-grounds in science and mathematics.*

*These analyses are from Ferko, A. M., Advanced Science Student Achievement in Biology, Chemistry, and Physics. New York: Second IEA Science Study--U.S., Teachers College, Columbia University, (Work in Progress).

TABLE 9

Scores of Some Sub-Groups of Advanced Physics Students Tested

	N	Mean Score in Percent
All Advanced Physics Students	500	45.5
Advanced Placement Students	280	49.0
NonAdvanced Placement Students	220	41.3
Students with at Least Four Years of Science	381	47.4
Students with Less than Four Years of Science	119	40.2

As shown in Table 9, here appears to be some advantage in being enrolled in an advanced placement physics program or having completed four years of science. However, since most of these students do have strong backgrounds in science, there is little difference in the scores of the different sub-groups of physics students.

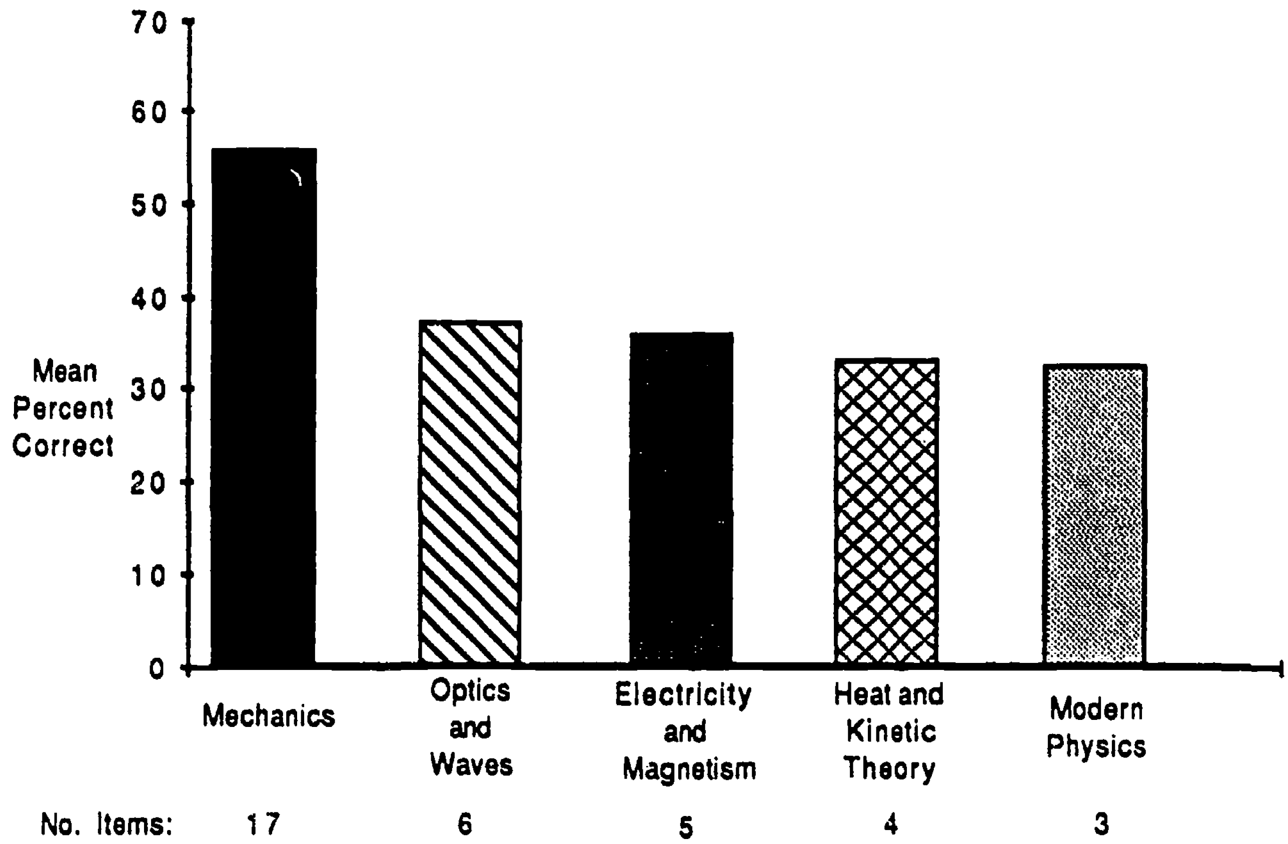
There is some evidence that prior learning of physics can contribute to learning in other sciences (Tamir, 1985, pp. 17-18). It may be that in the U.S. and other countries the possible contributions of physics concepts are not utilized as well as they might be. If a knowledge of physical science concepts does contribute to learning in other sciences, then the improvement of learning in physics is important for learning in other sciences as well.

Certainly, an international instrument has to contain items that deal with the content that is widely accepted in the countries that participate. Many of these items are in the field of mechanics. Curriculum analyses in the United States also indicate that mechanics is the most intensively studied section of physics. It is also the section of physics in which U.S. students had the highest mean score.

Figure 21 on Page 48 shows the mean percent correct in the various content areas of physics. It shows the emphasis on mechanics. This emphasis has been reported in other countries as well.

FIGURE 21

Physics Content Areas
and Mean Percent Correct (1986)*



Note: Since we do not have the comparable difficulty of items in different areas, direct comparisons should not be made.

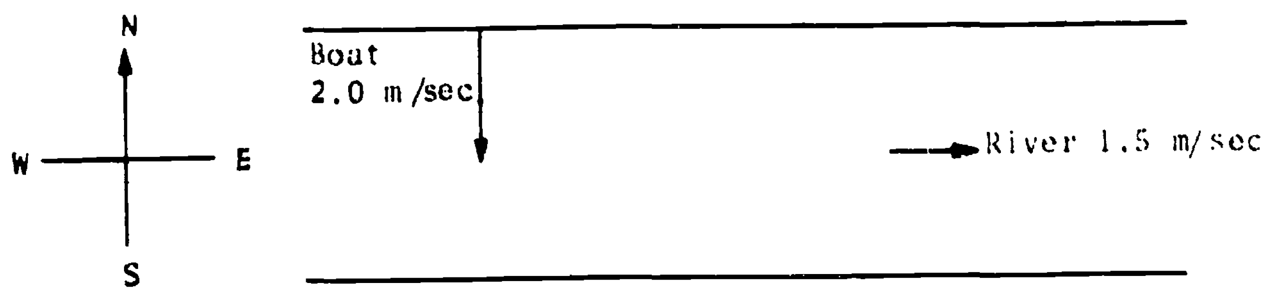
(Chandavarkar, 1988, p. 146)

U.S. second year physics students had their highest score on an item involving vectors (see Figure 22).

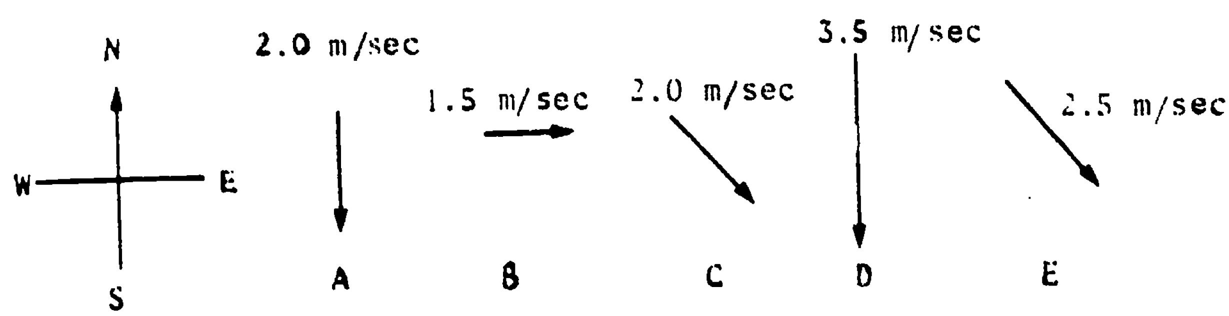
FIGURE 22

Item on Which U.S. Second Year Physics Students Did Best

A river flows due East at 1.5 m/sec. A motor boat leaves the North bank and heads due South at 2.0 m/sec.



Which of the vectors below represents the velocity of the boat relative to the river bank?



Percent Responding	
2.0	A
2.4	B
7.6	C
0.0	D
87.9	*E

While the item shown in Figure 22 features vectors, the problem is posed in a context which may be familiar to many students. In any case, about 88% of the U.S. second year physics students answered this item correctly.

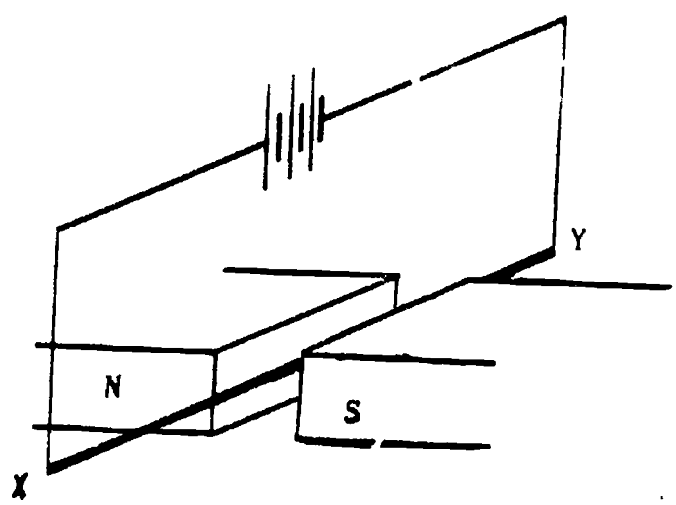
The most difficult physics item required an understanding of the relationship between magnetic and electrical fields and motion.

The item on which U.S. advanced physics students had the greatest difficulty involved the direction of motion of a conductor within the magnetic fields of a magnet and a flowing current (see Figure 23).

FIGURE 23

Item on Which U.S. Advanced Physics Students Had the Greatest Difficulty

A wire with an electric current passing through it is placed in a magnetic field as shown in the diagram.



Which direction will the wire move?

Percent Responding		
20.3	A	towards the North pole
12.9	B	towards the South pole
25.1	C	vertically up
14.8	*D	vertically down
17.1	E	in the direction of point Y

Of course, this item was rather difficult because certain conventions had to be remembered. Students had to remember the direction of current flow from the symbol for electric cells. They had to remember the convention for the direction of magnetic lines of force. They also had to remember how a conductor carrying a current is affected by magnetic lines of force. Each of the choices was attractive to some students, leading to a chance distribution. While this item was a difficult one, still, it is surprising that the correct answer was given by a lower percentage than chance.

Summary. In physics achievement, the U.S. advanced physics students ranked ninth of 13 countries. Hong Kong (Form 7) had the highest mean score; 89% of the U.S. schools scored lower than the lowest scoring school in Hong Kong (Form 7). There was a high between school variance in the U.S., Hungary, Japan, and Poland. U.S. second year physics students had a mean score 11 percentage points higher than that for first year physics students. In physics, as in both biology and chemistry, there appeared to be an advantage in being enrolled in an advanced placement course or in having taken at least four years of science.

Chapter VIII

SCIENCE ACHIEVEMENT IN THE 1970S AND 1980S*

There is little evidence of improvement of science achievement from 1970 to the 1980s.

One of the features of the Second International Science Study was that some of the questions, called "bridge items," were also used in the First International Science Study in 1970 so that some comparisons could be made between science achievement and teaching-learning conditions in 1986 with those in the early 1970s. There were also questions, called "anchor items," that were used at different grade levels so that comparisons could be made between science achievement in the 5th and 9th grades. Particularly interesting were the comparisons in growth between 5th grade and 9th grade in the 1980s as compared to the early 1970s.

There were many difficulties involved in making comparisons between two time periods. For example, the quality of the printing of the instruments in 1986 may seem to be better than it was in the earlier testing. To what extent did this affect the scores? In this study, the assumption was made that, in general, minor differences did not have a substantial effect upon the outcomes. In fact, it may very well be that small differences in the number of criteria counteract each other. In any case, the assumption was made that the various factors and conditions under which the testing was done were essentially the same in the early 1970s as in the 1980s.

The emphasis in this report is upon those results where there were interesting and important differences between the 1980s and the 1970s. In some cases, there will be mention of no significant differences between conditions or scores in 1970 and 1980.

There were no significant differences in science achievement between the fifth grade in 1970 and the fifth grade in 1986. However, for the ninth grade, the students in 1986 scored lower than those in 1970. The decline in scores from 1970 to 1986 for the ninth grade, is especially disconcerting. As will be seen in other results, we seem to be having difficulties in science achievement in the ninth grade in our schools. See Figure 24 on the next page.

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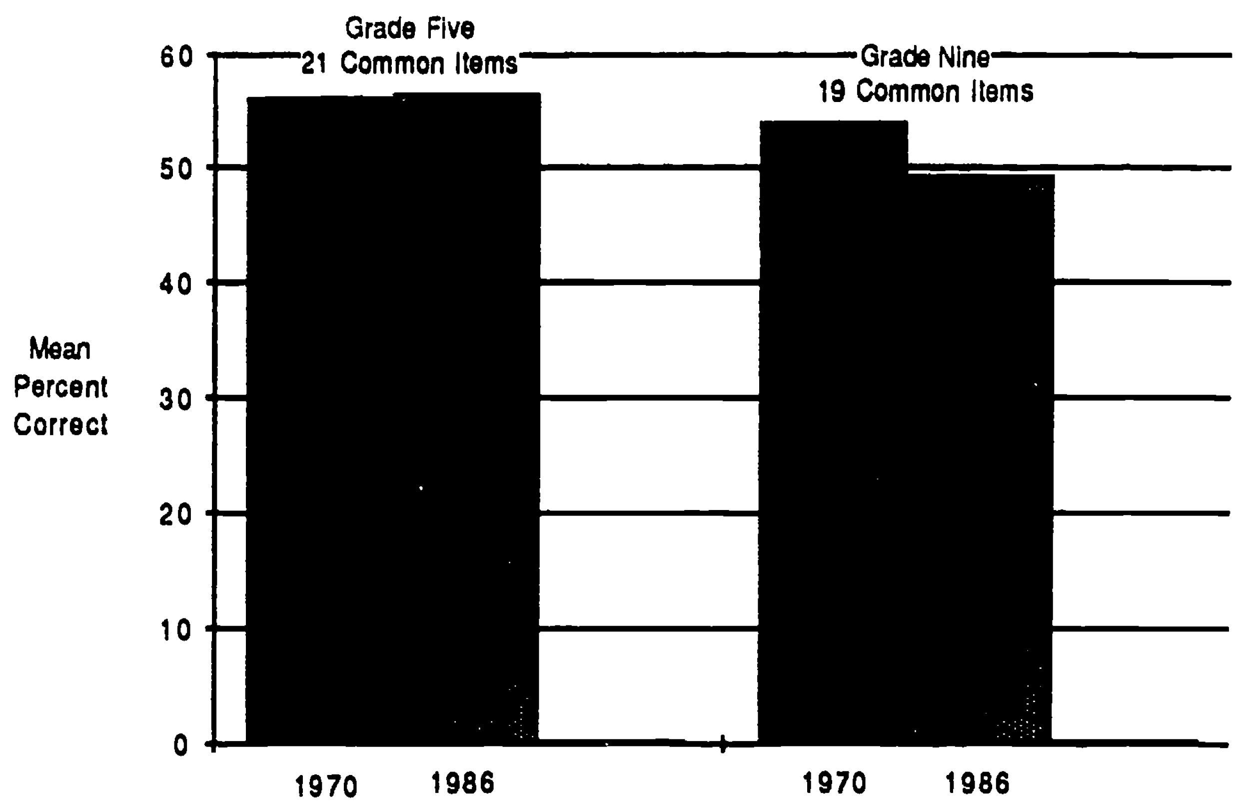
* A much more intensive discussion of achievement in the 1970s and 1980s is in Chang, E. Y. T., Science Education in the 1970s and 1980s: What Changes Have Taken Place? New York: Second IEA Science Study--U.S., Teachers College, Columbia University, (Work in Progress).

FIGURE 24

Science Achievement in 1970 and 1986
Mean Percent Correct

	GRADE FIVE			GRADE NINE		
	1970	1986	1986 minus 1970	1970	1986	1986 minus 1970
N	3504	2838		2339	2518	
Mean	55.9	56.3	+0.4	53.8	49.2	-4.6
S.D.	20.9	19.1		17.9	17.6	



On bridge items classified as being life science items, there were no differences in the scores between fifth grade studerts in 1970 and in 1986. However, ninth grade students scored 3.6% lower on life science items in 1986 than in 1970. On physical science items, fifth grade students in 1986 did about as well as their counterparts in 1970. However, the ninth grade students had 5.5% lower scores in 1986 than their counterparts in 1970. In general, there is little evidence of improvement in scores on common items from 1970 to 1986 in Grades Five and Nine.

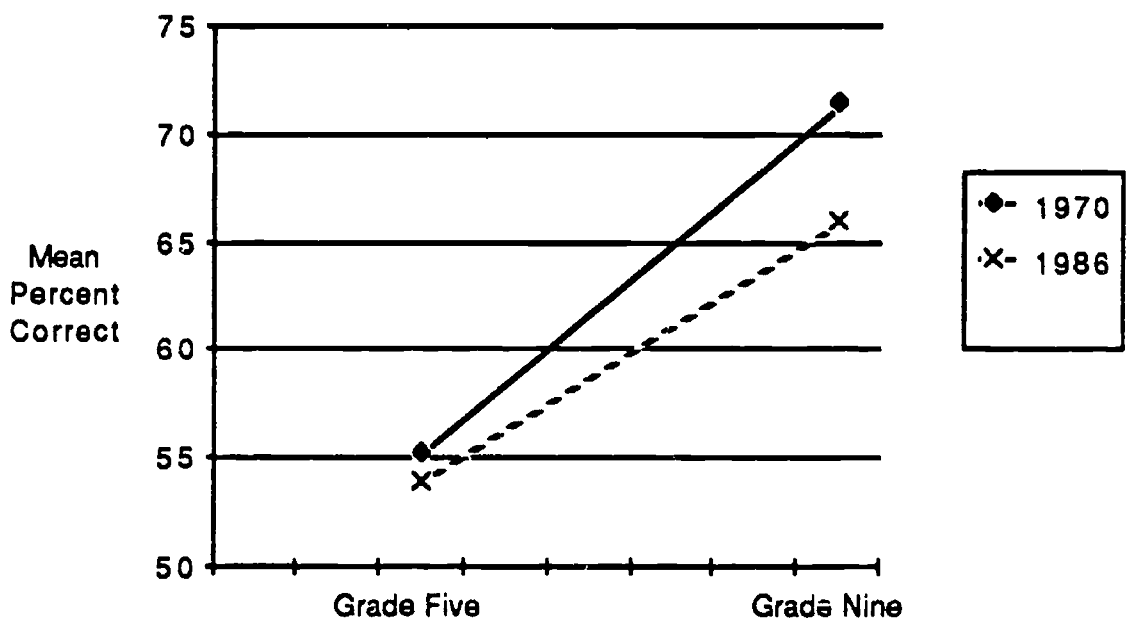
Items were classified as being "process" items or "nonprocess." There were 10 process items in the Grade Five instrument and 12 process items in the Grade Nine instrument. Grade Five students in 1986 scored essentially the same on science process items and nonprocess items as did their counterparts in 1970. In the ninth grade, there was a decrease of about 5% in the scores on process items from 1970 to 1986 and on the nonprocess items there was a decline of 4.2% between scores from 1970 to 1986. Why was there such a decline in scores in the ninth grade between 1970 and 1986?

There were items called "bridge/anchor" items that were used in both fifth grade and ninth grade in 1970 and in 1986. A study of the results on these items can yield a measure of the improvement from one grade level to another. Particularly intriguing is the question, "Are students making as great a gain between fifth and ninth grade now as they did in 1970?" There were nine "bridge/anchor" items between fifth grade and ninth grade. These nine "bridge/anchor" items consisted of four life science items and five physical science items. There was a smaller gain between Grade Five and Grade Nine in 1986 than there was in 1970. There was a gain of 12.1% between Grade Five and Grade Nine in 1986. This can be compared to a gain of 16.3% between Grade Five and Grade Nine in 1970 (see Figure 25).

FIGURE 25

Growth and Achievement from Grade Five to Grade Nine in 1970 and 1986

Study	Grade Five Mean %	Grade Five S.D.	Grade Nine Mean %	Grade Nine S.D.	Grade Nine minus Grade Five
1970	55.1	22.9	71.4	20.4	+16.3
1986	53.8	23.4	65.9	23.0	+12.1



The growth in science achievement from Grade Five to Grade Nine was less in 1986 than in 1970.

The decline in growth between Grades Five and Nine in 1986 as compared to 1970 is perplexing. To what extent is this decline due to the overall decline in the achievement of ninth graders?

The students were asked about the amount of homework that they did. In Grade Five in 1986, the students spent an average of 2.9 hours on homework a week, while the 1970 counterpart students devoted 3.7 hours on homework. per week. Again, at the ninth grade level, the students in 1986 were devoting less time (4.4 hours per week) as compared to their counterparts in 1970 who devoted, on the average, 5.9 hours per week to homework. Thus, there appears to have been a decline in the amount of homework done by students at both the fifth and ninth grade levels in 1986 as compared to 1970.

Fifth grade students watched television more hours in 1986 than in 1970. About 25% of the students in 1986 watched six or more hours of television a day, while, in 1970, only 7% of the students watched six or more hours of television per day. Could it be that some of the hours lost from the homework have been transferred to television watching?

There are many questions that can be raised and difficulties encountered in trying to make a comparative study over a period of 16 years. The difficulties are many. However, this study had a larger number of test items that were kept over a 16 year time-span than in any other research study in science. The very fact that this study, despite its many difficulties, provides some empirical evidence for the notion that we are not making as much progress in science education as many had hoped, is a base upon which this claim can rest. It may be that the same bridge items used in this study can be used again to study change in science achievement over time.

Summary. The science achievement scores on bridge items were about the same for the fifth grade in 1986 as in 1970. However, there was a drop of 4.6% from 1970 to 1986 for the ninth grade. The improvement from fifth grade to ninth grade was less in 1986 (12.1%) than it was in 1970 (16.3%). The analysis of the change in the achievement between 1970 and 1986 points out the weaknesses that apparently exist in 9th grade science. Certainly, further investigation of science for the early adolescent is warranted.

The science achievement scores of fifth grade students were about the same in 1986 as in 1970. There was a drop in achievement from 1970 to 1986 in the ninth grade.

Chapter IX

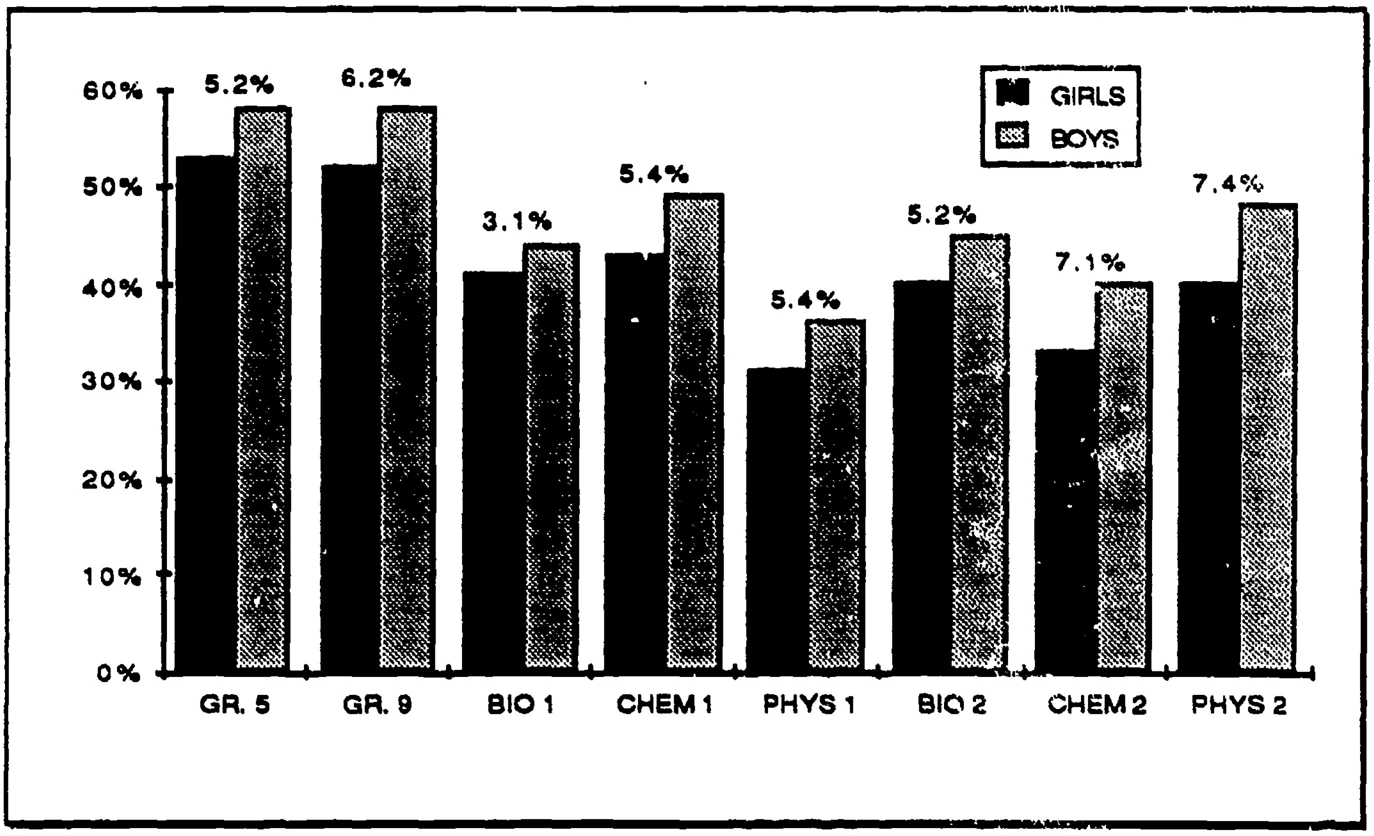
SEX AND SCIENCE ACHIEVEMENT*

In the U. S. at all grade levels and in all science subjects, boys had higher science achievement than girls.

In a number of studies, including the First International Science Study (FISS) that was carried out in 1970, boys generally had higher achievement scores in science than girls. Since science achievement was studied in three different grades and in three different science subjects in the Second International Science Study (SISS) in the United States, there was an excellent opportunity to study the comparative science achievement of boys and girls in schools in the U.S. and around the world. The graph in Figure 26 and Table 10 on the next page show the science achievement percent difference of boys and girls in the U.S. at Grade 5, Grade 9, first year biology, first year chemistry, first year physics, second year biology, second year chemistry, and second year physics. These are the scores for the students in the United States. In the United States boys had somewhat higher scores in all grades and in all subjects. Differences between males and females in science achievement range from 3.1% in first year biology to 7.4% in second year physics.

FIGURE 26

U.S. Male/Female Science Achievement and Percent Differences



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* A more extensive discussion of sex and science achievement is in: Humrich, E., Sex and Science Achievement. New York: Second IEA Science Study--U.S., Teachers College, Columbia University (Work in Progress).

TABLE 10

Population Descriptions and Percent of Each Sex Scoring Correctly

Grade/ Course	Number: Females N	(Percent)	Males N	(Percent)	Percent Scoring Correctly: Females	Males	Difference
Five	1426	(51.0)	1372	(49.0)	52.6	57.9	5.3
Nine	1204	(48.1)	1301	(51.9)	52.1	58.4	6.3
Nonscience	1131	(56.0)	890	(44.0)	45.0	48.8	3.8
Biology 1	1321	(53.5)	1148	(46.5)	41.4	44.5	3.1
Chemistry 1	1091	(47.6)	1201	(52.4)	43.3	48.7	5.4
Physics 1	997	(37.1)	1687	(62.9)	30.5	35.9	5.4
Biology 2	369	(58.5)	262	(41.5)	40.2	45.4	5.2
Chemistry 2	231	(43.6)	299	(56.4)	35.7	42.8	7.1
Physics 2	101	(21.4)	372	(78.6)	40.2	47.6	7.4

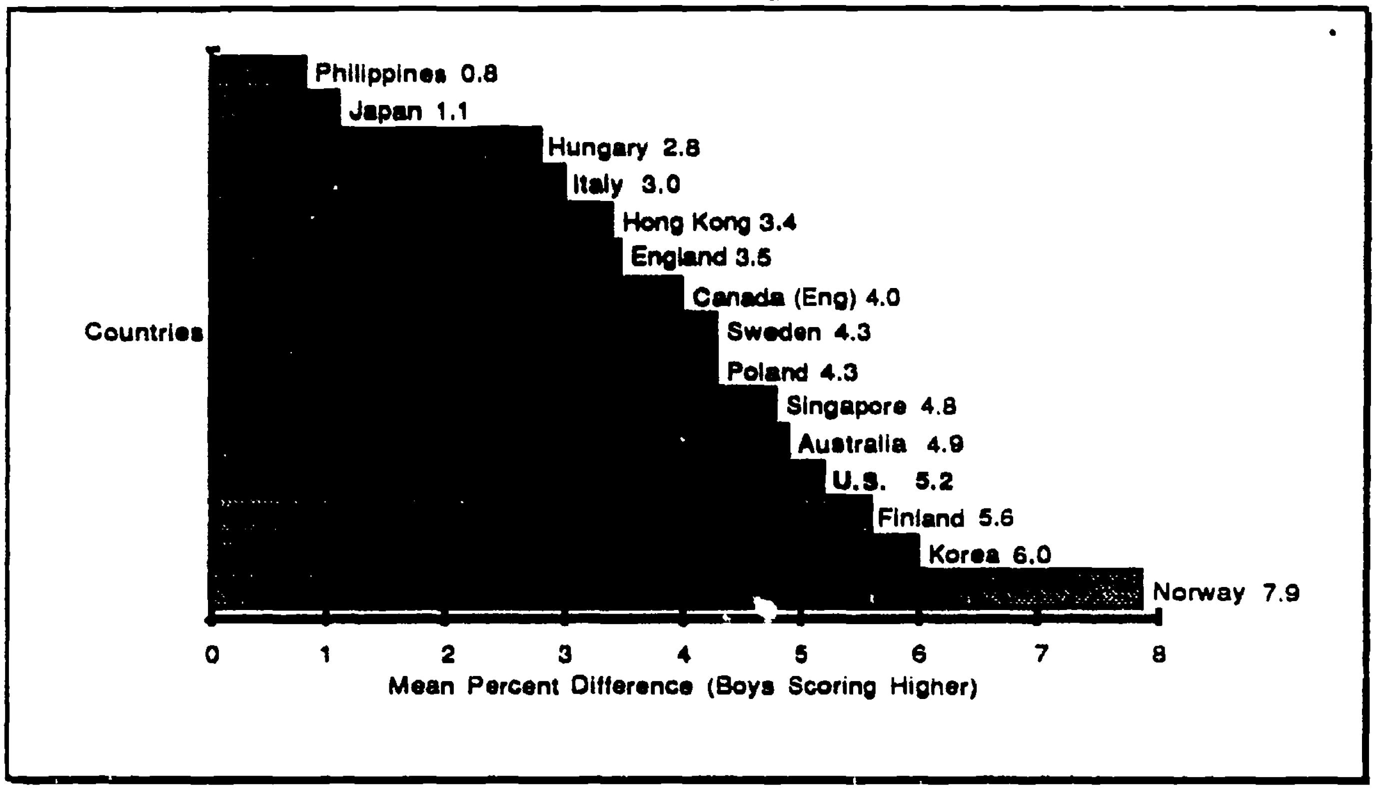
NOTE: Mean scores in this table are based on the complete tests taken by the students.

Thus, in the U.S. boys had higher science achievement scores than girls in all grades and in all subjects tested. But, one of the advantages of an international study is that phenomena can be studied in several countries and several cultures. The results in different countries are given in the following graphs. It should be remembered that the U.S. students in the study were advanced science students who had had more than one year of a particular specialized science. For example, the biology specialists had had two years of biology.

The differences in science achievement between males and females have been studied in a number of countries in the IEA Study. The countries and the "mean percent difference" in science achievement are given for the common, international items. For example, in the Philippines in Grade Five there is only an 0.8% difference in the mean scores of boys and girls. This is contrasted with the 7.9% difference in scores between boys and girls in Norway.

The male-female mean percent differences in Grade Five in 15 countries and Grade Nine in 17 countries are shown in Figures 27 and 28, respectively.

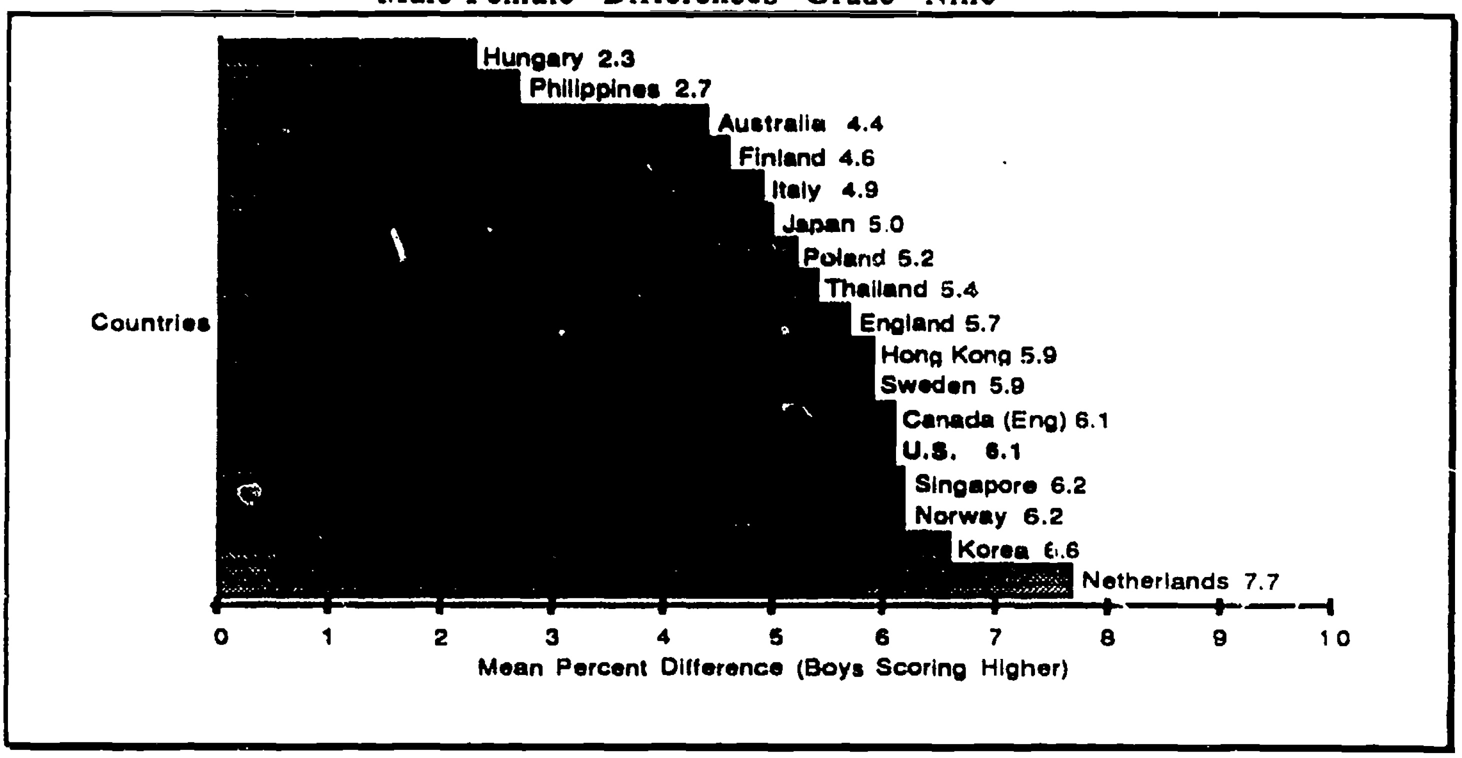
FIGURE 27
Male-Female Differences Grade Five



The U.S. Grade Five students ranked 12th with a male/female difference of 5.2%. Finland, Korea and Norway had greater differences on male and female mean achievement.

> **In Grade Five, the Philippines had the smallest male-female differences in mean achievement in science.**

FIGURE 28
Male-Female Differences Grade Nine

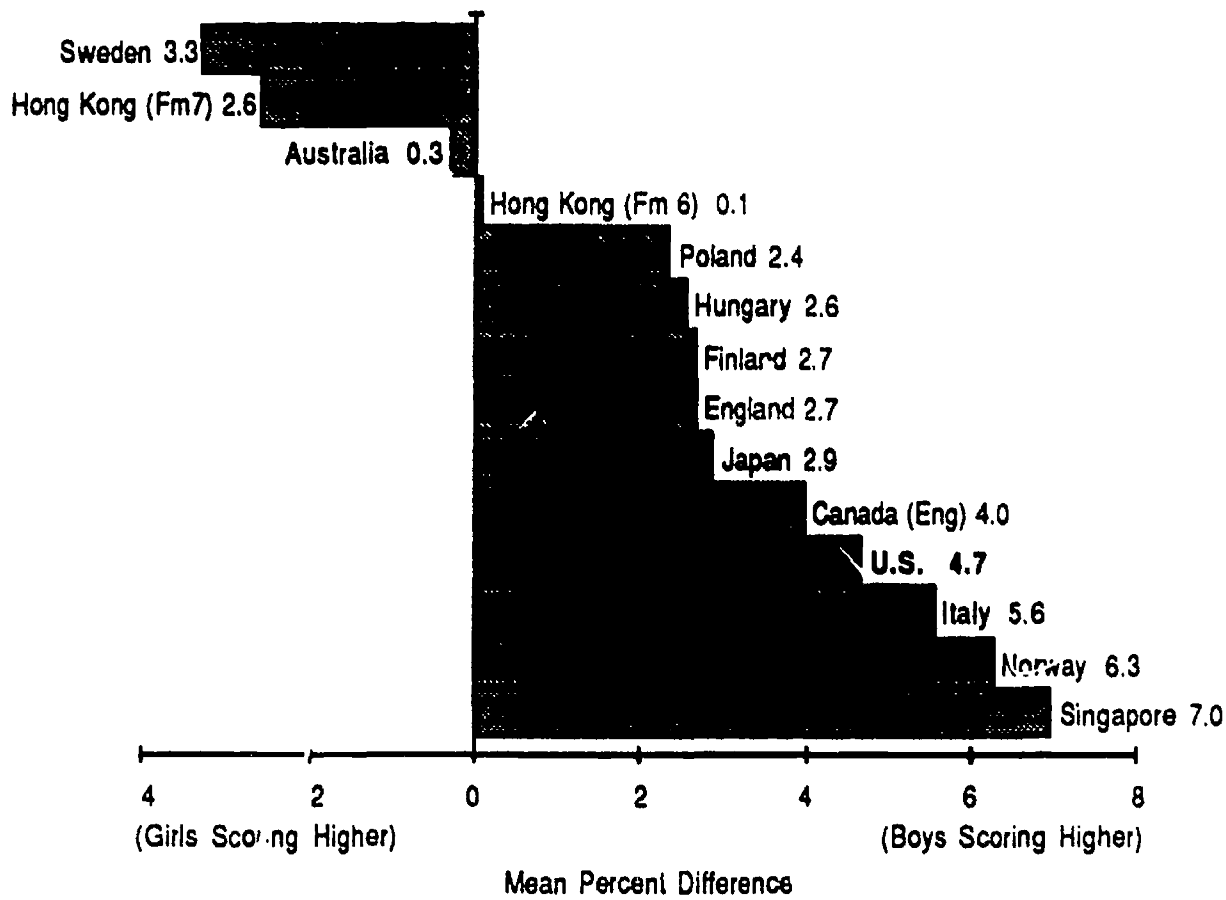


In Grade Nine, Hungary and the Philippines had the smallest male-female differences in science achievement.

In Grade Nine the differences between the scores of boys and girls tended to be somewhat greater than in Grade Five. In Hungary the mean percent difference between scores of boys and girls was 2.3%, while in the Netherlands the difference was 7.7%. The United States ranked 13th of 17 countries with a mean percent difference between the scores of boys and girls of 6.1%. Only Singapore, Norway, Korea, and the Netherlands had larger differences between the scores of boys and girls. In Hungary, Australia, and Finland, the mean percent differences between boys and girls declined from fifth grade to ninth grade.

FIGURE 29

Male-Female Differences in Advanced Biology



Biology is the only subject, in some countries, in which girls scored higher than boys.

Biology is the only subject in which girls did better than boys in science achievement in some countries (see Figure 29). In Sweden, Hong Kong (Form 7), and Australia the girls had higher science achievement scores than boys. Is there something about the way biology is studied and taught in these three countries that reduces the differences between boys and girls and, in fact, leads to girls having slightly better science achievement scores than boys?

In 10 countries the boys had higher biology science achievement scores than the girls. The greatest difference in achievement between boys and girls was in Singapore, where there was a 7% difference between boys' and girls' science achievement. U.S. students had a difference of 4.7% between the boys' and the girls' biology achievement scores. The U.S. ranked 11th of the 17 countries in the difference between males and females in biology achievement. Italy, Norway and Singapore ranked lower.

Except for biology in three countries, there is a pervasive difference in male and female science achievement in all subjects and in all countries. What causes this difference in science achievement between males and females? In general the differences are less in biology than in chemistry and physics. Is there something about biology and the way it is studied and taught that leads to a comparatively smaller difference between males and females in biology than in chemistry and physics? One of the obvious ways to explore the question is to take a look at biology in Sweden, Hong Kong and Australia.

In chemistry, Sweden had the smallest male-female differences in achievement.

In chemistry the differences between the boys' science achievement score and the girls' science achievement score ranged from 0.7% in Sweden to 12.5% in Hungary. Of the 14 countries that tested in chemistry, the United States ranked tenth in the differences between boys' and girls' chemistry achievement with a 7.5% difference. The relatively large difference between boys and girls science achievement scores in Hungary is puzzling. In Grade Nine, Hungary had the smallest percent difference between boys and girls. In biology it only had a 2.6% difference between boys and girls. What factors have led to such a large difference between the scores of boys and girls in chemistry in Hungary?

The difference between boys' and girls' achievement scores in the United States was greater in chemistry than for either biology or physics (see Figure 30). Interestingly, the largest difference between boys and girls in biology was in Singapore, where there was a difference of 7%. This difference is less than the difference in chemistry in eight countries. Is there something about chemistry and the way it is taught that leads to such relatively large differences in achievement between boys and girls?

In physics, England had the smallest difference between male and female scores.

Boys scored higher than girls in physics in all countries (see Figure 31). The differences range from 0.6% in England to 8.9% in Poland. Of the 14 countries that tested in physics, the United States students ranked ninth with a difference in scores between boys and girls of 6.6%.

FIGURE 30
Male-Female Differences in Advanced Chemistry

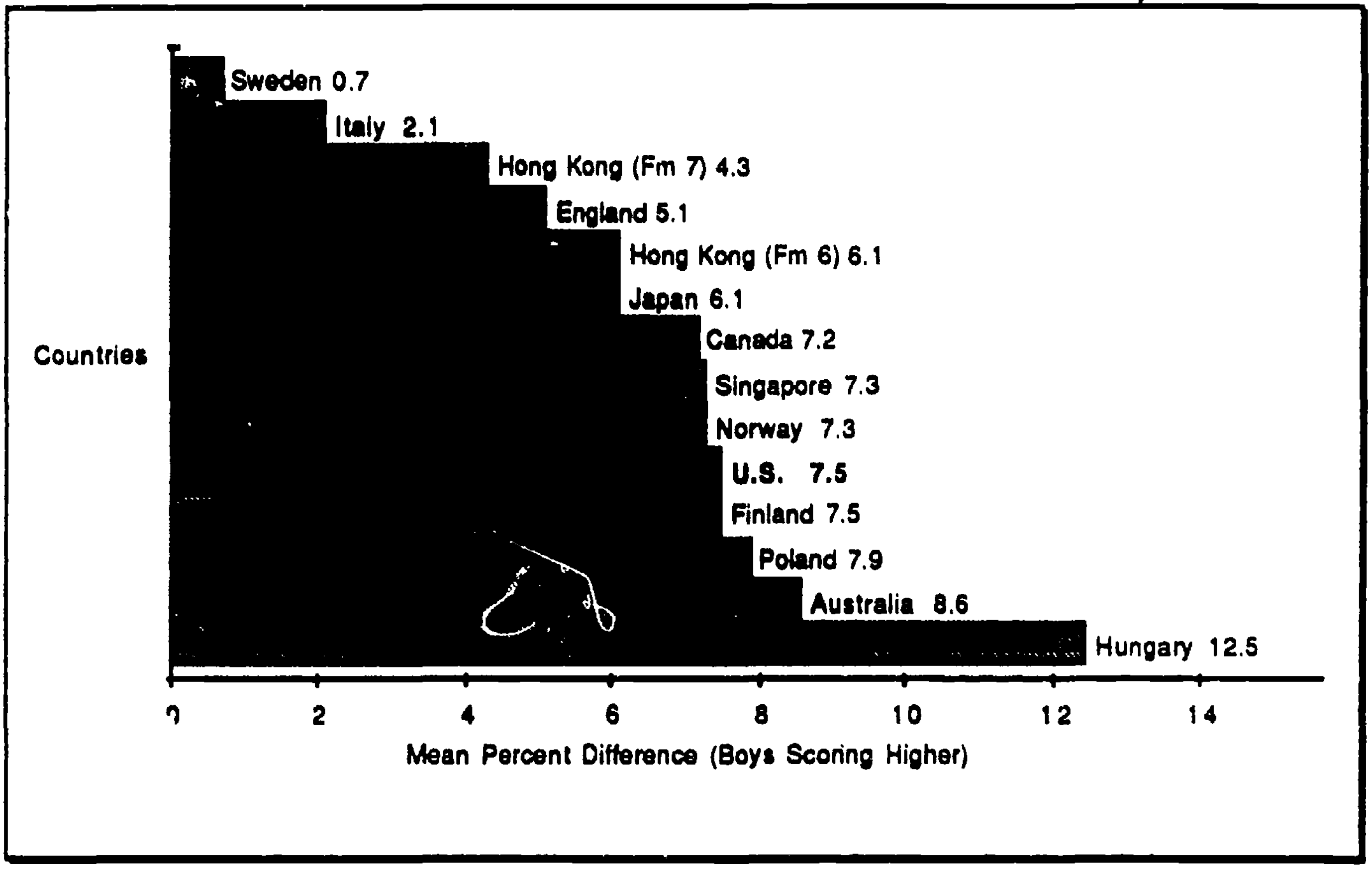
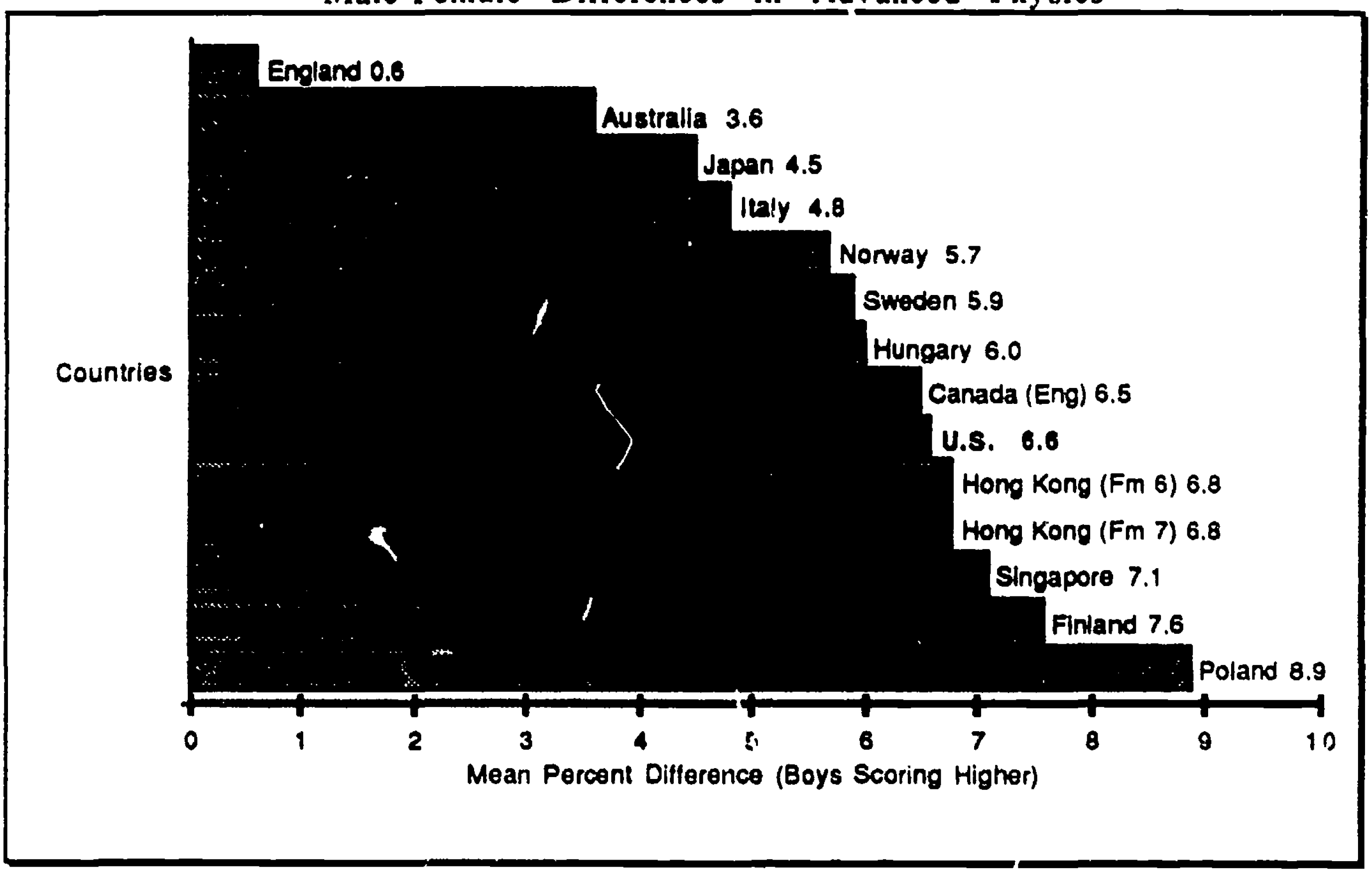


FIGURE 31
Male-Female Differences in Advanced Physics



The difference in achievement in physics is much smaller in England than in other countries. What is there in the study of physics in England that leads to this small male-female difference?

It was hypothesized that there would be a smaller sex difference in science achievement in the biological life sciences than in the physical sciences. The items in the achievement tests for Grades Five and Nine were classified as to whether they were physical science or life science. The difference between boys and girls in science achievement was greater in the physical sciences than in the biological or life sciences. In the secondary school, boys had higher science achievement than girls in each of the content areas. However, the difference between scores of boys and girls in biology was smaller than in chemistry or physics. Overall, it was found that there was a smaller sex difference in science achievement in the biological or life sciences than there was in the physical sciences.

The differences between boys and girls in science achievement was greater in the physical sciences than in the life sciences.

The items in the science achievement tests were classified as to whether they dealt primarily with knowledge, comprehension, or application. Of these categories, application is considered to be the highest level of cognitive classification. It had been hypothesized that there would be a larger sex difference in the area of application as contrasted to the areas of knowledge and comprehension. The results were mixed, and in many categories there were no significant differences. However, in biology in the tenth grade the difference between sexes in application was considerably lower than in the other two categories. Overall, the U.S. data do not support the hypothesis that larger sex differences would be found in the area of application than in the areas of knowledge and comprehension.

A unique feature of this study was the "hands-on" science process laboratory tasks that were administered to Grades Five and Nine (see Chapter X). To answer the questions in these tests, the student had to carry out certain kinds of laboratory operations. For example, the student might have to measure the temperature of a liquid or weigh an object. Students were required to use simple equipment and apparatus to carry out certain manipulations. After having carried out these manipulations and gathered data they were also asked to interpret and explain their findings.

It was hypothesized that on these science process laboratory skills tests there would be no differences between boys and girls. Overall, there was no significant difference between boys and girls on their scores on these laboratory science process skills tests. Girls, for example, scored somewhat higher on a ninth grade item called "Color Chromatography." This item required observation and interpretation. Boys, on the other hand, did better on items dealing with electricity. Both boys and girls did better at carrying out manipulations and making observations than they did in interpreting and explaining what had happened. It has been suggested that girls may do as well as boys in science when they are given equal access to equipment and materials. It may be that, too often, girls have to compete with boys in getting access to equipment and materials in classrooms and laboratories and, therefore, have less opportunity to engage in the "hands-on" dimension of science.

It has been suggested that female students would do better if they had access to or were taught by female science teachers. In Grade Five, 69% of the teachers were female. The sex of the teacher seemed to have no significant influence upon student achievement in Grade Five. In Grade Nine, 32% of the teachers were female, but the male teachers seemed to have a more positive impact on student achievement than female teachers. Interestingly, in biology, female teachers had a slightly greater influence on the science achievement of both boys and girls than did male teachers. For reasons that are not completely clear, female teachers seemed to be more effective in biology than in the physical sciences. In first year chemistry there seemed to be little gender difference in science achievement of students of male or female teachers. At the advanced level in both chemistry and physics, students of male teachers had higher achievement. Overall, the students of female teachers, both girls and boys, had higher achievement in biology. Male teachers had a more positive impact on students of both sexes in chemistry and physics. Unfortunately, there were too few female teachers in advanced physics (3) to provide sufficient data for valid comparisons.

Students of female teachers did better in biology. Students of male teachers did better in the physical sciences.

It has been suggested that there is a positive relationship between science achievement and background in mathematics. Boys scored higher in mathematics in tests associated with biology and chemistry. There was a small and insignificant difference between girls and boys achievement in physics and mathematics. Both boys and girls who scored higher in mathematics also scored higher in science. However, the relationship between scores in mathematics and scores in science was stronger for the boys than for the girls.

Secondary school students reacted to a "word knowledge" test consisting of paired words that students had to identify as "same" or "opposite." This Word Knowledge Test has been used to determine the level of verbal ability of the respondents. It was found that there was a relationship between the score on the word knowledge test and the science achievement for both girls and boys. Further, the relationship between word knowledge test score and science achievement was stronger for boys than for girls.

Summary. In the First International Science Study there was a pervasive difference in science achievement between boys and girls. These differences seem to continue through the Second International Science Study. Certainly, a very important problem has been identified. The lack of significant differences on the process tests is suggestive of steps that can be taken to raise the relative scores of girls in science. What else can be done to raise the science achievement of girls?

Chapter X

SCIENCE PROCESS LABORATORY SKILLS*

U.S. students in Grades Five and Nine were successful in manipulating, measuring, and recording, but were much less successful in explaining, investigating, and reasoning. The expected male-female differences were almost non-existent on these science laboratory skills tests.

The emphasis on inquiry skills, experimentation, and laboratory activities in science programs has been high in the U.S. for several decades. Curriculum projects and, subsequently, commercial materials have incorporated these goals into instructional products that are available for school use. Researchers have cited the impact of their programs on gains in student cognition, attitudes, science skills, and creative outcomes.

In the First IEA Science Study (FISS, 1970), students in England and Japan responded to an optional laboratory practical test (in Grade Nine). Comber and Keeves (1973, p. 104) concluded that these laboratory practical tasks were "measuring some attributes quite distinct from those measured by the written examination, and that these attributes are only probed to a limited extent by the pencil and paper type of 'practical' items."

As part of the Second IEA Science Study (SISS), six countries administered science laboratory skills tests to students in Grades Five and Nine. These countries were Hungary, Israel, Japan, Korea, Singapore, and the U.S.A. The U.S. data collection was conducted in the spring of 1986 with a sample of 2,585 fifth grade students and 2,248 ninth grade students.

A science process laboratory skills test can be designed and administered in elementary and secondary schools.

The U.S. process tests were administered by trained test administrators. The equipment and materials used in the process testing were identical in each of the schools tested. A detailed set of directions was prepared which standardized the in-class administration of the process tests. The test booklets completed by the students were scored by another set of people. These scorers were trained to examine the detailed answers for each of the science tasks.

The skills tests were developed by the researchers in the six participating countries. Students were asked to manipulate equipment and materials, observe, reason, record data, and interpret results. These specific skills were classified into three general categories: Investigating, Performing,

* A more extensive treatment is in Kanis, I. B., An Analysis of the Science Process Practical Examination Administered to Grade Five and Grade Nine Students in the United States of America, New York: Second IEA Science Study--U.S., Teachers College, Columbia University, (Work in Progress).

and Reasoning. Figure 32 shows the specific skills included in these three general categories. The tests were based on science content and equipment believed to be common to the respective grade levels, with the biology, chemistry, and physics areas being represented.

FIGURE 32

Process Test Categories

Skill	Comments
Performing	To include: observing, measuring, manipulating.
Investigating (problem solving)	To include: planning and design of experiments.
Reasoning	To include: interpreting data, formulating generalizations building and revising models.

Figures 33 and 34 list a description of the tasks in each of the process tests used in Grades Five and Nine.

FIGURE 33

Process (Lab) Tests Used in Grade Five, Second IEA Science Study--U.S.

5A1. Describe and explain color change of bromthymol blue solution after blowing through a straw. (Chemistry)

5A2. Cite at least three similarities and differences of two plastic animal specimens. (Biology)

5A3. Determine if four objects are electrical conductors by testing in a battery-bulb circuit. (Physics)

5B1. Predict and measure the temperature of the mixture of equal amounts of hot and cold water. (Physics)

5B2. Observe and explain the dissolving of coffee crystals in water. (Chemistry)

5B3. Determine which seeds contain oil by rubbing them on paper. (Biology)

FIGURE 34

Process (Lab) Tests Used in Grade Nine, Second IEA Science Study--U.S.

9A1. By testing with battery-bulb apparatus, determine the circuit within a "black box." (Physics)

9A2. Using phenolphthalein and litmus paper, prepare and execute a plan to identify three solutions as to being acid, base, or neutral. (Chemistry)

9A3. Using iodine solution, prepare and execute a plan to determine the starch content of three unknown solutions. (Biology)

9B1. Using a spring scale and graduated cylinder, determine the density of a metal sinker. (Physics)

9B2. Explain movement rates and separation of water soluble dots in paper chromatography activity. (Biology)

9B3. Using a sugar test tape and iodine solution, identify three unknown solutions as to presence of starch and/or sugar. (Chemistry)

The Science Process Laboratory Skills Test

Results from two of the six tasks for Grade Five and two of the six tasks for Grade Nine will be discussed in some detail. For each task, the questions as they appeared in the student test booklet and a picture of the equipment set up as the student experienced it is presented. Then the percentages of students that received the possible point values are discussed.

Temperature of Water Mixture (Grade Five) (5B1)

The equipment for this task was several styrofoam cups, a thermometer, and water at two temperatures (hot and cold). Students were likely to have experienced the measurement of temperature at home and at school. See Figure 35.

The students were asked to measure the temperature of the water in the two cups and then predict the temperature of a mixture of equal amounts of water from the two cups. After pouring the water from the two cups into one cup, they were asked to measure the temperature of the mixture and then explain any differences between their prediction and the measured temperature of the mixture. Lastly, they were asked to apply what was learned in the previous item to a novel situation: "in a paper and pencil 'word problem,' predict the temperature of a mixture of equal amounts of water at 5°C and 75°C."

FIGURE 35

Temperature of Water Mixture (5B1)

	Score	Percent Response
<u>Prediction of Temperature of Mixture</u>		
Within ± 1°C of midpoint (of actual value)	1 pt	16
	0 pts	84
<u>Measure Temperature of Mixture</u>		
Within ± 6°C of midpoint	2 pts	86
Within ± 10°C of midpoint	1 pt	8
	0 pts	6
<u>Explanation of Difference</u>		
Plausible explanation (spill, cooling,	1 pt	26
unequal amounts, etc)	0 pts	74
<u>Predict Temperature of New Mixture</u>		
Temperature of 40°C <u>or</u> temperature of midpoint	1 pt	7
	0 pts	93

INTERNATIONAL SCIENCE STUDY — LAB EXERCISES, SET 5B, PAGE 2

Experiment 1

Use the thermometer to find the temperatures of the water in the cup marked "X" and cup marked "Y."

1. What is the temperature of the water in cup "X"? ____________

2. What is the temperature of the water in cup "Y"? ____________

3. When water from cup "X" and cup "Y" are poured into the larger cup, what do you think will be the temperature of the mixture? ____________

Now pour the water from cup "X" and cup "Y" into the larger cup. Stir the mixture.

4. What is the temperature of the mixture? ____________

5. If the temperature of the mixture is different from what you predicted in Question 3, what might be the explanation?

____

____

6. What do you predict would be the temperature if you mixed <u>equal amounts</u> of water at 5 °C and 75 °C? Explain.

____

____

____

It was decided to not score the first two questions because of the difficulty of maintaining constant water temperature during the testing period. Few students (16%) were successful in predicting the temperature of the mixture (this was a U.S. option question). The measurement of the temperature of the mixture (within 6°C of the midpoint of their measured temperature in questions 1 and 2) was successfully completed by 86% of the students.

The students were not adept at explaining differences between their predicted and measured temperatures for the mixture. Lastly, the percentage of the fifth grade students who were able to predict the temperature of the mixture of two samples of water (5°C and 75°C) was extremely low. Only 7% of the students responded with answers within 1°C of 40°C (the actual midpoint). Many students added the two temperature values (5°C + 75°C) and predicted that the mixture temperature would be 80°C.

Testing Nuts and Seeds for Oil Content (Grade Five) (5B3)

This fifth grade, life science task used familiar materials: nuts, seeds, cooking oil, and Q-tips (see Figure 36). This task reflected the application of the following science process skills: observing, planning, manipulating, recording data, and inferring. This pattern of skills made it an excellent tool for analyzing higher level performance. The students were guided to observe the effect on the paper when rubbed with oil. They were then asked to describe how they would test the seeds (and nuts) for oil. Lastly they indicated which seeds, according to their tests, contained oil.

The students were very successful in completing the first step. Over 80% were able to describe the oily paper as translucent (in appropriate fifth grade words--"can see through" . . .).

Students were much less successful in "planning" their procedures for testing the seeds. Approximately 43% were able to produce an acceptable plan. Identifying both the pecan and peanut as containing oil was done by approximately 39% of the students and an additional 20% correctly identified one of these seeds as containing oil. Approximately 40% of the fifth grade students were not able to complete this last question correctly.

FIGURE 36

Oil from Nuts and Seeds (5B3)

	Score	Percent Response
<u>Oily Q-tip Rubbed Against Paper</u>		
Plausible Description	1 pt	82
	0 pts	18
<u>Plan to Determine Which Seeds Contain Oil</u>		
Adequate Plan	1 pt	43
	0 pts	57
<u>Identity of Seeds That Contained Oil</u>		
Listing Both Pecan & Peanut	2 pts	39
Listing One Seed	1 pt	20
Inappropriate Response or Listed All Seeds	0 pts	41

INTERNATIONAL SCIENCE STUDY — LAB EXERCISES, SET 5B, PAGE 4

Experiment 3

Before you is a "Testing Sheet," a Q-tip, and some cooking oil. Dip the Q-tip in the cooking oil and then rub it against the "Testing Sheet" in the space labelled "cooking oil" and observe what happens.

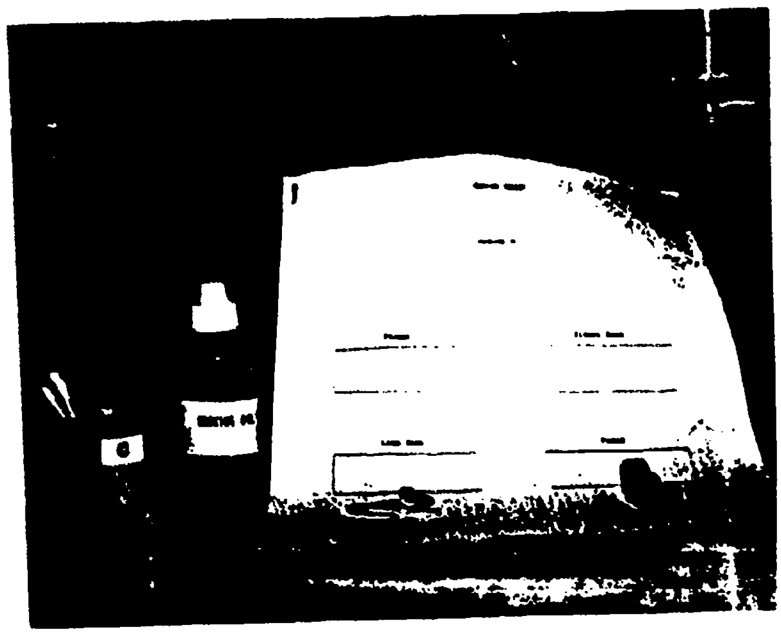
1. Describe what you saw happen when you rubbed the oily Q-tip against the paper.

In a container you will find different plant seeds. Determine which seeds contain oil.

2. Describe the procedure you used to determine which seed(s) contained oil.

3. List the name(s) of the seed(s) which, according to your tests, contain oil.

Throw away the used Q-tip when you are asked to clear your work area.



Testing Solutions for Starch (9A3)

This ninth grade, life science task required students to test three unknowns with prepared iodine solution. They were told what color change occurs in a starch solution when iodine is present. See Figure 37.

Approximately 70% of the ninth graders were able to describe a procedure for testing the solution for the presence of starch. They were told to devise a plan "using a few drops of the iodine solution," and they were expected to place iodine in each of the three solutions. Only 35% of the students were able to successfully perform the testing and recording of results for two of the three samples. The last question asked students to conclude whether each solution contained starch or not and to cite their reasons for this conclusion. Only 31% were able to correctly identify the solutions and cite a logical reason.

FIGURE 37
Testing Solutions for Starch (9A3)

	Score	Percent Response
Describe Plan for Starch Testing		
Adequate plan	1 pt	69
	0 pts	31
Observe/Record Results from Testing		
Correct color changes for all three samples	2 pts	35
Correct color changes for two of three samples	1 pt	23
	0 pts	41
Identify Solutions and Explain Reasons		
Correct identification and logical reason	2 pts	31
Not applicable for this question	1 pt	
	0 pts	69

INTERNATIONAL SCIENCE STUDY — LAB EXERCISES, SET 9A, PAGE 5

Experiment 3

It is suspected that starch has been added to a brand of cream substitute to make it appear thicker. One or more of the samples of cream substitute on the table contain starch.

Iodine solution is used to test for the presence of starch. Starch will turn blue-black in the presence of iodine.

1 Using a few drops of the iodine solution, how would you find out which sample or samples contain starch? Outline your plan.

______

CARRY OUT YOUR PLAN

Record your observations

Sample A ______

Sample B ______

Sample C ______

3 What are your conclusions? What are the reasons for these conclusions?

Sample A Conclusion ______

Reason ______

Sample B Conclusion: ______

Reason ______

Sample C Conclusion ______

Reason: ______

Determining Density (Grade Nine) (9B1)

The equipment for this ninth grade, physical science task was a spring scale, graduated cylinder, metal sinker, and water, and should be available in most junior high school science programs. However, only 35% of the teachers reported that this activity was part of their school's science programs during the current or previous years.

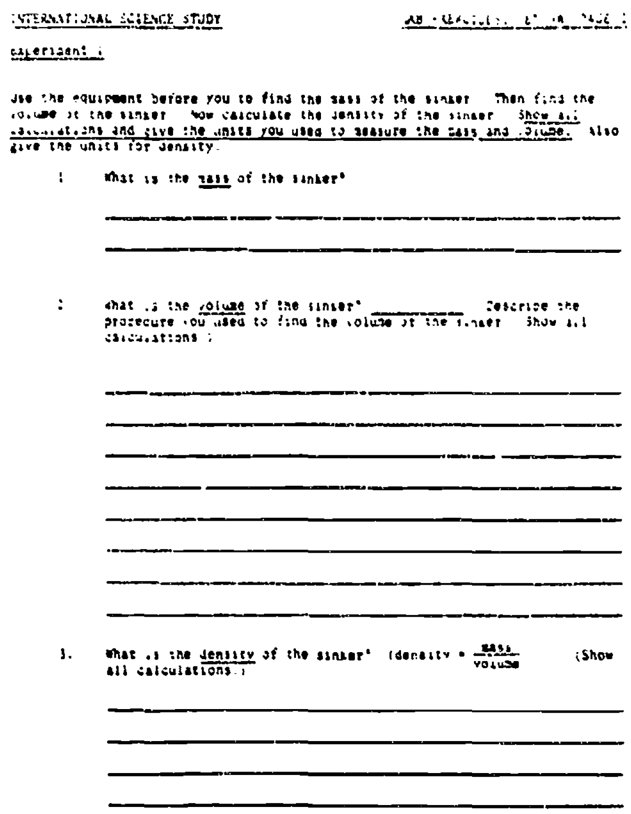
The students were asked to first find the mass of the sinker, then the volume of the sinker, and lastly, to determine the density of the sinker (given the formula). See Figure 38. The student booklet included reminders to "give the units" and "show all calculations" when appropriate.

Approximately half of the students were able to determine the mass of the sinker to within ± 1 gram. Less than 30% were able to determine the sinker's volume (including units) and describe the procedures used. Only 8% of the students were able to determine the density (within an acceptable range and with units). Success on this task was dependent upon success on the earlier two steps: finding mass and volume.

FIGURE 38

Density Determination (9B1)

	Score	Percent Response
Finding the Mass		
Accurate within ± 1 gm (including units)	2 pts	51
Less accurate (within ± 5 gm and including units)	1 pt	12
Inaccurate or no units	0 pts	36
Finding Volume		
Procedure stated. Correct value with units.	2 pts	29
Procedure stated. Error in calculation or no units	1 pt	16
Incorrect procedures or error in calculation and/or no units.	0 pts	55
Density Determination		
Appropriate calculation procedures, correct value and units	2 pts	8
Two of above three correct	1 pt	41
Two of above three incorrect	0 pts	52


INTERNATIONAL SCIENCE STUDY [illegible]

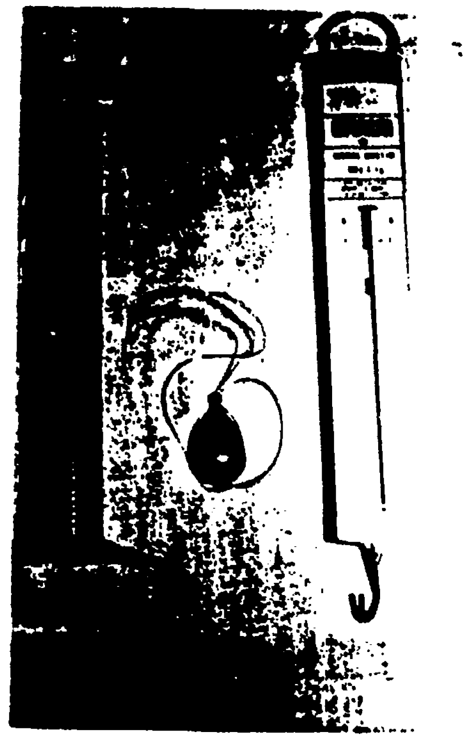
Experiment [illegible]

Use the equipment before you to find the mass of the sinker. Then find the volume of the sinker. Now calculate the density of the sinker. Show all calculations and give the units you used to measure the mass and volume. Also give the units for density.

[illegible] What is the mass of the sinker?

[illegible] What is the volume of the sinker? ________ Describe the procedure you used to find the volume of the sinker. Show all calculations.

3. What is the density of the sinker? (density = mass/volume) (Show all calculations.)



Male-Female Differences

> **On the science process laboratory skills tests the mean scores for boys and girls were about the same.**

There were few differences between the U.S. boys and girls on the science process skills tests. This is in sharp contrast to the gender differences on the paper and pencil achievement tests in science. The results on the skills tests by gender are given in Table 11.

On both subtests (A and B), each given to half of the Grade Five students tested, the mean scores for boys and girls were not statistically different. At the Grade Nine level, the mean score on Subtest A for boys was 3% higher than for girls, but the mean scores on Subtest B were not significantly different.

Performance (by boys and girls) on some of the individual tasks did vary. Generally, boys did better on tasks with a physical science content and girls did better on tasks for the life sciences. For instance, the items with the greatest differences favoring the boys were two types of items (one at each grade level) involving electrical circuits and one item requiring the measurement of mass and volume and the calculation of density. Girls achieved higher than boys on an item testing seeds for oil content and on an item involving paper chromatography.

TABLE 11

Manipulative Process Test for Girls and Boys
(Percent Scoring Correctly)*

	Percent Scoring Correctly			
	Grade 5		Grade 9	
Item	Girls	Boys	Girls	Boys
<u>Subtest A</u>				
A1	50.0	52.2	70.7	76.9
A2	64.7	61.3	46.0	47.0
A3	62.1	67.0	44.0	46.3
Mean (A)	60.1	61.1	53.1	56.1
<u>Subtest B</u>				
B1	44.5	47.2	38.2	44.6
B2	44.4	45.2	71.8	67 5
B3	60.4	52.7	45.3	44.0
Mean (B)	49.8	48.5	49.0	49.8

* Weighted Scores, since each item has a different point value.

The performance of U.S. fifth and ninth graders on science laboratory skills tests has been discussed with respect to gender and tasks with life science and physical science content have been described. Another important perspective is that of the science skills assessed in the several tasks. The results will now be described with respect to the skill categories: investigating, performing, and reasoning (see Figure 32, page 68).

<u>Investigating Skills</u>

This process skill category includes the planning of a complete study or some part of an investigation. At the Grade Five level, only one item was classified in this category. It was the plan for determining which seeds contained oil, after having rubbed an oily Q-tip against paper. Only 43% of the students were able to describe a plan which included rubbing the seeds against the paper.

At the Grade Nine level, the investigating skills were assessed on the acid-base testing task and a task involving testing for starch. Of the ninth grade students tested, 64% described a plan for using litmus paper to test samples for acid-base content. After having the iodine test for starch described in detail, 71% of the ninth graders proposed to test each of the samples for starch with the iodine solution.

These results are quite positive, but must be analyzed in the context of testing situations. In each case, considerable information was presented and parts of procedures demonstrated or described. Further, the plans were for steps or phases of an investigation, by no means a complete investigation.

Performing Skills

Skills within the performing category are poorly measured by paper and pencil instruments. Therefore, attempts were made to assess such skills in these manipulative tests. At the Grade Five level, students were expected to observe and describe color changes of a solution, similarities and differences of animals, measure temperature of water, observe diffusion of a substance, and describe an oil stain. Generally, the fifth grade students performed well on these skills. For instance, 85% of the students were able to measure temperature within accepted limits and 82% were able to fully describe the oil stain on paper.

At the ninth grade level, students were asked to test electrical circuits in a "black box," observe changes in indicators, and measure mass and volume. Of the U.S. ninth graders tested, 90% could assemble the equipment for electrical testing and 57% accurately tested all circuits. Over 75% of the ninth graders were able to put a few drops of an indicator solution in three samples and correctly describe the color changes. Only 52% of the ninth graders were able to find the mass of an object to within ± 1 gm with a spring scale. Using a graduated cylinder and water, only 30% were able to determine the volume of the object.

Reasoning Skills

Some of the skills in this category may be partially measured by paper and pencil instruments. It is believed that it is important to also assess these skills within the context of a "practical" situation.

At the fifth grade level, students were asked to explain color changes, predict temperature changes, and cite experimental evidence for conclusions. Only 10% of the fifth grade students could explain the color change of a bromthymol solution after blowing into it. Similarly, only 27% could explain the motion or solution of coffee crystals in water. When asked to predict the water temperature of equal volumes of water mixed together (with initial temperatures of 5°C and 75°C), only 7% of the fifth graders were successful. Citing the evidence for testing seeds for oil content was done successfully by 40% of the students samples. Only 9% were able to correctly identify objects as electrical conductors and give reasons for their conclusions.

Ninth grade students were asked to select diagrams that fit the data that had been collected, plan an investigation, make interpretations, draw conclusions, and give reasons for their conclusions. About 75% of the ninth graders tested were able to select two ways that electrical terminals were connected. However, only 17% of the students were able to conclude which test tube contained acid, base, or water. About 69% of the ninth grade students were able to plan an investigation to determine which cream substitute contains starch, but only 31% were able to identify the sample that had starch and give reasons. In determining the density of an object, most students were able to find the mass and volume of an object, but only 8% were able to carry out all the operations needed to find the density of an object. Many students had difficulty in using units. In the ninth grade, as in the fifth, students generally were able to make the observations and measurements called for but were less able to use the data to make inferences and to explain findings.

Students were able to carry out manipulations, but were less successful at performing tasks requiring investigation and reasoning.

Opportunity to Learn

The teacher of each of the classes tested was asked if these process tasks were part of the science instruction program at their school, and 59% of fifth grade teachers and 44% of ninth grade teachers reported that these activities were among the instructional experiences of students in their school this year or a previous year. It is also clear from the information in Table 12 that there is considerable variation by task and by grade.

TABLE 12
Teachers Reporting Percent of Student Opportunity to Learn
by Task and Level

Percent of Student Opportunity to Learn							
Grade 5				Grade 9			
Task	Previous Year	This Year	Total	Task	Previous Year	This Year	Total
5A1	7	29	36	9A1	18	32	50
5A2	33	52	85	9A2	16	47	63
5A3	23	39	62	9A3	15	26	41
5B1	23	41	64	9B1	12	23	35
5B2	23	36	59	9B2	12	23	35
5B3	14	36	50	9B3	12	29	42
Average			59	Average			44

Summary. Students at Grades Five and Nine from randomly selected schools were tested with science laboratory skills tests. Students at both levels were quite successful at tasks requiring manipulative skills (performing, measuring, etc.), but less successful at investigating and reasoning skills. The achievement of boys and girls on these skills tests were very similar. On some life science tasks, girls performed better than boys. By contrast, the boys performed better than girls on some physical science tasks, especially those with electrical equipment. Roughly half the teachers reported that their students had had an opportunity to learn the skills required to carry out the science process laboratory tasks.

"Hands on?" Yes. But, students also should learn to interpret, analyze, and explain.

Chapter XI

THE INFLUENCES OF SCHOOL AND HOME

The home and the activities that do or do not go on in the home influence science achievement.

A large concern of SISS was to search for variables which may help to explain levels or patterns of achievement. Questionnaires were developed to assess some aspects of the schools that participated and to elicit information about the home and community backgrounds of the students. The school questionnaire was completed by an official of the school who was well informed about their science program. This person may have been a science chair or supervisor, a curriculum coordinator, or building principal. Students provided information about their home and community backgrounds.

Characteristics of Schools

Most of the questions were asked about Grade Five schools as well as schools including the high school grades. A few special questions were asked about Grade Five schools, and several additional questions were developed for the high schools. There were a number of questions about general characteristics of schools, such as area or location, public/private status, size of community, size of school, number of teachers, length of school year, and length and structure of school day. There also were questions about characteristics of the school more specifically related to the science program, including math/science graduation requirements, availability and use of laboratory equipped rooms, lab assistants, enrollment in science courses, time allotted to science lessons (Grade Five only), and money spent on materials. Responses to these questions and trends across the grade levels will be discussed.

The schools in which the testing occurred were located in a wide range of urban/suburban/rural settings. Overall, approximately 16% of the schools reported being within an area described as "an inner urban part of a metropolitan area" and between 2.5% and 35% each in "rural areas," "outer urban/suburban as part of a metropolitan area" and "urban/suburban area but not part of a metropolitan area."

A majority of the schools were reported to be located in areas which had populations "between 1,000 and 10,000" and "between 10,000 and 100,000." Less than 25% of the schools were in small communities (populations less than 1,000) or very large cities (more than 1 million). The percentage of schools that were identified as being "non-public" was about 10%. This value is very close to information published through the Center for Education Statistics.

The structure of the school day was very similar for Grade Nine and all the specialty science courses. From 95% to 100% of the schools divide their school week into periods. However, less than 40% of the Grade Five schools indicated such a "period division." The large majority of schools (46% to 70%)

divided their ~~school~~ week into 31 to 40 periods and a substantial proportion with 21 to 30 periods per week. These "periods" were reported to be from 41 to 50 minutes long in most schools (40% to 60%) and more than 50 minutes (25% to 60%) in others. At Grade Five, 58% of the schools had periods of 41 to 50 minutes length and 24% indicated period length from 31 to 40 minutes. This shorter period length is consistent with the attention span of the younger students. The above data can be summarized in terms of hours of class time per week. From 28% to 57% of the schools reported a school week of 31 to 35 hours (or about 6 to 7 hours per day). Further, 25% to 50% indicated having a school week composed of 26 to 30 hours. Less than 25% of schools had school weeks of "25 hours or less" or "more than 35 hours." Most schools indicated a "school year" of 171 to 180 days (52% to 76%). A substantial proportion of schools (19% to 44%) reported a school year of 181 to 190 days. Very few schools had a school year with "less than 170 days" or more than 191 days.

The modal number of years of high school science (Grades 9 through 12) required for graduation was two years (50% to 70%). Some schools (13% to 35%) required three years, while a few (6% to 17%) only required one year of high school science for graduation. Several states are considering an increase of this requirement. The modal years of high school math needed for graduation also was two years, but more schools indicated a three-year math requirement than a three-year science requirement.

Few schools have laboratory assistants or technicians to help with instruction.

At the high schools in the study, it was reported that the science rooms were used for science teaching "more than 80% of the time" in the majority of schools (64% to 78%). The exception is Grade Five, in which 60% of the schools reported having "no science rooms at this school." While schools do provide an adequate number of "science equipped rooms," science laboratory assistants or technicians are available in only a few schools, even for the advanced science classes. Seventy-five percent to ninety-eight percent of these schools reported having no technicians to help prepare materials and equipment for the laboratory experiences.

Characteristics of Students and Their Backgrounds

The distribution of students by sex in the various classes tested is presented in Table 13.

The enrollment of girls in science continues at a proportion near 50% of all classes except second year chemistry (43%) and second year physics (22%). It is interesting to note that in both first year and second year biology classes, more than 50% of the students are females.

The amount of education (beyond high school) expected to be completed by the students in these science classes is impressive. See Table 14.

The percentage of students who expect more than four years of education beyond high school increases from Grade Nine (23%) to second year physics (75%). Further, the focus on science courses within this post high school education is impressive. Science was a popular choice for these students as the "best description of courses you expect to be taking." The percentage that chose this option increase from Grade Nine (26%) to second year physics (69%).

TABLE 13

Percentage of Female Students by Course

Course or Level	Percentage of Female Students
Grade Five	51.6
Grade Nine	48.1
Biology 1	54.0
Biology 2	57.9
Chemistry 1	47.3
Chemistry 2	43.0
Physics 2	21.8

TABLE 14

Amount of Student Expected Education Beyond High School

Choices	Grade 9	Bio 1	Bio 2	Chem 1	Chem 2	Phys 2
No Decision Yet	23.9	19.3	9.5	10.0	3.0	2.7
No Further Education	6.8	3.5	2.4	1.5	0.5	0.5
One-Two Years	11.1	11.4	6.0	4.8	2.7	0.4
Three-Four Years	34.9	37.5	36.0	46.1	29.9	21.8
More Than Four Years	23.3	28.4	46.2	37.6	63.8	74.6

The grades these students report earning in school also increase steadily from Grade Nine through second year physics. In Grade Nine, 38% of the students reported earning "about half B and half C" grades. For the second year chemistry and second year physics classes, 38% and 43% reported receiving "mostly A" grades in school. Considerable academic selection is occurring along the pathway from Grade Nine to the advanced science courses.

A further indication of the differentiation of students across the course spectrum is available through the "years of mathematics studied" variable. Most of the students in first year biology (65%) have studied two years of math since the eighth grade. However, most of the first year chemistry students (64%) have completed three years of mathematics. Interestingly, the percentage of students in the second year science courses that have completed four years of mathematics varies considerably: biology 27%, chemistry 45%, and physics 62%.

The amount of time these students watch television (during weekdays) is considerable. Students in Grades Five and Nine, 25% and 19%, report that they spend six hours per day or more watching television. For the secondary specialty science courses, this percentage ranged from 9% (second year physics) to 16% (first year biology). The proportion of high school science students who indicate watching television "about 3 hours" per weekday range from 13% (second year physics) to 20% (second year biology). The number of students who reported that they watch television about one hour or less per weekday increased from 15% (fifth graders) to 44% (second year physics). See Table 15.

Considerably fewer hours a week are spent on homework than on watching television.

By contrast, the hours spent <u>per week</u> on all homework appears to be considerably less than those spent watching television. At Grade Five, 57% of the students reported spending "up to 2 hours" a week on "school work out of class" for all students. For Grade Nine and first year biology, "up to 2 hours" was the response given by the greatest number of students, with the percentage being 33% and 30% for Grade Nine and first year biology students, respectively. For the other secondary science courses, the modal category reported was "between 2 and 5 hours" (for first year and second year chemistry and second year biology) and "between 5 and 10 hours) (for second year physics). It appears that even the advanced science students spend as much (or more) time watching television as doing homework. See Table 16.

The results on "science homework" are very easy to interpret. Across all the science class categories (Grade Nine to second year physics), the majority of students (46% to 57%) report spending "up to 2 hours" per week on science homework. The consistency of the results leads one to believe that these findings are "real." See Table 17.

TABLE 15

Time Spent Watching Television Per Week-Day by Science Course

Choices	Gr. 5	Gr. 9	Bio 1	Chem 1	Bio 2	Chem 2	Phys 2
	Percent of Students Responding						
Don't Watch	2.3	2.3	3.3	4.2	4.2	3.5	5.9
Less Than 1 Hour	4.7	5.8	8.9	11.1	11.7	14.6	16.5
About 1 Hour	7.5	9.0	11.7	13.4	13.9	15.6	21.4
About 2 Hours	15.0	15.7	18.6	21.0	20.9	20.3	19.9
About 3 Hours	18.7	19.9	18.7	18.3	20.4	18.6	13.2
About 4 Hours	15.4	16.8	13.0	11.2	12.8	10.1	9.1
About 5 Hours	11.5	11.4	10.2	8.8	6.1	6.7	5.3
6 Hours or More	24.9	18.9	15.6	12.0	9.9	10.6	8.7

TABLE 16

Time Spent Per Week on All Homework by Science Course

Choices	Gr. 5	Gr. 9	Bio 1	Chem 1	Bio 2	Chem 2	Phys 2
	Percent of Students Responding						
No Homework Assigned	3.1	2.1	1.2	0.2	1.0	0.7	--
Assigned, But Don't Do It	3.6	9.0	6.3	4.4	5.8	5.3	4.1
Up to 2 Hours	56.7	33.0	29.7	21.1	28.5	23.4	16.6
Between 2 & 5 Hrs	24.7	28.3	27.8	28.6	32.7	27.4	20.6
Between 5 & 10 Hrs	8.0	17.2	21.3	28.0	20.4	21.6	28.3
Between 10 & 20 Hrs	2.7	8.2	11.5	15.1	10.2	17.5	24.2
More Than 20 Hrs	1.3	2.1	2.1	2.7	1.3	4.1	6.3

TABLE 17

Time Spent on Science Homework Per Week by Science Course

Choices	Gr. 5	Gr. 9	Bio 1	Chem 1	Bio 2	Chem 2	Phys 2
	Percent of Students Responding						
No Homework Assigned	--	10.3	8.7	3.4	7.9	8.0	2.7
Assigned, But Don't Do It	--	9.4	7.9	9.6	8.8	9.8	8.3
Up to 2 Hours	--	56.4	57.6	57.2	56.4	46.0	48.2
Between 2 & 5 Hrs	--	17.8	21.1	24.3	20.1	25.7	31.2
Between 5 & 10 Hrs	--	4.6	3.6	4.5	6.2	8.0	6.6
More Than 10 Hrs	--	1.5	1.1	1.0	0.6	2.5	3.0

The students reported on the amount of their parents' education, the nature of their parents' work, and the number of books in their homes. These variables have been viewed as indicators of family socio-economic status (SES). Data for father's and mother's education is given in Table 18. A large percentage of the students in the advanced secondary science courses reported that their parents had completed a college education. The parents of the advanced science students were more likely to have had a higher level of education than the parents of fifth and ninth grade students.

Many of the students reported that their parents worked in "professional or executive" positions (see Table 19). Of parents of advanced science students, more fathers held professional or executive positions than mothers. Among the mothers, about the same number held professional and executive positions as were homemakers.

TABLE 18

Mother's and Father's Highest Level of School Completed

Level of Schooling		Percent of Students Responding by Grade or Course						
		5	9	B1	C1	B2	C2	P2
A Do not live with father (or step-father or male guardian).		7.5	4.4	5.2	2.9	2.9	2.6	0.7
Do not live with mother (or step-mother or female guardian).		1.2	1.1	0.3	0.2	0.6	1.3	0.0
B Grade school.	Father:	3.2	3.4	2.4	2.2	2.2	2.1	1.6
	Mother:	2.2	2.3	2.4	2.0	1.1	2.5	1.9
C Some high school.	Father:	4.9	9.7	7.0	5.4	5.9	4.7	3.8
	Mother:	4.7	9.1	6.8	5.4	7.6	3.8	2.1
D High school.	Father:	14.9	24.4	22.2	22.0	22.3	21.1	12.5
	Mother:	21.1	35.5	32.9	31.0	30.6	27.9	21.1
E Some education after high school (a vocational, trade, or business school).	Father:	6.4	14.9	18.3	18.5	15.6	18.9	14.2
	Mother:	8.9	15.9	20.2	21.2	20.1	20.2	17.0
F College or higher.	Father	32.0	32.0	37.1	44.6	48.0	48.8	66.0
	Mother:	33.5	28.5	31.8	37.0	37.2	42.4	56.3
G I don't know.	Father:	31.1	10.9	7.8	4.5	3.2	1.8	1.2
	Mother:	28.4	7.4	5.5	3.3	2.9	1.8	1.6

TABLE 19

Mother's and Father's Work

Vocation			Percent of Students Responding by Grade or Course						
			5	9	B1	C1	B2	C2	P2
A	Do not live with father (or step-father or male guardian).		--	8.0	8.8	4.6	4.6	5.1	1.9
	Do not live with mother (or step-mother or female guardian).		--	1.6	1.2	0.9	1.4	2.3	0.7
B	Semi-skilled	Father:	--	16.0	12.6	14.0	14.5	10.8	5.9
		Mother:	--	17.7	14.6	13.0	14.1	10.0	8.5
C	Skilled	Father:	--	31.5	24.2	25.7	21.0	24.5	18.6
		Mother:	--	20.2	10.4	8.3	7.3	7.4	8.9
D	Clerical and Sales	Father:	--	19.0	11.1	8.6	8.3	10.7	7.1
		Mother:	--	20.3	24.5	26.2	22.5	22.4	20.4
E	Professional and Executive	Father:	--	12.7	31.5	39.1	43.6	44.5	63.2
		Mother:	--	21.2	20.1	23.0	25.6	25.9	35.6
F	Homemaker	Father	--	7.1	1.1	0.3	0.0	0.2	0.2
		Mother:	--	15.5	22.0	23.7	24.1	27.6	22.6
G	Some Other	Father:	--	5.1	10.7	7.6	8.1	4.2	3.1
		Mother:	--	3.4	7.3	4.9	5.1	4.4	3.3

The question labelled "books in home" asked students to check one of six categories indicating a large range of books, from "none, or very few" (1-10) to "a room full: library (more than 500)." Most students reported that there were one to four full bookcases (26 to 500 books) in their homes.

<u>Summary</u>. Most of the schools in this study required two years of science for high school graduation. As students continued to enroll in elective science courses, they also completed additional study of mathematics. In general, the students who enrolled in the advanced science courses had parents who had completed extensive schooling beyond high school and who were employed in professional or executive positions. Approximately equal numbers of females and males were enrolled in all science courses except

second year physics. The amount of time spent watching television by all of the students was considerably more than the time they spent on homework.

Parents of advanced science students were more likely to have had a higher level of education than parents of fifth and ninth grade students. Parents of advanced science students were more likely to hold professional/executive positions than were parents of other science students.

Chapter XII

TEACHERS AND TEACHING

Most of the teachers of science in the schools sampled were experienced and had strong backgrounds in science and education in general.

A critical component of the teaching-learning process is the teacher. A review of the NSF-initiated surveys of the status of science education in the U.S. concluded that "the teacher is the key." The science program objectives are translated by the teacher and implemented via planned science lessons for the students.

A questionnaire for the teacher was developed as part of this study. Several questions surveyed the teachers' age, years of teaching experience, gross salary, number of years of college completed, and percentage of college courses in science areas. The issue of preparation for teaching was assessed by a series of questions on science fields for which certification has been earned, certification for class being tested, and teaching out of certified fields. The professional activities of the teachers were surveyed by questions about membership in science/science teacher associations, frequency of reading of science and general academic journals, and extent of inservice education in the most recent 12 months.

The existence and frequency of use of science equipment (specifically, calculators and computers) and laboratories was assessed. The teachers were asked about the amount of time per week that they taught science, mathematics, and other subjects, and the time (at school and outside school) spent on marking tests and preparing lessons. The teachers were asked to rate eight determinants of what they teach (e.g., textbooks, official curricula or syllabus, external examinations). The frequency of use of ten different teaching strategies was surveyed (e.g., lectures, field trips, demonstrations, etc.). Lastly, teachers were asked to indicate the frequency of use of five assessment techniques (e.g., standardized tests, teacher-made objective tests, laboratory exercises or projects). Responses to these questions will be summarized and trends across the grade levels will be cited.

Age and Experience of the Teachers

Across all the levels and kinds of courses tested, the modal range of teacher age was 38 to 47 years. From 36% to 50% of the teachers responded as being within that age range. The age distribution was quite "normal" with relatively few teachers of "27 years or younger" and "58 years or older." Similarly, most teachers (30% to 50%) reported having had between 10 and 20 years of teaching experience.

The education background of these teachers was impressive: 42% to 62% had completed more than six years of full-time, college education. Further, 44% to 64% of these teachers indicated that of their college education, more than half of these courses were in science subjects. Clearly, these teachers are experienced and well educated in general and in science subjects. The annual gross salary of these teachers was reported almost equally in four salary ranges: $16 thousand to $20 thousand, $21 thousand to $25 thousand, $26 thousand to $29 thousand, and more than $30 thousand. Apparently there is quite a bit of variability in salary among schools in different states or communities.

Certification Status

Almost all the teachers reported that they were certified to teach the class being tested.

Each state establishes its own certification categories and the criteria for issuing these licenses. Almost all the teachers indicated that they were certified to teach the class being tested. Relatively few reported having teaching responsibilities which are outside their area(s) of certification. Given the wide variety of science teacher certificates offered, Table 20 summarizes the responses by science class. As you would expect, the vast majority of biology teachers are certified in biology, chemistry teachers certified in chemistry, and physics teachers certified in physics. While most Grade Nine teachers are certified in biology and general science, 90% of the elementary school teachers report that they are certified to teach in the elementary school.

TABLE 20
Percentage of Teachers Certified by Certificate Title

Title	Gr. 5	Gr. 9	B1	C1	B2	C2	P2
Physics	1.0	23.7	16.0	41.8	13.0	36.5	95.7
Biology	4.9	75.4	98.1	58.4	97.2	50.9	17.6
General Science	16.0	73.4	62.3	74.2	75.2	79.8	63.6
Life Science	7.6	47.8	67.6	32.9	53.5	36.5	13.7
Science (N-9)	10.7	28.2	20.0	21.0	10.0	22.5	19.8
Chemistry	2.2	41.0	37.2	91.6	32.0	100.0	44.0
Earth Science	10.5	31.0	27.6	23.1	25.3	29.1	18.5
Physical Science	4.6	55.0	36.0	61.9	32.1	54.1	72.1
Middle/Jr. H.S.	22.7	53.0	51.2	43.3	25.3	45.2	48.9
Elementary Grades	88.9	8.1	7.1	6.1	0.0	7.5	7.2
Other	0.5	19.8	13.1	6.7	5.1	3.5	12.4

It is also clear that many teachers are certified in several different science fields. They were instructed to indicate certification for all the possible fields listed. There is overlap among the titles and several interpretations of some certification titles are possible. Nevertheless, the extent of multiple certificates for these teachers is impressive.

Equipment for Science Teachers

Almost all of the secondary school science teachers (70% to 98%) indicated that 80% or more of their science teaching takes place in a room or laboratory equipped for science teaching. Five percent of Grade Nine teachers and sixty-seven percent of Grade Five teachers reported that none of their science teaching takes place in a specially equipped room.

Most of the secondary school teachers of science reported that their teaching takes place in a room equipped for science teaching. Most Grade Five teachers do not teach science in a specially equipped room.

Most of these teachers (67% to 90%) had access to a computer for use in their science teaching. However, the usage of these tools during science lessons was minimal. Sixty percent to eighty-four percent of the teachers indicated that they rarely or never have students use a computer during science classes. The use of calculators varied considerably by course title: 50% of Grade Nine teachers indicated an occasional or frequent use, while 96% of the advanced science teachers indicated frequent or occasional use of calculators during science lessons.

The students were also asked to indicate the availability and use of calculators and computers at school. The results confirm the extensive availability but minimal use of these devices. The students have access to an electronic calculator for their use at school. The percentage of access grows from 53% of Grade Nine students to 98% of second year physics students.

Almost every school (98% to 100%) has computers at their school. However, the percentage of students that report never using a computer at school ranged from 69% in first year biology classes to 41% in second year physics classes. See Table 21.

Computers are widely available but little used in instruction.

TABLE 21

Time Spent Per Week Using a Computer (Including Microcomputers)
By Science Course

Choices	Percent of Students Responding by Course Bio 1	Chem 1	Bio 2	Chem 2	Phys 2
Never Use at School	69.1	59.4	61.8	57.6	40.9
Up to 2 Hours	18.1	17.0	17.2	19.7	23.3
Between 2 & 5 Hours	8.0	14.6	15.0	14.2	20.4
Between 5 & 10 Hours	3.4	6.6	4.6	5.7	10.2
More Than 10 Hours	1.5	2.5	1.4	2.8	5.2

Professional Activities

Most of the science teachers (51% to 69%) reported that they were a member of a science teacher association or science association. The majority of these teachers (75% to 85%) indicated that they read a journal or periodical on science subjects each month or more frequently. They indicated somewhat less monthly reading (55% to 68%) of academic journals or periodicals related to teaching in general. Wide variation in the amounts of inservice training on science and science teaching topics (in the last 12 months) was indicated. Few reported no such in-service training (8% to 21%). Many (26% to 40%) indicated that they had experienced more than five days of this in-service training during the last 12 months.

Teaching Responsibilities

Most of the science teachers (60% to 84%) spent more than 20 hours per week teaching science subjects. A few of the advanced science teachers (2% to 17%) reported spending more than 5 hours per week teaching mathematics subjects. These science teachers indicated that most of them (90% to 100%) spend less than 5 hours per week teaching other subjects. It appears that the teaching assignments of these science teachers is quite consistent with their certification.

Most of the teachers (50% to 60%) indicated spending 5 to 10 hours per week at school marking examinations and preparing lessons. Further, most of these teachers (70% to 85%) report that, additionally, they spend 6 hours or more per week outside of school marking exams and preparing lessons.

Determinants of What Is Taught

These teachers were asked to rate the importance of various guidelines in determining what they teach. In Table 22, these eight determinants are listed. It is clear that all teachers reported that student-related concerns were the major determinants of what they teach; what students will need when they leave school, what students will need in the next course, student ability to think scientifically, and students acquiring science concepts. The pattern for teachers of Grade Five classes was somewhat different than for the other classes.

TABLE 22
Determinants of What to Teach by Grade or Course
Response Most Often Given

	5	9	B1	C1	B2	C2	P2
What students will need when they leave school	2	2	2	2	2	2	2
Official Curriculum or Syllabus	1	1	2	1	1	1	1
Prescribed Textbooks	1	1	1	1	1	1	1
External Examinations	1	1	1	1	1	1	1
What Students Will Need Next	0	2	1	2	1	2	1
Student Thinking Ability	2	2	2	2	2	2	2
Student Scientific Concepts	0	2	2	2	2	2	2
Availability of Lab Equipment	1	1	2	2	1	2	1

2 Very Important
1 Of Some Importance
0 Of Little Importance

Teaching Techniques

In Table 23, a summary of the "use categories" (frequent, occasional, rarely, never) reported by the greatest number of teachers is presented. The pattern of teaching was very similar across the science courses. The techniques reported as getting frequent use were: question and answer, lecture, give same assignment, and use student experiments. Occasionally, these teachers would divide students into small groups, use audio-visual materials, and provide teacher demonstrations. Only rarely did students go on field trips, follow individualized programs, or interact with guest speakers.

TABLE 23

Frequency of Use of Teaching Techniques by Course
Response Most Often Given

	5	9	B1	C1	B2	C2	P2
Question-Answer	-	3	3	3	3	3	3
Lecture to Class	-	3	3	3	3	3	3
Same Assignment	-	3	3	3	3	3	3
Small Groups	-	2	2	2	2	2	2
Individualized Programs	-	1	1	1	1	1	1
Audio-Visual	-	2	3	3	2	2	2
Field Trips	-	1	1	1	1	1	1
Guest Speakers	-	1	1	1	1	1	1
Teacher Demonstrations	-	2	2	2	2	2	3
Student Experiments	-	3	3	3	3	3	3

3 Frequently
2 Occasionally
1 Rarely
- Never

Evaluation Techniques

Teachers were asked to indicate the frequency of use of several evaluation procedures. Table 30 summarizes the results by course. These teachers, across all courses, indicated that they frequently used teacher-made objective tests, homework assignments, and laboratory exercises or projects in assessing the work of their science students. Only occasionally did these science teachers use their own teacher-made essay tests for assessment of science classes. These teachers report that only rarely did they use standardized tests (produced outside the school) to assess their science students.

TABLE 24

Frequency of Use of Evaluation Techniques
Response Most Often Given

Evaluation Techniques	5	9	B1	C1	B2	C2	P2
Standardized	-	1	1	1	1	1	1
Teacher-Made Essay Tests	-	2	2	2	1	2	2
Teacher-Made Objective Tests	-	3	3	3	3	3	3
Homework Assignments	-	3	3	3	3	3	3
Lab Exercises or Projects	-	3	3	3	3	3	3

3 Frequently
2 Occasionally
1 Rarely

Summary. The teachers involved in this study had impressive educational and experiential backgrounds. They were engaged in a variety of professional activities, such as inservice education, professional organizations, and reading journals and periodicals. Most of them were teaching in the areas for which they were prepared. They used a variety of teaching and evaluation techniques. Computers were reportedly available in most schools, however, their use in science classes was minimal.

Chapter XIII

TEACHING AND LEARNING OF SCIENCE

Science classrooms are teacher-centered, and textbooks and tests are frequently used.

In the section of the study we are reporting on here, the students were asked to respond to a science learning questionnaire that asked how they had studied science. Educators are quick to offer their view of the nature of science, school, and learning. But, what are the views of the consumers, our students? In general, the data speak for themselves.

The questions have been grouped into three categories to facilitate discussion; general teaching techniques, specific science teaching procedures and approaches to homework.

General Teaching Techniques

TABLE 25

Frequency of General Teaching Techniques Used As Reported by Students In Percentages Indicating "Often"

Technique	5	9	B1	C1	Advanced Sciences
Uses tests on science	68	85	91	92	88
Uses textbook	61	62	59	48	48
Overview of today's lesson	--	--	57	52	47
Helps students with difficulties	--	--	47	58	51
Reviews past lessons	--	--	40	43	35
Summarizes today's lesson	--	--	33	33	25
Makes science lessons interesting	--	--	32	30	38
Explains relevance of science	--	--	28	22	35
Discusses science careers	--	--	12	10	17
Uses students ideas in lessons	--	--	10	9	14

It is clear from Table 25 that at all levels students have tests on the science they have been taught. At the Grade Five level, this happens often with 68% of the students, but with the Grade Nine and the high school science courses 85% to 92% report being tested often in science. It is also apparent that most classes at all levels (48% to 62%) use textbooks "often" for science lessons. Teachers are reported to "help students with difficulties" (47% to 58%) and provide an "overview for a test lesson" (47% to 57%). The frequency of "review of past lessons" (35% to 43%) and "summarize today's lessons" (25% to 33%) was less "frequently" done than the overview of a given test lesson. Students were asked to indicate the degree to which their teacher "made science lessons interesting". Only 30% to 38% of the students reported their teachers do this "often." Similarly, 22% to 35% of the students reported that their teacher "often" explained the relevance of science to them. Even fewer students (10% to 17%) reported that their teacher "often" discussed science careers with them. Use of student ideas and suggestions in planning science lessons was indicated as an "often" occurrence by only 9% to 14% of the students sampled.

The summary of these results indicate that science classes are structured and teacher-centered with minimal attention to the relevance of science, science careers, or using student ideas in science lessons.

Specific Teaching Techniques

Of considerable interest are the student views on the specific strategies related to science teaching with an emphasis on laboratory activities. See Table 26.

TABLE 26
Frequency of Specific Science Teaching Techniques by Course
Percentages Indicating "Often"

Teaching Technique	5	9	B1	C1	Adv. Sci. B2	C2	P2
Teacher Demos	12	18	40	56	42	49	57
Do Lab Work	22	35	50	63	48	76	66
Small Lab Groups	-	-	66	83	67	87	66
Teacher Gives Lab Directions	-	-	77	83	75	77	76
Lab Instructions From Book	-	-	67	85	66	84	56
Write Lab Reports for Homework	-	-	20	51	30	53	41
Teacher Gives Lab Problems/ Students Make Up Methods	-	-	19	26	21	26	23
Students Make Up Lab Problems/ Teacher Helps Plan Experiments	-	-	5	4	6	3	4
Students Make Problems & Methods	-	-	5	4	5	4	5
Do Field Trips	-	-	5	3	9	4	4

Teacher demonstrations are a valuable way of presenting science phenomena, concepts, and skills. Students in Grades Five and Nine report that their teachers do not use demonstrations often (12%, 18%), but students in high school courses report "frequent" use of teacher demonstrations. "Often" use of teacher demonstrations was reported by 40% to 56% of the high school science students.

Student laboratory work as part of science lessons is a key element of most attempts to improve science curriculum. The level of use of student laboratory activity increased from Grade Five to the high school courses. "Students doing science lab work" was reported as an "often" occurrence by 22% of the Grade Five students, 35% of the Grade Nine students, and 50 to 76% of the high school science students. It appears that student laboratory work is most intense in the second year chemistry classes.

Laboratory work is often done and is frequently carried out in small groups.

Much student laboratory work is done in "small groups." From 66% to 87% of the student groups reported that small groups are used "often," with the greatest level of occurrence in the second year chemistry classes. It is clear that most of the direction of laboratory activities is given by the teacher, using a book or other written instruction. "Teachers 'often' giving instructions about what to do in science experiments" was reported by 77% to 83% of the high school science students. Similarly "a book or other written instructions" was "often" used by 56% to 85% of the students in the high school science classes. Students indicated that for homework they "often" write up laboratory reports; 20% to 53% of the students stated that this happens "often." Chemistry students indicated greater frequency of writing laboratory reports than did biology or physics students.

There is an issue as to whether the teacher or the student determines the problems investigated in the laboratory, the planning of the experiments, and the methods of investigation. From the consistent responses of the students, U.S. high school science laboratory activities are strongly structured and teacher-book centered. The case in which the "teacher gives the problem and the students work out the method and solution" was done more frequently: 19% to 27% of the students reported that this happens "often." Laboratory work in which students "make up our problems and work out our own methods to investigate the problems" was seldom done: this was reported to happen "often" by 4% to 5% of the high school students sampled. The same infrequent occurrence was reported for "students make-up the problems and the teacher helps us to plan experiments to solve them." As has been reported elsewhere, the field trip as part of U.S. high school science classes is an "endangered species." Only 3% to 6% of the high school students report that field trips occur often within their science programs.

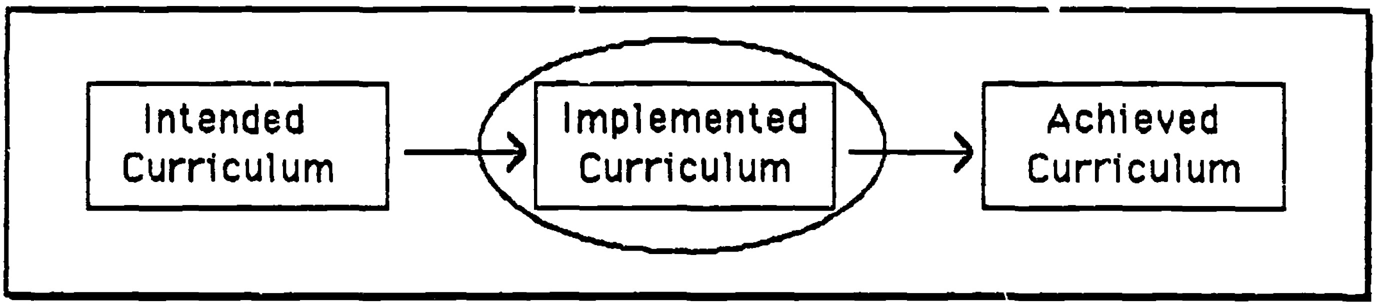
Summary. A wide variety of teaching techniques were reported to have been used. Included were considerable laboratory work and teacher demonstrations. Students reported that their work in the classroom and the laboratory was mostly teacher directed. Tests were widely used at all grade levels.

Chapter XIV

THE OPPORTUNITY TO LEARN

If you want students to learn something, teach them.

The opportunity to learn is a measure of the "Implemented Curricula."



There were three dimensions to the opportunity to learn rating:

1. The amount of time in school
2. The amount of organized instruction in science
3. The teacher judgement as to whether students had had an opportunity to learn the concepts related to questions on the achievement tests

Most schools in the U.S. have 171 to 180 days in the school year, while the Japanese students go to school 240 days a year.

The amount of time in school is a factor affecting opportunity to learn. While much learning takes place in home and community, the school is the institution whose primary mission is to give children and young people an opportunity to learn. In the IEA science studies it has been found that there is a strong relationship between the amount of time that students had to learn science and achievement in science. For example, in Grade Five, science students in Japan had about 10% higher science achievement scores than Grade Five U.S. students. But, Japanese children are in school about 240 days a year as compared to about 180 days in school per year in the U.S. Could it be that the higher average achievement scores in Japan are due, at least in large part, to the larger number of school days per year? Suppose ways were found to increase the number of days of schooling in the U.S., would U.S. students have science achievement scores similar to those of their Japanese counterparts?

There are differences between many countries in the number of years that students study a subject. The typical pattern in the United States (see Page 7) is to study science for one year in the well-known "layer cake" arrangement in which schools offer a different subject each year. In the upper secondary school, the frequent pattern is to offer biology in the 10th grade, chemistry in the 11th, and physics in the 12th. The number of students studying science typically declines as we move up the secondary school. It has been estimated that more than 67% of our high school students study biology in high school, mostly in grade 10 and about 35% study chemistry, largely in the 11th grade, but only 16% study physics, mostly in Grade 12 (Welch, et al., 1984, p. 16). However, in many of the countries, such as England and Hong Kong, some students in the upper secondary study science almost exclusively for three or more years. In these countries, some students at about age 15 will choose to concentrate on science and mathematics, and they will study the various sciences and mathematics for the next three years. They will have little opportunity to study the humanities and social science, but they will have much greater opportunity than their American counterparts to learn science and mathematics. Countries that have early specialization ranked highest in science achievement in the upper secondary school. Should U.S. schools move in this direction to provide American young people greater opportunity to learn science and mathematics? Should some American secondary school students have the opportunity to study science and mathematics almost exclusively for three or four years?

The amount of time in school and time devoted to science are factors that affect science achievement.

A more detailed study was made of the opportunity to learn the science concepts associated with each of the questions in the science achievement instruments. These international science tests were based upon concepts that were generally in use in the countries participating. The teachers of the students who took part in testing were asked to indicate whether all or most of the students in their class had had the opportunity to learn the concepts tested by each question:

A during a previous year's science course

B during this year's science course

C in a future science course in this school

D not in any part of the science program at this school

E I don't know

Table 27 shows the percentages of items that teachers reported students have had opportunity to learn this year or this year and previous years.

TABLE 27
U.S. Teacher Reported Mean Percent
Student Opportunity to Learn Science Topics

	Mean Percent: This Year's Science Course	Mean Percent: This Year's or a Previous Year's Science Course
Grade 5	42	64
Grade 9	35	60
Grade 10 Biology (U.S. only)	68	78
Grade 11 Chemistry (U.S. only)	74	80
Grade 12 Advanced Biology	42	79
Grade 12 Advanced Chemistry	42	81
Grade 12 Advanced Physics	53	88

In general, there was a higher opportunity to learn rating in the upper secondary school science courses than in the fifth and ninth grades. For example, high school specialty courses all had opportunities to learn ratings of 78% or higher while the fifth grade had 64% and the ninth grade 60%. The upper secondary science courses are quite standardized around the world. However, the elementary and lower secondary science programs vary widely. While the concepts on which the Grade Nine tests were based were agreed upon by the countries participating, the actual Grade Nine courses taught in the United States may have had considerably different emphases. U.S. science courses taught at the ninth grade level include general science, life science, earth science, physical science, and biology. There appears to be greater emphasis on earth science and environmental science in the U.S. than in many other countries. Individual teachers in the U.S. may have based their opportunity to learn responses on the course they had been teaching.

Figures 39 and 40 show the ninth grade items that were reported to have the highest and the lowest opportunities to learn.

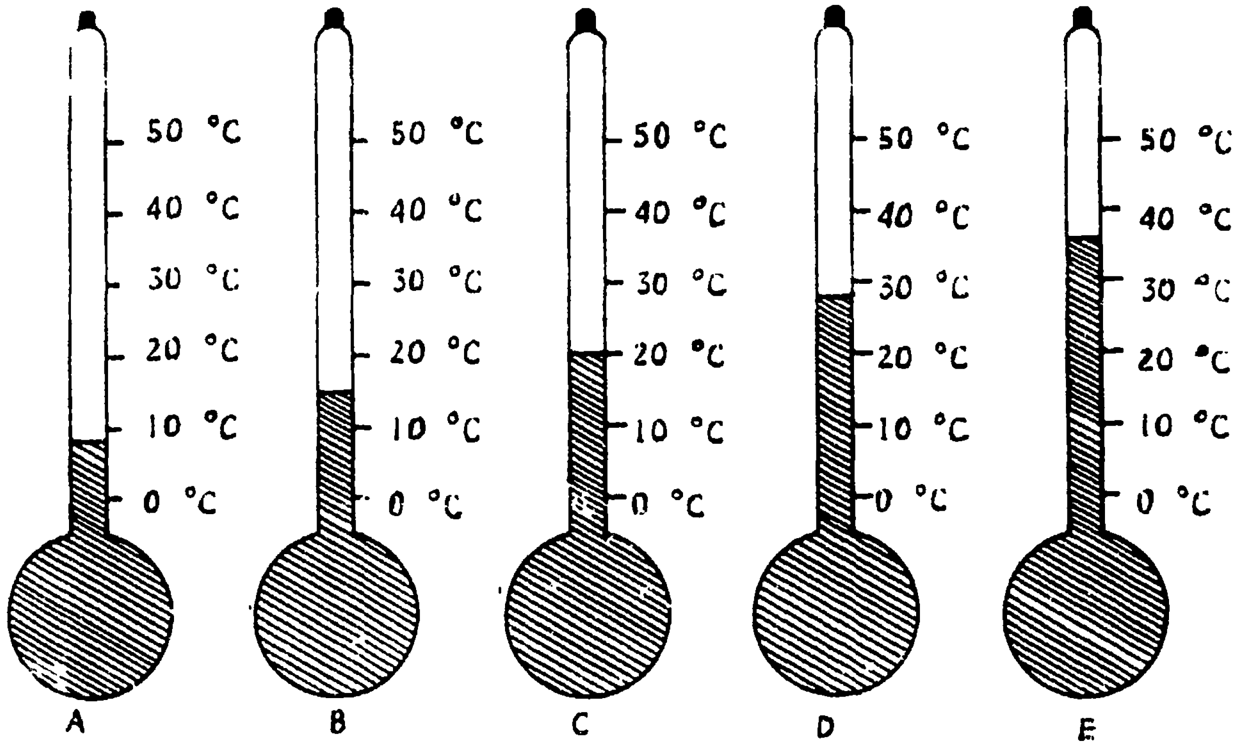
Figure 39 shows the item that teachers reported that ninth grade students had the greatest opportunity to learn. Basically, the item requires the ability to find the requested temperature in a table and select the thermometer that shows that temperature. About 70% of the teachers reported that their students had had the opportunity to learn this.

FIGURE 39

Item on Which U.S. Students Had the Highest Opportunity to Learn

	6 a.m.	9 a.m.	12 noon	3 p.m.	6 p.m.
Monday	15 °C	17 °C	20 °C	21 °C	19 °C
Tuesday	15 °C	15 °C	15 °C	10 °C	9 °C
Wednesday	8 °C	10 °C	14 °C	14 °C	13 °C

Which of the following shows the temperature at 6 a.m. on Wednesday?



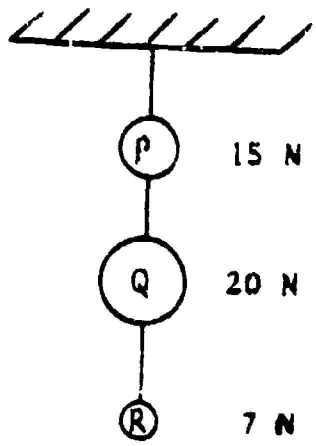
Percent Responding	
88.0	*A
9.4	B
1.4	C
0.4	D
0.5	E

Figure 40 shows the item that teachers reported the students had the lowest opportunity to learn. It was a difficult item for 9th graders in all countries except Hungary and Japan.

FIGURE 40

Item on Which U.S. Students Had the Lowest Opportunity to Learn

The objects P, Q, and R of weight 15 N (newtons), 20 N, and 7 N, are hung with a light thread as shown in the figure.



What is the tension in the thread between P and Q?

Percent Responding		
88.0	A	42 N
9.4	B	35 N
1.4	*C	27 N
0.4	D	15 N
0.5	E	7 N

In the U.S., only about 11% of the 9th grade students were reported to have had an opportunity to learn the concepts tested by this question. It appears that this is taught at this grade level in Hungary, Japan, the

Netherlands, Poland, and Norway. In all the other countries, including the U.S., students did not have much opportunity to learn the concepts on which this question is based. .

In general, the evidence seems to indicate (Table 28) that there are strong correlations between science achievement and the opportunity to learn.

TABLE 28

Correlations of Opportunity to Learn with Science Achievement by Science Course

	Gr 5	Gr 9	Bio 1	Chem 1	Bio 2	Chem 2	Phys 2
Opportunity to Learn	-.03	.06	.25	.38	.19	.47	-.35

The small correlations for Grades Five and Nine may be functions of the wide variety of programs for elementary and middle/junior high school levels. The comparatively high correlations between opportunity to learn and science achievement in first and second year biology and first and second year chemistry may be a result of more standardized biology and chemistry courses in the participating countries. The negative correlation for second year physics is puzzling.

In general, the "opportunity to learn" is a school factor that strongly influences science achievement.

Summary. In many of the cultures in which our students live, there may be many kinds of "opportunities to learn." Students may learn from conversations with parents and other members of the family, from radio and television, and the reading of science and science fiction books. But, among the factors in the schools that affect achievement, the "opportunity to learn" appears to be the most influential factor. School opportunity to learn may be especially important for females, who may not have had out-of-school science experiences.

Chapter XV

STUDENT ATTITUDES TOWARD SCIENCE AND SCHOOL

U.S. students have positive attitudes toward science and school.

At each level and subject tested, the students responded to an instrument eliciting the students' reactions to science and school.

Grades Five and Nine

Because of the testing time required by the science process skills test, we were able to include only five questions from the attitude inventory for students in Grades Five and Nine. The questions were chosen to represent several perspectives: science as a school subject, school, and the contribution of science to our country. Table 29 presents the percentage of each sample that responded to these questions with "Agree," "Disagree," or "Uncertain."

TABLE 29

Responses in Percent to Grade Five and Grade Nine Student Attitude Opinionnaires

	Grade	Agree	Disagree	Uncertain
School-Not Enjoyable	5	29	55	16
	9	28	52	19
Science-Enjoyable Subject	5	71	14	15
	9	52	4	34
School Science-Interesting	5	72	15	13
	9	53	26	21
Science-Difficult Subject	5	28	55	17
	9	39	43	19
Science-Important for Country's Development	5	79	6	15
	9	80	6	14

The first statement the students responded to was "School is not enjoyable." Approximately half of the fifth and ninth graders disagreed with this statement, indicating a favorable attitude toward school. Approximately 30% of fifth and ninth graders agreed that school is not enjoyable and 16% to 19%

were uncertain about whether or not they enjoyed school. This is generally a positive situation. However, there was a sizeable group of youngsters who were negative or uncertain about school being enjoyable.

The next three questions probed "school science" as to whether it is viewed as being enjoyable, interesting or difficult. To the students responding, the statements about school science being enjoyable or interesting received very similar responses. Approximately 70% of fifth graders indicated that school science is interesting and is enjoyable, while 50% of Grade Nine students indicated the same. This level of response is slightly higher than their reaction to school in general. The fifth and ninth grade students disagreed with the statement that "Science is a difficult subject" (55% for Grade Five, 43% for Grade Nine). It seems clear--more ninth graders think science is difficult than do fifth graders.

The last statement about science being "important for a country's development" received very positive responses. Approximately 80% of fifth and ninth graders agreed with that statement. There was no difference between the grade levels.

Responding to statements about school in general, fifth and ninth grade students indicated that they enjoy school. With respect to science as a subject they study in school, they found the science taught at school enjoyable and interesting, and *not* too difficult. With respect to the relationship between science and society, most students believed that science is important for a country's development.

Secondary School Students

For students at the secondary school level, a large attitude inventory was administered. In the spring of 1986, students in first year biology, first year chemistry, and the advanced science classes (second year biology, chemistry, and physics) were surveyed. The inventory included a series of randomly ordered statements which related to school and schoolwork, science, the difficulty and enjoyment of science, and science and careers. Each statement had as possible responses: "Agree," "Disagree," and "Uncertain."

School and Schoolwork

The secondary school science students queried had positive attitudes toward school (see Table 30). Their continued study of science probably is in itself a reflection of their belief in the importance of education.

Approximately 70% of the students (in all science courses) indicated that school is challenging. On the other hand, only 35% of these students agreed with the statements "being bored in school," "school not being enjoyable," and "disliking their school work." As these were negatively worded statements, it seems that these students generally found school to be enjoyable and they liked their school work. There was strong similarity of response to these statements across the three science classes: first year biology, first year chemistry, and the three advanced science courses.

While most students found school challenging, about a third of the students did not find school to be very enjoyable.

These students did indicate that there are school subjects that they don't like. The trend from first year biology to first year chemistry to advanced science may reflect less dislike of school subjects as students are enrolling in more elective courses of their own choosing.

TABLE 30

Student Opinions About School and School Work

	Percentage Agreeing		
Statement	First Year Biology	First Year Chemistry	Advanced Science
I find school challenging	70	72	67
I am bored most of the time in school*	37	35	35
School is not very enjoyable*	35	32	27
I generally dislike my school work*	35	34	30
There are many school subjects I don't like*	52	46	39

*Negatively worded statement

Student Opinions of Science

As these secondary school students will soon become voting citizens, their opinions about science and the importance and usefulness of science are important. The statements in Table 31 are listed in order of positive view of science held by students in first year biology classes. A large majority of these students (enrolled in science classes) had very positive perceptions of the contributions of science to our standard of living, to our country's development, is relevant to everyday life, and that science will help to make our world a better place to live, and that science is useful for solving the problems of everyday life.

TABLE 31

Student Opinions of Science
Ranked in Order of Positive View of Science

Statement	Percentage with Positive View of Science Biology 1	Chemistry 1	Advanced Science
Scientific inventions improve our standard of living.	84	88	92
Science is very important for a country's development.	81	91	94
* Science has ruined the environment.	71	72	77
Science is relevant to everyday life.	62	65	80
* Scientific discoveries do more harm than good.	59	63	67
Science will help to make the world a better place in the future.	57	61	69
Science is useful for solving the problems of everyday life.	55	58	74
Money spent on science is well worth spending.	51	61	74
Scientific inventions have increased tensions between people.	40	42	42
* Science and technology are the cause of many of the world's problems.	37	41	49
People who understand science are better off in our society.	35	39	54
* Much of the anxiety in modern society is due to science.	31	36	42

* Percentage of students <u>disagreeing</u> was listed as these were negative statements.

Upper secondary school students have a positive view of science and its contributions to society.

Generally, these secondary school science students believe that the "money spent on science is well worth spending." The statement about "people who understand science are better off in our society" was only moderately supported. Students may have been unclear whether "better off" means financially, intellectually, or in terms of job success. These students did not believe that "science has ruined the environment," nor that "scientific discoveries do more harm than good," nor that "science and technology are the cause of many of the world's problems." Lastly, these students did not believe that the "anxiety in modern society is due to science" nor that "scientific inventions increased tensions between people."

It appears that these science students had developed a position favorable toward science and scientific contributions to society. Similarly, these students rejected the notion that science has ruined our environment and that scientific discoveries do more harm than good.

Difficulty and Enjoyment of Science

From the data associated with the first two statements on Table 32, these science students reported that science as a school subject is enjoyable and interesting. That result is expected as these students have chosen to continue studying science. It is clear that this positive view of school science increases as one looks from first year biology and first year chemistry to the advanced science classes. For the first question, detailed results are listed for students in advanced biology, advanced chemistry, and advanced physics classes. Again, the "positiveness" of the responses increased as you look at the group of students in a second year course of biology, chemistry, and physics.

TABLE 32
Difficulty and Enjoyment of Science

	Percentage Agreeing				
	1st Yr.	1st Yr.	Advanced Science		
Statement	Bio	Chem	Bio	Chem	Phys
Science is an enjoyable school subject.	44	47	65	76	80
The science taught at school is interesting.	52	52	68	72	75
Science is a difficult subject.	52	61	53	52	46
Science is difficult when it involves calculations.	54	51	56	36	21
Science is difficult when it involves handling apparatus.	26	20	19	16	13
There are too many facts to learn in science.	51	49	37	32	22

Students recognized that science is a difficult subject, yet they found it enjoyable and interesting. The difficulty of science when it "involves calculation" was recognized by the students in first year biology, first year chemistry, and second year biology, but was viewed much less as a concern by students in second year chemistry and second year physics. These students did not view science as being difficult "when it involves handling apparatus." These science students agreed that "there are too many facts to learn in science," but this difficulty is of less concern in the advanced science classes.

Science and Careers

Most advanced science students have positive views toward science careers.

As shown in Table 33, those students enrolled in science classes do believe that future jobs will "require a knowledge of science." The strength of their belief increases from the first year biology group to the first year chemistry group to the advanced science classes. There was less agreement that "working in a science laboratory would be an interesting way to earn a living." There may be laboratory jobs that are not interesting to these science students. Their expected future use of the science they learned in school increased sharply between the several groups cited. It is clear that the advanced science students were much more likely to be considering a science related career. In the minds of these students, there are many good jobs for which it is not important to know science. Lastly, few of these students expressed an interest in becoming a science teacher.

TABLE 33
Opinions About Science and Careers

	Percentage Agreeing		
Statement	Biology 1	Chemistry 1	Advanced Science
In the future, most jobs will require a knowledge of science.	57	62	69
Working in a science laboratory would be an interesting way to earn a living.	41	42	53
In my future career, I would like to use the science I learned at school.	34	40	65
It is important to know science in order to get a good job.	21	23	26
I would like to become a science teacher when I leave school.	2	2	3

Summary. U.S. students had positive attitudes toward science and school. Most students found school to be challenging, but some reported that school was not enjoyable. The students generally found studying science to be enjoyable and interesting. They indicated that studying science was not difficult when it involved handling apparatus, but that there were many facts to learn in science.

Chapter XVI

TOWARD A BETTER SCIENCE EDUCATION

The ultimate purpose of the Second IEA Science Study (SISS) was to improve the science education of the children and young people in the countries that participated. We hope that the youngsters who trudge off to school at the age of five or six will have 12 or 13 years of science education that will be just a little better because of the insights gained from this Study.

A basic assumption of this Study is that friends can learn from each other. Some other countries have joined the U.S. in the struggle to find effective science education for all young people. No one has had much success in this quest for better "science for all." We can learn from the unique approaches that Sweden has tried and from the dedicated struggles of the Filipino teachers. Why not learn from others?

The U.S. is a large country, proud of its pluralism. A few communities may wish to try practices that seem to work in some countries. Still, the entire nation need not try out an innovation that may or may not succeed in another land and a different culture.

We may not choose paths that others have chosen, but we should be aware of them and the advantages that accrue and the prices that are paid. In some countries a great deal of attention is given to tests, test making, and test taking. Experiences in test taking and the preparation for testing seem to lead to comparatively high scores on science achievement tests. But, a price is paid! For example, less time is available for other experiences in science. U.S. science program developers may choose not to place as much emphasis on tests as in Japan and some other countries, but they should be aware that other countries have tried it.

In this chapter we list some of the findings of the Second IEA Science Study (SISS) that may have important implications for the improvement of science education in the U.S. There are brief suggestions of how these findings may be applied to improve science education, but these applications should be made by those who know the nature of their students, schools, and communities.

Nurture relationships between school and the home. Education is a joint venture. The most important participant is the student. The student must become involved in the various activities that can lead to learning science. The deep commitment of the student will depend upon the kinds of experiences that s/he has in school, but some of the motivation can come from the home.

One of the factors that has been found to have a high correlation with science achievement is "books in the home." Obviously, books in the home that are never read will have little influence on science achievement. But, "books in the home" may be a general surrogate for the general level of culture in the home. It has been said, "A seed needs a culture to grow." The home and school can provide the academic culture in which the student can experience intellectual growth. The home can provide the books, visits to museums, walks in the woods, help with homework, and general support for the efforts of the school. Evidence from countries such as England, Hungary, and Japan show how student learning is enhanced when home and school work together.

The cooperation of parents and teachers can help improve the science education of children and young people.

The contributions of the home are most apparent in elementary and junior/middle school grades. Many parents can work with children in elementary and general science. Fewer parents can help in advanced chemistry or physics. However, an important suggestion stemming from this research is that ways should be sought to improve the contributions that both the home and school make to a student's science education.

Improved science for girls. In every science subject and at every grade level, males had higher science achievement scores than females. This gender difference was found in all countries whose results have been analyzed. In the U.S., there was a greater difference in the physical sciences than in the biological sciences. For whatever reason, girls are not scoring as well on science achievement as boys. What can be done to raise the science achievement scores of girls?

One way to improve the science achievement of females is to make certain that girls have equal access to science equipment and materials.

It has been hypothesized that female students who had female teachers would score higher in science. In general, this was not found. In the fifth grade, teacher gender seemed to have little influence on student achievement. In biology, both girls and boys seemed to do better with female teachers. In the physical sciences, students with male teachers had higher science achievement scores.

The results of the testing of the science process laboratory skills are suggestive of an important possibility for improving the achievement of girls in science. In this testing, every student was given a kit of materials and equipment. The materials and equipment had to be used to answer the questions that were asked. There was no competition for the science materials and equipment; every student had everything that was required. Under these conditions, girls scored as well as boys. If all students, and especially the girls, always had all the equipment and science materials that are needed to study and learn science, would girls do as well as boys?

The differences between female and male achievement scores are greater in the physical sciences than in the life sciences. Since some understanding of key physical science concepts may be important for future study and learning, it appears important that female students have ample opportunity to learn these concepts.

Girls did not do well on science dealing with electricity. They probably should have more opportunities to experiment with the equipment and materials used in the study of electricity.

We need to find ways to make it possible for all children and young people to study and learn science. Almost all countries in the Study succeed in holding their students through the ninth grade. In the U.S., about 90% of the students in the age group are in school. But, many of these students do not continue to study science. It is estimated that 67% of our students study biology, mostly in the 10th grade, 35% study chemistry, mostly in the 11th grade, and 16% study physics, mostly in the 12th grade. (Welch, et al. 1984, p. 16). Thus, only a small percentage of the upper secondary school students in the U.S. study chemistry and physics.

No countries are doing very well in providing science education for all young people in Population 3. The U.S. tries to provide education, including science education, for all, but the U.S. students of science that are enrolled in school rank very low in science achievement in an international context. Other countries have science students who score very well in science achievement, but their science students may comprise no more than 10% of the individuals who could be studying science. In the science education literature, most countries acknowledge the importance of "science for all," but actually provide school science for a very small percentage of their upper secondary school population. The U.S. retains a comparatively large percentage of its young people in school, but a small percentage elect to study a second year of science.

Identify and teach concepts that will be helpful in future learning. In the analysis of the science backgrounds of many advanced science students, it was found that students who had some background in the physical sciences did better in advanced science courses. In the SISS study in Israel, it was found that ". . . prior learning of biology did not affect achievement in topics other than biology." For chemistry, ". . . prior study of chemistry did not contribute to achievement in physics, but made considerable contributions to achievement in biology and chemistry." For physics, "Prior learning of physics contributed to achievement in physics, chemistry, and earth science" (Tamir, 1985, pp. 17-18).

An attempt should be made to identify the science concepts that are helpful in the learning of other concepts. For example, several items on the SISS tests deal with the concept of balance. The concept of balance is important in different science topics:

simple machines	-	general science
homeostasis	-	biology
equations	-	chemistry
action and reaction	-	physics

Would the introduction of such pervasive concepts early in the secondary school help students throughout their studies in science?

Science achievement might be raised if key science concepts that are helpful in future science study are identified and taught several times.

Choose carefully the science that students will be asked to study and then approach it several times in different ways. It may be that to gain an understanding of certain concepts, the concepts should be taught and studied several times. Children in the kindergarten or first grade may gain some understanding of "balance" as they slide back-and-forth on a teeter-totter to balance a child at the other end. This level of understanding is important, and all children should have many such experiences. Probably, they form the basis for more sophisticated learning later on.

Some science concepts may require more than one approach at one time in the science program. Our ninth grade students did not handle the concept of density very well in the science process laboratory test. The concept of density requires the understanding of volume and mass and the ability to use these values in the calculation of density. It may be that students would gain a more sophisticated understanding of density if it were studied from different approaches several times during a K-12 science program. It may be that to study a concept once, which is often the case in the "one year, one science" approach, is not enough. In order to understand many concepts in science, they should be studied more than once and with different approaches.

Advanced science students in the U.S. do study two years of a science, but even these advanced students did not achieve as well in science as their counterparts in many other countries. Advanced science students in the U.S. might have scored better if their advanced science study had been coordinated with the science studied in the previous two or three years. Advanced Placement science students, in general, had higher science achievement than other advanced science students. Most of the Advanced Placement science students had had at least one year of prior study of that science course, and their study could be linked to the college science course.

More attention should be devoted to science in the ninth grade and in the middle/junior high school program. Out of 16 countries, the U.S. ninth graders ranked 15th in science achievement. In their attitudes toward science and schools, 9th grade science students were less positive than 5th and 12th graders. Teachers of ninth grade science reported their students had less opportunity to learn the concepts on which the items in the science achievement instruments were based than did any of the other populations. These data suggest a careful examination should be made of the nature of middle/junior high school science programs.

It may be that the instruments developed for testing ninth grade science did not reflect the actual science taught and learned in the ninth grade. The curriculum analyses made for SISS indicated that considerable attention in many middle/junior high school science courses is devoted to environmental and earth sciences. It can be argued that these science topics are at least as important as those covered by items in the test.

It can also be argued that the sciences that students study and learn in the middle/junior high are of special importance. If there are certain science concepts that are especially helpful in subsequent science study, they probably should be introduced in the middle/junior high school. If students do not begin to learn the science concepts at that time, they may be handicapped for the rest of their science studies.

<u>Analysis, interpretation, and explanation.</u> A unique dimension of the Second IEA Science Study (SISS) was the Science Process Laboratory Skills Tests. They were administered at the fifth and ninth grade levels. The tests consisted of a series of questions, tasks, appropriate materials, and equipment. In order to answer the questions, the students had to carry out "hands on" tasks using the materials and equipment that were provided. One of the very significant findings of this Study was that this kind of testing using science equipment and materials could be conducted on a national and international scale.

> **While "hands-on" science activities are important, more attention should be given to analysis, interpretation, and explanation.**

Fifth and ninth grade students performed the tasks reasonably well and were able to carry out the operations and make the required observations. For example, they were able to observe and describe the rate of movement of a drop of color in a chromatography exercise, but only 12% were able to give an acceptable explanation of the phenomenon. Many of the fifth and ninth grade students had had some experience with "hands on" science activities. But, they apparently were less able to carry out the more complicated processes of analysis, interpretation, and explanation. It appears that more time and energy should be devoted to these higher-order skills. To do, to experiment, and to observe are important, but it is also important to have experiences in analysis, interpretation, and explanation.

<u>Some science every year.</u> The highest science achievement in the upper secondary school was in England, Hong Kong, Singapore, and other countries, where students have a chance to study biology, chemistry, and physics every year for several years. In these countries, at about the age of 15, students choose which academic track they will enter. Some choose the mathematics/science track and will study largely science and mathematics during the rest of their secondary schooling. In countries such as The Soviet Union and China, secondary school students study science and mathematics for even more years. Thus, in many countries, including those countries that had

the highest science achievement scores, students study the sciences intensively for several years.

U.S. students were unable to answer correctly some items that graduates of our secondary schools should know. Of the ninth grade students who were asked to find the density of an object, only 8% were able to do so correctly. Some of these students will have no further opportunity to develop these skills. On another physical sciences question only 20% of the ninth graders were able to add two weights to determine the tension when they were suspended. Unless these students have another opportunity for study of the concepts underlying questions such as this, 80% of the students will leave school without learning these basic concepts. The concept had been learned by 62% of the students who were taking second year physics. While leaving much to be desired, the score of the advanced students shows that growth does take place when there is further opportunity to learn. Should U.S. students have a chance to study basic concepts in biology, earth science, chemistry, and physics each of the years of the secondary school?

The U.S. approach to science education programming is sometimes called the "one year, one science" approach. Others have called it the "layer cake" approach. There may be many reasons for the comparatively low achievement in science in the upper secondary school, but one reason may be that U.S. students characteristically study biology, chemistry, and physics for one year in the upper secondary school, and the number of students enrolling in a science declines each year until only 16% of the 12th grade students study physics in the last year of the secondary school.

In general, U.S. students have a positive attitude toward science and schools. But, consider a student who studies biology in the 10th grade and becomes enthusiastic about it. In many schools, this student will not have another chance to study biology. Later in the secondary school the student exhibits a decline in attitude toward schooling and science. Could the failure to provide additional experiences in a science such as biology be a contributing factor?

Some concepts are needed to learn other concepts. A biology or earth science student may need a basic concept in physics in order to master some ideas in biology or earth science, but ordinarily, s/he will not study these concepts until taking physics in the 12th grade. Some learning requires incubation and cogitation over time. It may be best to introduce students to a concept early in their school experience and then come back to the same concept from different perspectives at different times. Our "one year, one science" approach is not conducive to concept development over time.

Perhaps, our students should have a chance to study "some of each science, each year."

Our experiences in this Study with 23 countries suggest that there may be better ways of organizing science than our "one year, one science" approach. Perhaps, it is time for "some of each science, each year."

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HELGESON

International Science Report Card

From the Second IEA Science Study
United States
Teachers College, Columbia University

By
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Rodney L. Doran
Eve Humrich
Ira B. Kanis

Developed by the International Association for the Evaluation of Educational Achievement, Teachers College, Columbia University, New York, NY 10027. Produced by the National Science Teachers Association, 1742 Connecticut Avenue, NW, Washington, DC 20009

INTERNATIONAL SCIENCE REPORT CARD

FROM THE SECOND IEA SCIENCE STUDY—U.S.
TEACHERS COLLEGE, COLUMBIA UNIVERSITY

This material is based upon work supported by the National Science Foundation under Grant No. 8470382. Any opinions, findings, and conclusions or recommendations expressed in this publication are those of the author and do not necessarily reflect the views of the National Science Foundation.

This Study is based on the assumption that people around the world can learn from each other. This report card conveys a few of the findings of the Study. In the future, additional findings will be made available in more extensive reports.

Data on science achievement, student opinions, and teaching/learning practices have been collected from random samples of classes at the 5th, 9th, and 12th grade levels in the United States and 23 other countries. The testing in the United States was done in 1986. The comparisons of science achievement are based on student results on common multiple choice items.

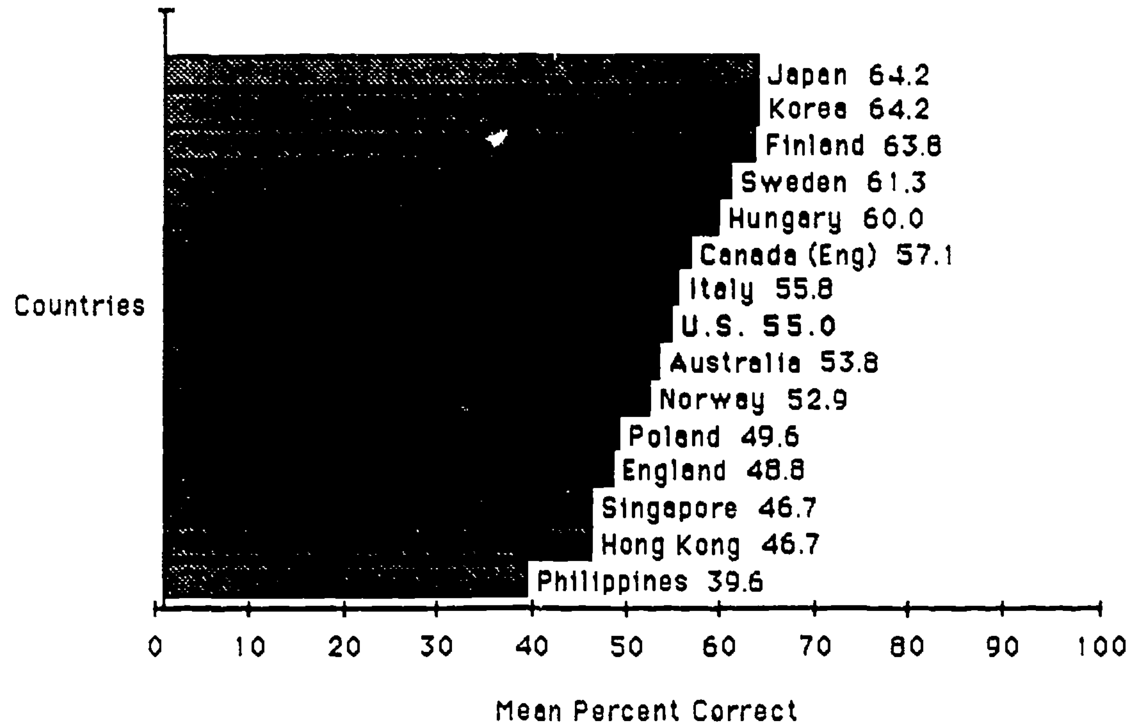
Science achievement was measured by international tests that were based on science curriculum case studies in each country. An Analysis of Science Curricula in the United States will be produced by the International Association for the Evaluation of Educational Achievement and be available from the National Science Teachers Association in spring, 1989. The tests used to collect the data for this survey will also be available from NSTA in spring, 1989.

SCIENCE ACHIEVEMENT IN GRADE FIVE

On an international science achievement test, U.S. Grade Five students ranked 8th among the 15 countries whose data have been analyzed. In the United States, 2,822 students in 123 schools responded to the science achievement tests.

GRADE FIVE SCIENCE ACHIEVEMENT IN 15 COUNTRIES

(Mean Percent Correct)



Note that the differences between many countries are small. Mean scores for four countries [Canada (Eng), Italy, Australia, and Norway] are less than 2.1% from the U.S. score.

U. S. Grade Five students scored about 8% higher on physical science items than on the life sciences.

On a common set of items, U.S. students in Grade Nine scored 19% higher than students in Grade Five.

U.S. Grade Five students in 1986 performed at about the same level as did Grade Five students in 1970 on a common set of 21 items.

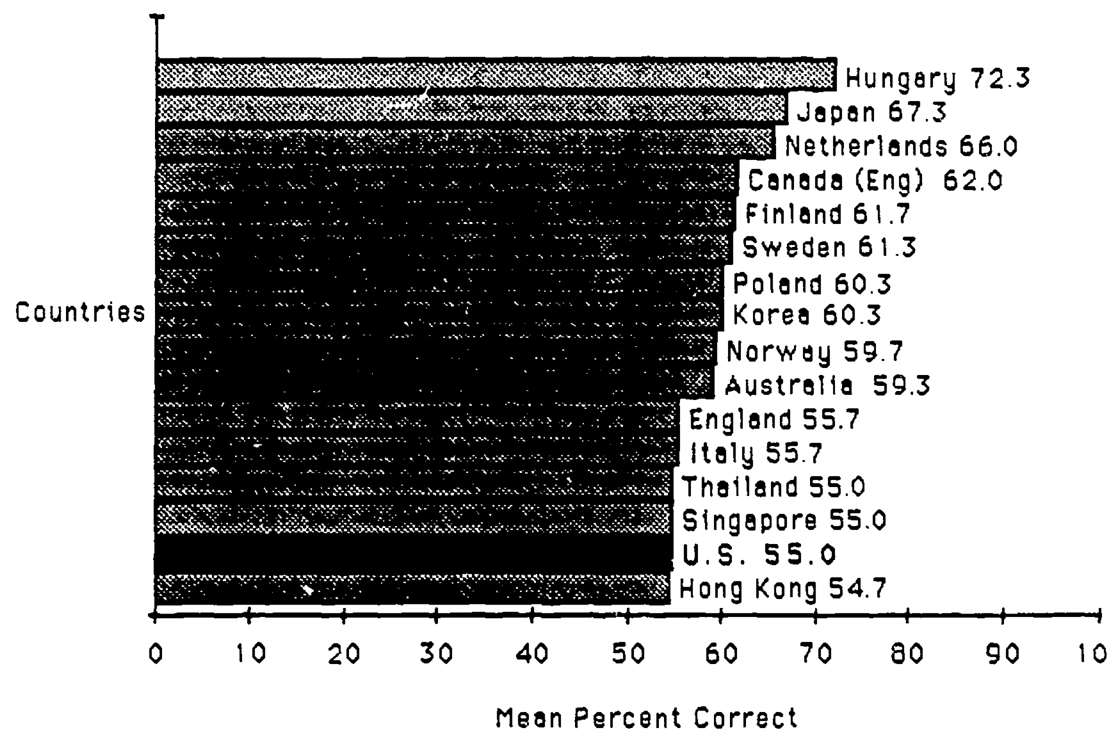
INTERNATIONAL SCIENCE REPORT CARD 2

Science Achievement in Grade Nine

On an international science achievement test, U.S. Grade Nine students ranked 15th among the 16 countries whose data have been analyzed. In the United States, 2,519 students in 119 schools responded to the science achievement tests.

Grade Nine Science Achievement in 16 Countries

(Mean Percent Correct)



Note that the differences between many countries are small. Mean scores for six countries (England, Italy, Thailand, Singapore, Hong Kong, and the United States) vary by less than 1%.

U.S. Grade Nine students scored 13% higher on life science items than on physical science items.

On a common set of items, U.S. students in Grade Nine scored 19% higher than students in Grade Five.

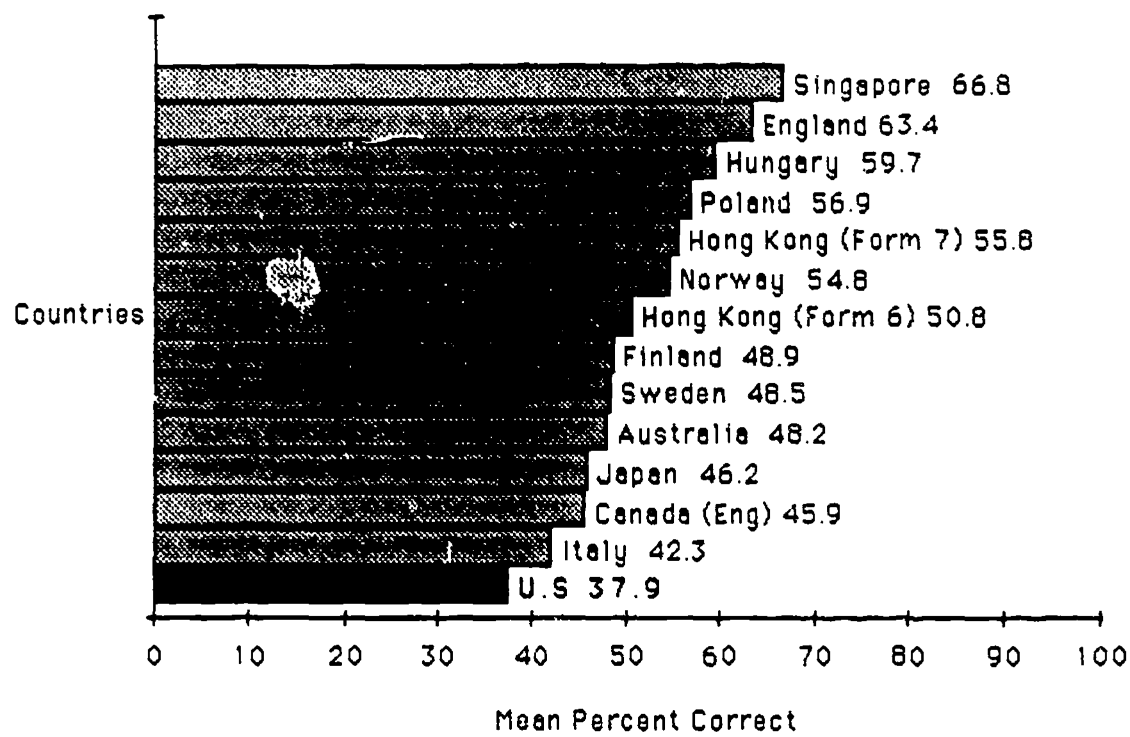
On a common set of 20 items, U.S. students in 1986 had an average score that was lower than that for Grade Nine students in 1970.

U.S. Advanced Science Students

In 1986, U.S. students who were completing a second year of study in biology, chemistry, or physics were administered a test in their specialty area.

Biology Specialists

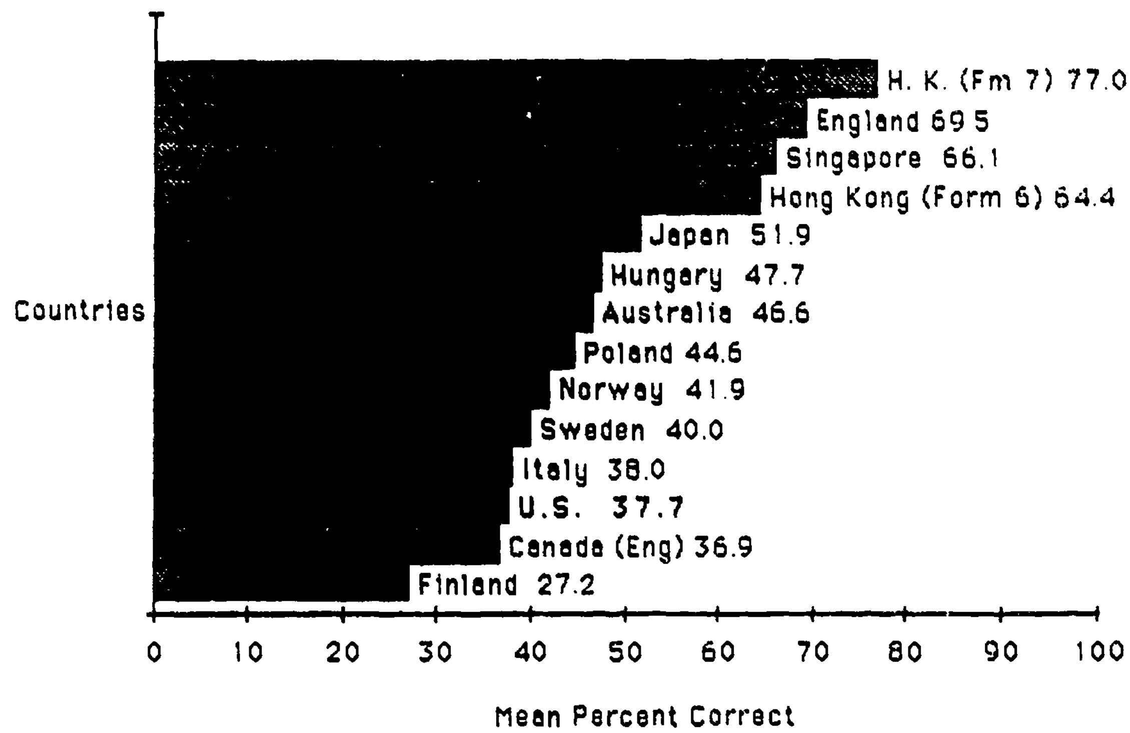
(Mean Percent Correct)



Of 13 countries, the U.S. second-year biology students had the lowest score.

The results for the U.S. advanced science students who were mostly in Grade Twelve and who had had two years of biology were disappointingly low. What can be done to improve the U.S. student scores in biology?

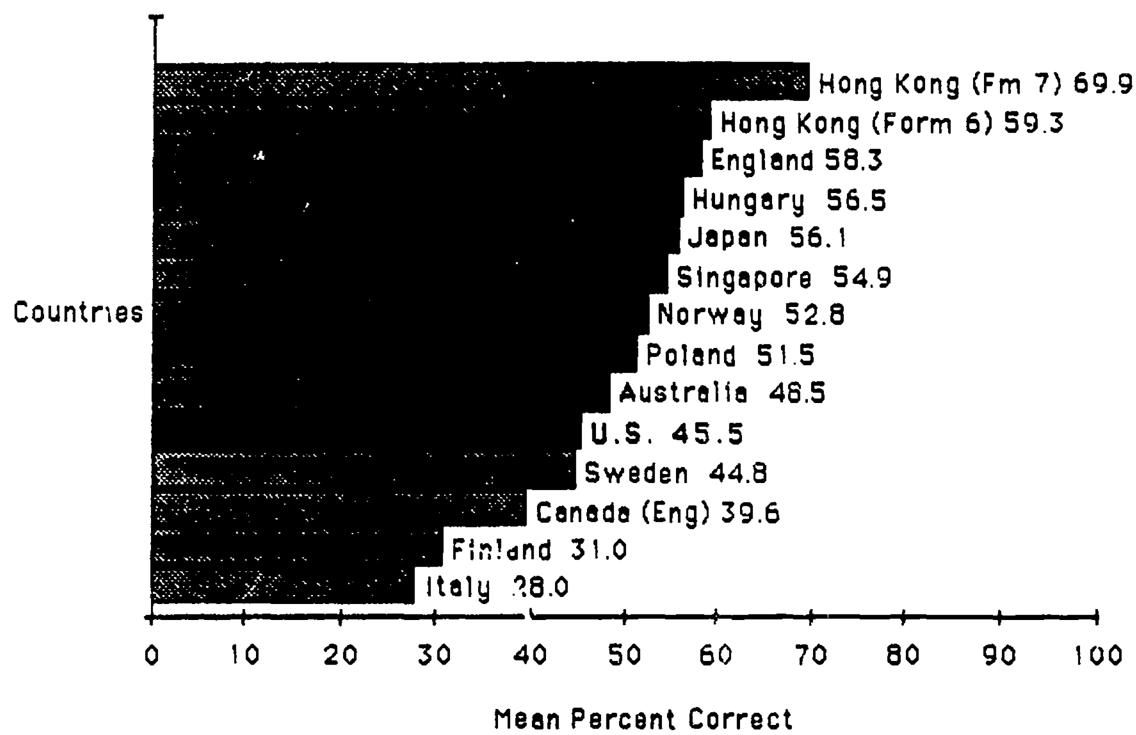
CHEMISTRY SPECIALISTS
(Mean Percent Correct)



The U.S. second-year chemistry students scored about the same as students in Italy and Canada (Eng).

U.S. students who had studied two years of chemistry ranked 11th among 13 countries. What steps can be taken to raise achievement in chemistry?

PHYSICS SPECIALISTS
(Mean Percent Correct)



The scores of the U.S. second-year physics students ranked 9th of 13 countries.

Most U.S. physics students study physics for the first and only time in Grade Twelve. Such students were tested in 1983. It has been found that the second-year U.S. physics students tested in 1986 scored about 10% higher than the first-year physics students. Should more U.S. physics students have an opportunity to study physics for more than one year?

Science Process Laboratory Skills

In the spring of 1986, a sample of 2,585 Grade Five and 2,248 Grade Nine U.S. students responded to an internationally designed laboratory process skills test in which they were asked to manipulate science equipment and materials, observe, measure, record data, and interpret results. These tests also were administered in Japan, Hungary, Israel, Korea, and Singapore.

U.S. students in Grades Five and Nine had scores ranging from 60% to 90% correct on tasks requiring the manipulation of apparatus, measurement of quantities, and recording of data. Students in the other countries had similar scores.

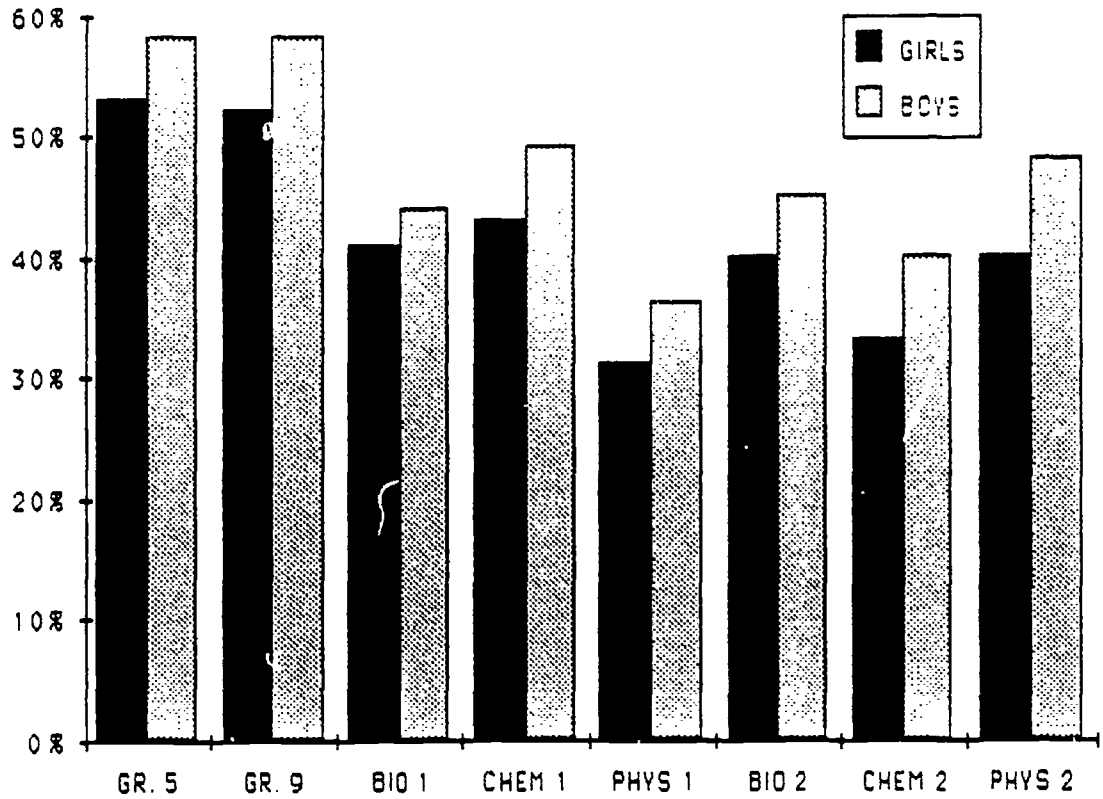
The U.S. students in Grades Five and Nine had lower scores, ranging from 7% to 62% correct, on tasks requiring the drawing of conclusions, explanations, and interpretations of findings than on "manipulative" skills. Students in the other countries had similar scores.

On these tasks, the U.S. female students earned average scores at about the same level as the U.S. male students at the Grade Five level. At the Grade Nine level, males performed slightly better than females on science process tests. On some specific questions with life science content, females did better than males. The males outperformed the females on some questions with a physical science content.

Male-Female Differences

In Grades Five and Nine in all countries reporting, boys had higher scores than girls. In Grade Twelve in biology, chemistry, and physics, boys had higher scores than girls except in biology in Australia, Hong Kong (Form 7), and Sweden.

U.S. Sex Difference by Grade Level and Subject



In the United States at all grade levels and subjects, boys had higher science achievement scores than girls.

Female students in secondary schools who were taught chemistry and physics by male teachers performed better than those taught by female teachers. Male and female students who were taught biology by female teachers outperformed those taught by male teachers.

ATTITUDES TOWARD SCIENCE AND SCHOOL

In general, U.S. students had positive attitudes toward science and school.

	Science Is Important for a Country's Development	Science Is an Enjoyable Subject	Science as Taught in School Is Interesting
Grade 5	79%	71%	72%
Grade 9	80%	52%	53%
Grade 10 Biology (U.S. only)	81%	44%	52%
Grade 11 Chemistry (U.S. only)	91%	47%	52%
Grade 12 Advanced Biology	92%	65%	68%
Grade 12 Advanced Chemistry	94%	76%	72%
Grade 12 Advanced Physics	96%	80%	75%

A large majority of the students at all levels and each subject believe that science is important for national development.

C-ade Five students and advanced science students found science enjoyable and in eresting.

Students in Grade Nine, Grade Ten biology, and Grade Eleven chemistry did not find their science studies as enjoyable and interesting as younger students did.

The Opportunity to Learn

The school factor most strongly correlated with achievement in science was the "opportunity to learn."

Teachers were asked to indicate whether the students had had an opportun[illegible] to learn the science concepts tested by each question.

The following are the percentages of items that teachers report students have had the opportunity to learn this year, or this year and previous years.

	This Year's Science Course	This Year's or a Previous Year's Science Course
Grade 5	42%	64%
Grade 9	35%	60%
Grade 10 Biology (U.S. only)	68%	78%
Grade 11 Chemistry (U.S. only)	74%	80%
Grade 12 Advanced Biology	42%	79%
Grade 12 Advanced Chemistry	42%	81%
Grade 12 Advanced Physics	53%	88%

Report Background

More than twenty thousand students and more than one thousand teachers gave the time and effort to complete the tests and reply to questionnaires. Review boards in each country compiled and analyzed the data. A complete discussion of methods will be included in the final report on this material, available from NSTA in spring, 1989.

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