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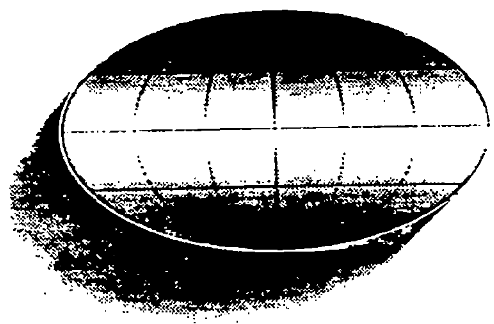
ABSTRACT

The world of education can be considered a natural laboratory in which different countries are experimenting with different strategies. This report presents the findings of the First and Second International Association for the Evaluation of Educational Achievement (IEA) Science Studies. The book contains the following chapters: (1) Issues in Science Education; (2) Introducing Science in the Primary School; (3) Science for All in the Middle Secondary School; (4) Graduating from High School; (5) Learning Science; (6) The Science Curriculum; (7) Teachers of Science and Their Influence; and (8) Planning Science Education for the Future. (PR)

Learning Science in a



Changing World

Cross-national Studies of Science Achievement: 1970 to 1984

J. P. Keeves

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

The Studies in Outline

Countries

In 1970-71, 19 countries took part in the First IEA Science Study.

In 1983-84, 24 school systems from 23 countries were involved in the Second IEA Science Study.

Participating in the second study were:

Australia	Ghana	Korea	Poland
Canada(English)	Hong Kong	The Netherlands	Singapore
Canada (French)	Hungary	Nigeria	Sweden •
China	Israel	Norway	Thailand •
England	Italy	Papua New Guinea	United States
Finland	Japan	Philippines	Zimbabwe

The countries taking part in both the first and second studies are marked ( ).

Target Populations

Population 1. Students aged 10:0 to 10:11 or in the second study students in the grade where the modal age was 10 years - referred to as **10-year-old students.**

Population 2. Students aged 14:0 to 14:11 years or in the second study students in the grade where the modal age was 14 years - referred to as **14-year-old students.**

Population 3. The terminal or pre-university year of secondary schooling - referred to as **upper secondary students.**

Population 3S. Students specializing in science - referred to as **science specialists.**

Population 3N. Students not specializing in science - referred to as **non-science specialists.**

Testing Program

All students in 1983-84 took a 45 minute common core science test appropriate for their age and grade level. In addition, students took rotated science tests of 45 minutes duration. In Population 3 these rotated tests covered the fields of science - biology, chemistry, physics, earth science, and general science.

Practical Skills Assessment

In 1983-84, subsamples of students in Populations 1 and 2 from Hungary, Israel, Korea, Japan, Singapore, and the United States were given a 45 minute test of performance in science practical skills.

Questionnaires

All students in the samples responded to a background questionnaire and attitude and descriptive scales. All science teachers of students tested responded to a questionnaire on teaching practices. All schools in the samples responded to a questionnaire on provision for science teaching.

Samples

Two-stage probability samples were drawn, with at least 100 schools in the first stage and at least 20 students per school in the second stage. Many countries in the second study tested intact classes.

Testing Procedures

All countries adhered to uniform test administration procedures, and conducted the testing program within three months of the end of the school year.

National Science Education Case Study Reports

In the second study countries prepared a case study report to a standard format to supply information on science curricula and science teaching within the country. In addition, they provided ratings on the planned or intended science curriculum at the three levels tested.

LEARNING SCIENCE
IN A
CHANGING WORLD

Cross-national Studies of Science Achievement: 1970 to 1984

J. P. Keeves

The Flinders University of South Australia

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

The International Association for the Evaluation of Educational Achievement (IEA) is an independent international cooperative of research centres. It has taken as its mission the conduct of comparative studies focussing on educational policies and practices in order to enhance learning within and across systems of education. IEA has committed itself to a cycle of studies of learning in the basic school subjects and to additional studies of particular interest to its members.

The International Coordinating Centre for the Second IEA Science Study was at the The Australian Council for Educational Research.
International Data Processing Centres were established at:
The Institute of International Education at the University of Stockholm
The Institute of Comparative Education at the University of Hamburg.

The assistance of Dr. D. Kotte and P. Lietz, M.Ed. at The Flinders University of South Australia, in the design and production of this report is gratefully acknowledged.

This report can be obtained from the IEA International Headquarters.

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About the Author

John Keeves was a school teacher of science and mathematics in Australia and England from 1947 to 1961, and from 1963 to 1967 was Federal Secretary of the Australian Science Teachers Association. He has studied at the Universities of Adelaide, Oxford and Melbourne, and has obtained doctorates from the Australian National University and the University of Stockholm. From 1977 to 1984, he was Director of the Australian Council for Educational Research, which was the international coordinating centre of the Second IEA Science Study. In retirement he has worked at the Universities of Melbourne and Stockholm, and at The Flinders University of South Australia on the analysis and reporting of this study. He was Chairman of the International Project Council for the Second IEA Science Study.

Contents

The Sizes of the IEA Science Studies

The second study collected data in 1983-84 from a very large number of schools, teachers and students in 23 countries. The size of this study is indicated by the total numbers involved.

Second IEA Science Study [1*]

1983-84	**Schools**	**Teachers**	**Students**
10-Year-Old	3,096	5,065	81,855
14-Year-Old	3,658	9,830	94,972
Upper Secondary	2,828	7,860	85,449
Total	9,582	22,755	262,276

In addition, this report draws on data from 10 of the countries that took part in the first study conducted in 1970-71. This involves data from further large numbers of schools, teachers and students in those 10 countries.

First IEA Science Study [2]

1970-71	**Schools**	**Teachers**	**Students**
10-Year-Old	1,373	6,885	27,538
14-Year-Old	1,491	9,472	36,795
Upper Secondary	940	8,212	23,483
Total	3,804	24,569	87,816

Six of the countries tested students in Science Practical Skills in 1983-84.

Practical Skills Testing Program [3]

1983-84	**Schools**	**Students**
10-Year-Old	486	7,684
14-Year-Old	570	8,975

This is the richest and largest body of data on the teaching and learning of any school subject ever collected.

* The superscripts are reference numbers which are listed on Page 52 where details are given for the location of further information.

Preface

In the late 1950s a group of leading educational research workers met in England and at the Unesco Institute of Education in Hamburg to discuss common problems in the conduct of educational research. From their deliberations they recognized the need for a comparative research program that was empirically oriented and that investigated problems which were common to many national systems of education. They saw the world of education as a natural laboratory in which different countries were experimenting with different strategies of teaching and learning. By examining the naturally occurring differences between countries in both the conditions of learning and educational outcomes, they thought it might be possible to identify the significant factors that influenced educational achievement. The program of research would be both comparative and cooperative. Decisions were to be made through scholarly debate and not political pressure. Members of the organization would be research centres and scholars with the competence to undertake survey research and not necessarily governmental instrumentalities. For over 30 years the organization that developed from these early discussions has undertaken a continuing program of research. This organization formally called the International Association for the Evaluation of Educational Achievement, is now commonly referred to as IEA.

A Second Science Study was proposed at the IEA General Assembly Meeting in 1980. From within the General Assembly an International Science Project Council was formed to make the major policy decisions concerned with the planning and conduct of the study. The second study was designed as a replication of the first study which was undertaken as part of the IEA Six-Subject Study in 1970-71. A Steering Committee was also formed with five members and with a sixth member from a developing country, to be added at a later stage, when the project was in operation. The Australian Council for Educational Research accepted the responsibility to become the International Coordinating Centre. All operational decisions were made by the Science Study Committee which comprised the National Research Coordinators who were appointed by the participating National Centres.

The Second IEA Science Study placed a greater emphasis on the production of national reports than have other studies conducted by IEA. In its organization and its conceptualization, the study sought to train National Centres and National Research Coordinators to undertake a 'do-it-yourself' study and to address problems in science education of national interest and concern. There was, however, full collaboration to ensure that detailed comparisons could be made both across countries and over time.

The external funding for the study to cover the international costs was very limited and amounted to only a mere US$ 120,000 coming from the Japanese Shipbuilding Industry Foundation, and the Victorian Education Department, Australia. However, the costs of testing, data preparation and analysis within each country were substantial and were borne by each participating National Centre.

This study could not have been conducted without a great deal of goodwill, support and cooperation from each of the 24 international centres involved. In two cases, national centres in Mexico and Tanzania, were forced to close after data had been collected and before the data had been prepared for analysis. In three other centres, namely, Canada (Fr.) in Quebec, Ghana and Zimbabwe, the data were assembled and made available for international analysis only through the dedication of individuals after those national centres had closed. The Swedish International Development Agency supported this work in Zimbabwe.

It proved extremely difficult to raise money subsequently to undertake international analyses of the data and two centres were established, one in Stockholm and the other at Hamburg to work together on the preparation of reports. The work in Stockholm was supported by the Bank of Sweden Tercentenary Fund, The Wenner Gren Foundation, The Swedish National Board of Education, The Swedish Ministry of Education and *Svenska Handelsbanken*. The work in Hamburg was funded by the Maxwell Family Foundation in England, the Carnegie Corporation of New York, the National Science Foundation and the National Center for Educational Statistics in the United States.

This summary report draws on the four recently published reports of the Second Science Study and the report of the First Science Study which was published in 1973. In addition it presents information that is available in the report of the Practical Skills Testing Program which is published in *Studies of Educational Evaluation*. These publications are listed on the back cover of this report.

With studies of this magnitude a very large number of people have been involved. In the published reports the names are recorded of the National Centres, the Project Council members, the Steering Committee members, and the Study Committee members together with the Chairmen of the different committees and the staff who worked on these projects over a period of up to 10 years.

IEA thanks them one and all for their contributions to this major international investigation into the learning of science in a world of change between the years 1970 and 1984.

T. Plomp
Chairman of IEA

1

Issues in Science Education

The world of science is one. Research scientists in laboratories and field stations, wherever they are located, draw on findings established in other lands. By consensus and challenge a common body of scientific knowledge evolves across the boundaries of nations and races. The application of this knowledge has, particularly during the past 100 years, transformed the standards of living, the health and the daily activities of a rapidly growing number of people in all corners of the world. Nonetheless, the advances of science have also brought new problems to be solved and some of these problems threaten to destroy life on Earth. In recent decades it has become clear that long term benefits are attained by those countries that can harness scientific knowledge to increase the production of goods, enhance standards of living, and control destructive forces. While the solutions to problems encountered may differ in different parts of the world scientific knowledge itself remains universal.

Over the past century the provision of education has gradually expanded and science has found a central place in the curriculum of schools at all levels. Of particular significance has been the growth of secondary education across the world during the past 50 years. In this development of secondary schooling science has displaced more traditional subjects in the curriculum.

With acceptance as universal of scientific knowledge itself, there has been world-wide recognition of a largely common body of fundamental scientific content that should be taught to students by the end of secondary schooling. However, because science is rapidly advancing, there has been a continuing demand for reform in the content of science courses. Thus science teaching cannot remain unchanged. Science curricula and teaching methods must not only be developed to meet new needs and circumstances, but must also incorporate the advances occurring in science itself.

The Wave of Reform of the 1960s and 1970s

The growth of scientific knowledge, and the power of technological advances in the first half of the twentieth century and more particularly during World War II in the United States and Europe led to a demand for extensive curriculum change in school science during the 1960s and 1970s. The major features of these reforms across different countries of the world were:

- biology gained greater acceptance as a field of secondary school science;
- content of physics and chemistry courses was revised and updated;
- processes of science and laboratory experiences were emphasized; and
- science was introduced in the primary school to replace nature study programs.

Several new approaches were advanced but gained limited acceptance:

- historical, cultural and technological contexts as factors influencing the growth of scientific knowledge were recognized;
- discussion of social and ecological consequences was advocated;
- integration across the different fields of science was recommended; and
- greater flexibility in teaching science using modular programs was proposed.

There were, however, certain shortcomings in the changes introduced:

- reduced emphasis on technology and the applications of science;
- attempts at integration met problems in stating unifying principles; and
- expansion of secondary schooling led to shortages of competent science teachers.

Gradually by the end of the 1970s in many countries, the wave of curriculum reform had lost momentum. Moreover, science education had lost direction under a demand to cater for greater student retention at the senior secondary school level and a severe shortage of competent teachers in the physical sciences.

The Impact of Technological Change [4]

In the late 1970s and early 1980s it became apparent that: (1) advances in microelectronics would change the nature of employment in the office and the factory; (2) new information technology would modify the storage and retrieval of information, and also greatly change the procedures employed in commerce and industry; (3) new technology had the potential to change modes of transport and the sources of energy; and (4) biological technology would change the production of food and beverages, the provision of health and medical services, and plant and animal breeding. Such changes demanded a greater knowledge of scientific principles by three groups of people. First, there were those who would be engaged in science-based professional occupations. Secondly, there were those who would be employed as skilled workers in industry which would be changed by the introduction of new technology and robotics. Thirdly, there was the large number of people who needed to understand and debate within a democratic society the issues raised by scientific and technological development.

The result was a demand for reform in science teaching. But, the strategies of reform that had been employed earlier were no longer considered appropriate. Moreover, there was no clear view of the directions which such reforms should follow. The goal was not simply the upgrading of scientific content.

Such was the climate in which the Second IEA Science Study was planned.

New Problems Emerge [5]

During the 1980s while the second science study was in progress the magnitude of the many problems which faced all countries and all people scattered across the 'global village' became clear. These problems included:

- the population explosion;
- emergence of new drug resistant diseases;
- feeding of starving people in Third World countries;
- effects of genetic experimentation and engineering;
- ecological impact of modern technology;
- environmental effects of deforestation of jungle regions;
- desertification and degradation of land in arid and semi-arid zones;
- dangers of nuclear war; and
- the possibility of major climatic change.

The mass media have publicized these problems and have promoted debate. As a consequence, students, particularly at the upper secondary level, are not only aware of such problems, but seek the knowledge to debate meaningfully the issues raised. Science courses in schools can no longer afford to ignore such problems, lest they are seen as irrelevant by students. Furthermore, without an informed public there is little chance that resources would be made available for the resolution of these problems. Science education must accept responsibility for control instead of catastrophe in human affairs. In addition, science education has to be seen as life-long and not limited to the years of schooling.

Whither Science Education?

The demands made on science education are not only diverse but also immense. Moreover, these demands arise not only in advanced technological societies but also in the developing countries of Africa, Asia, and Latin America. While some problems may seem more pressing in certain countries than in others, none can be safely ignored by any country. Such is the nature of our interdependence on this planet. Yet, it must be argued that the prime tasks of science education lie in the dissemination of scientific knowledge, the development of the ability to apply scientific principles, and the inculcation of skills associated with the investigatory processes of science as a method of inquiry. However, the production of a generation of students who are very knowledgeable in science, but who lack an understanding of the problems listed above is to invite disaster. Likewise, to produce a generation of students who are aware of issues but who lack competence in science, and are ignorant of the scientific principles which might be applied to these problems could be equally disastrous.

Thus the finding of new directions for science education is a task that faces all countries. Furthermore, it would appear of value that common goals and strategies should be sought. The undertaking of a joint enterprise across many countries, which examined the teaching of science from a global perspective, would seem to provide an appropriate starting point for future reform.

Comparisons across Countries and over Time

Some countries have established testing programs to assess standards of science achievement within the country and to make comparisons between the levels of achievement of particular subgroups of students. Such information can be of considerable value. Nevertheless, there is commonly insufficient variation within a particular country for a proper examination of factors which influence educational outcomes. By undertaking a study across many different countries, it is possible to use the natural variation that exists between countries to identify factors which have an effect. Similarly, by undertaking repeated studies within the same country over time, it is possible to use the variation occurring over time to investigate the effects of change on educational outcomes. This possibility of making comparisons across countries and over time led the founders of the International Association for the Evaluation of Educational Achievement (IEA) to collaborate together, in an ongoing quest to identify factors influencing school achievement.

Such a purpose for investigation demands that the participating countries have the willingness and the capacity to carry out an investigation in each country that adheres to common procedures in the administration and the conduct of a testing program. Moreover, countries must be prepared from the outset to collect a substantial body of supplementary data, in addition to performance on achievement tests. Such data would be used to search for factors to account for differences in outcomes both between countries and over time.

Studies conducted with these ends in view are hazardous enterprises. There is need for meticulous work in collecting data, with as high a degree of accuracy as possible, from large numbers of students and on a large number of outcome and explanatory variables. The problems of translation of tests and questionnaires into many different languages are major obstacles that need to be surmounted. The procedures employed and the relationships under examination must be sufficiently robust if strong and meaningful relationships are to be found.

At the same time each country participating in a study on each occasion must also be free to collect data that are relevant to the educational problems of that country. Thus a study is carried out within each country that seeks to provide answers to the research questions asked within that country. In addition, parallel studies are simultaneously undertaken across countries that provide answers to the research questions being asked from a cross-national perspective.

The major focus of these investigations is not to determine the rank ordering of countries with respect to science achievement, but to explain why such differences arise. With a knowledge of reasons why differences occur in educational outcomes, there is evidence to base advice on how science education might be improved within individual countries. Without such knowledge, based on empirical evidence and analysis, administrators, policy makers and science teachers are vulnerable to a wide range of conflicting pressures and ill-informed advice. Such investigations are incomplete unless consideration is also given to how science teaching and science curricula might be changed in the future, and to where decisions are made to improve science education in different countries.

Some Problems Encountered

In making comparisons between countries in cross-national research studies four problems are encountered. The first is a substantive problem, since some countries inevitably perform at a higher level than others, and countries achieving at a very high or very low level commonly consider such comparisons to be invidious. As far as is possible the emphasis in this report is on the presentation of relationships. It seeks to provide answers to questions with respect to why such differences between school systems in the outcomes of science learning occur. Furthermore, it is inevitable that some countries perform above or below what is expected from a particular relationship. This report also attempts to indicate wherever possible the reasons that can be advanced.

The second problem is a statistical problem. The samples employed in these studies are large and complex ones. The sampling errors for such samples can not be readily computed for most of the statistical procedures employed, by using simple formulae. Where possible, particularly for science achievement test scores, errors of sampling have been obtained using jackknife procedures. This is time consuming work. Resources of manpower and computer power did not permit the accurate estimation of all such errors being carried out, particularly in multivariate analyses. As an alternative, reliance has had to be made on the form and magnitude of the results. The reader of this present report is invited to examine the pattern of results, displayed where possible in graphical form, and make an assessment of the reasonableness and strength of the conclusions. [6]

The third problem is a measurement problem. The comparisons made and the analyses undertaken in the reports of the First and Second IEA Science Studies are heavily dependent on the achievement test scores which were calculated. There is no one way of computing achievement test scores that is free from some qualifications. As a consequence, three different procedures for calculating and reporting achievement test scores have been employed in this report. In presenting results, every attempt has been made to use the most appropriate and meaningful science achievement test score to address the issue under consideration. [7]

The fourth problem arises from the subdivision of the work of data analysis between different centres. As a result, some analyses which are reported in this volume are restricted to the 10 countries that were involved in both the first and second science studies.

In studies of this magnitude, it is perhaps inevitable that there should also be some shortcomings in the sample designs and their execution, in the quality of data collected under difficult circumstances, and in the analyses carried out. Such shortcomings cannot be expected to enhance relationships but rather to reduce them. However, the validity of the data collected must be judged by the strength and the meaningfulness of the relationships reported. [8]

2

Introducing Science in the Primary School

A recent world-wide survey conducted by Unesco found that nearly all countries now teach science in some way at the primary school level (Mayor, 1991). In the 1983-84 IEA science survey, it was decided to test students at a stage towards the end of the primary schooling. In most countries science was taught to such students by their regular class teacher and not by a science specialist teacher. This group of students is referred to as '10-year-olds'. The formal definition is:

> **All students aged 10:0 to 10:11 years on the specified date of testing OR all students in the grade where most 10-year-old students were to be found on the specified date of testing.**

After the tests had been prepared, some developing countries realized that these tests were much too difficult for the 10-year-olds in their country. Under such circumstances, countries were given permission to test grade groups where the tests would be more appropriate. In general, their students performed poorly on the tests, so that meaningful conclusions can still be drawn about levels of achievement in science in such countries.

Appendix 1 presents the percentage correct mean scores for each country on the science tests and subtests and the ages and grade levels for the students tested in each country. Figure 2.1 shows the mean scores for the different country groups with an estimate of the sampling error associated with each mean score. The countries fall into five groups, after errors of sampling are considered.[9]

Group 1	Group 2	Group 3	Group 4	Group 5
Japan	Sweden (Gr.4)	Italy	England	Philippines
Finland	Canada (Eng.)	United States	Poland	Nigeria
Korea	Hungary	Australia	Israel	
	Canada (Fr.)	Sweden (Gr.3)	Singapore	
		Norway	Hong Kong	

The issue of interest is not the rank ordering of countries, as if they were competing in a race. IEA research workers are more interested in accounting for why the recorded differences have arisen. Appendix 1 provides further evidence.

The higher performance of the Korean students may be due in part to their slightly greater age. A similar qualification may be made for the achievement of the Canadian (English and French) and the United States students. Furthermore, the lower performance of the English and Hungarian students may have arisen from their slightly younger ages. It is clearly difficult to test age or grade samples that are strictly comparable, since students start school at different ages in different countries as shown in Appendix 1. Thus, although the English students were younger, they were in Grade 5, having started school at the age of five years.

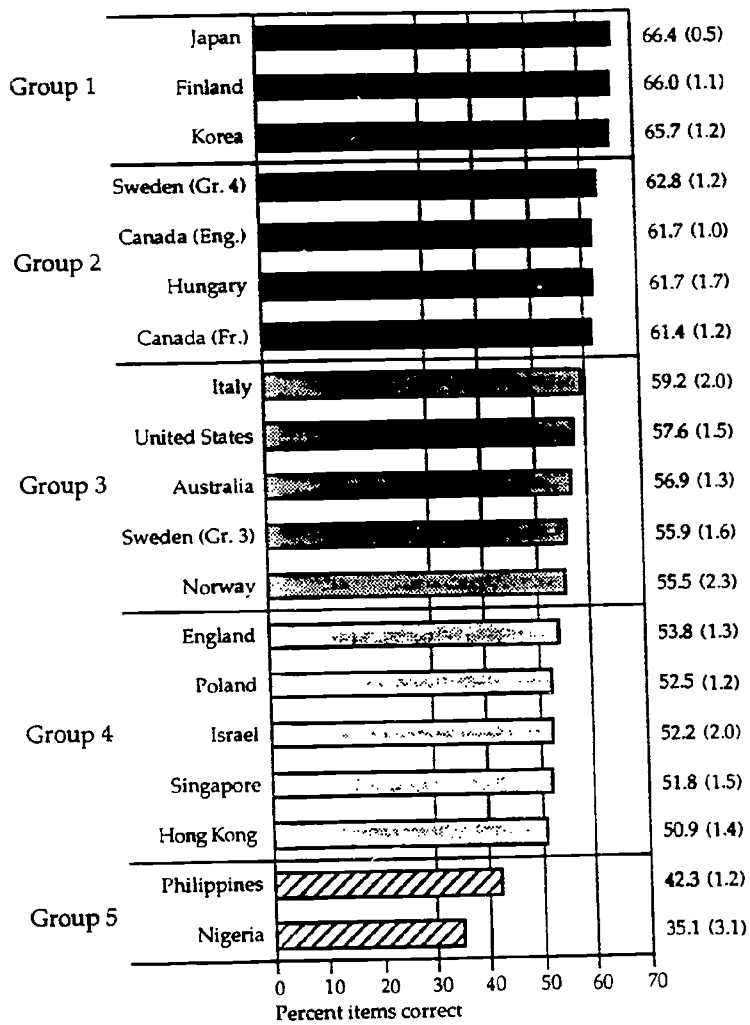
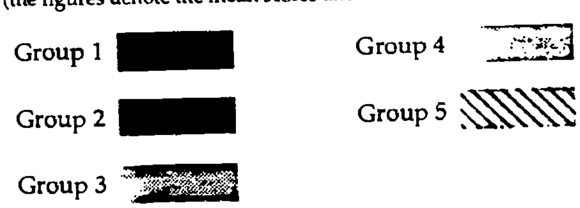


Figure 2.1 Science Performance at the 10-Year-Old Level, 1983-84
(the figures denote the mean scores and two standard errors [in brackets])



Change in Achievement over Time

The data collected allow comparisons in science achievement to be made over time. Appendix 2 gives the data on which these comparisons are made. Australia did not collect data at the 10-year-old level in 1970-71, and The Netherlands and Thailand did not in 1983-84.

The science achievement test scores have been scaled to an international science achievement test scale. This scale is shown on the inside of the back cover. The test used at the 14-year-old level in 1983-84 provided the fixed point on the scale at 500. The natural interval of the Rasch scale was set at 100 scale units. Five performance levels were set at 125 scale units apart and were referred to as the *basic* level (250), *elementary* level (375), *intermediate* level (500), *advanced* level (625) and *specialist* level (750). [10]

Figure 2.2 records performances on a common scale and the thin lines show the raw gains made between occasions. In all seven countries the change over time is positive indicating a gain. It is estimated that 33 score points on this scale is equivalent to a year of schooling. The mean raw gain over time of 30 score points across the seven countries is between three-quarters and a full year of schooling in science. [11]

In Appendix 2 evidence is also presented to show differences in the ages, grade levels and enrolment rates of the students sampled. No changes occurred in enrolment rates over time at this level of schooling. Only in Thailand on both occasions was there less than 99 percent of students enrolled at school. However, changes occurred as a result of differences in definitions of the target populations and in the structure of some school systems. For example, in Sweden the evidence suggests that some students were permitted to enter school a year earlier in the late 1970s than in the mid-1960s. These differences are of sufficient size to indicate that in comparisons over time some allowance must be made. Adjustments were made to allow for differences in the age and grade composition of samples and Appendix 2 gives these adjusted gain scores. Figure 2.2 also shows by heavy lines the adjusted changes in science achievement over time. The mean gain is reduced slightly as a result of adjustment to about two-thirds of a year of science learning at school. Only in the United States is there evidence of a deterioration in student performance. In all other countries there is evidence of major advances in science achievement.

The achievement gains over time in such a high proportion of the countries involved suggests that over the period of 14 years significant changes occurred in the way in which science was taught in these countries.To explain these gains over time, five aspects of science teaching were considered and data are given in Appendix 3:

age at which learning science begins;
grade at which learning science begins;
percent of schools teaching science at Grades 1 to 3;
percent of students reporting use of a textbook in science; and
percent of students reporting doing experiments in science lessons.

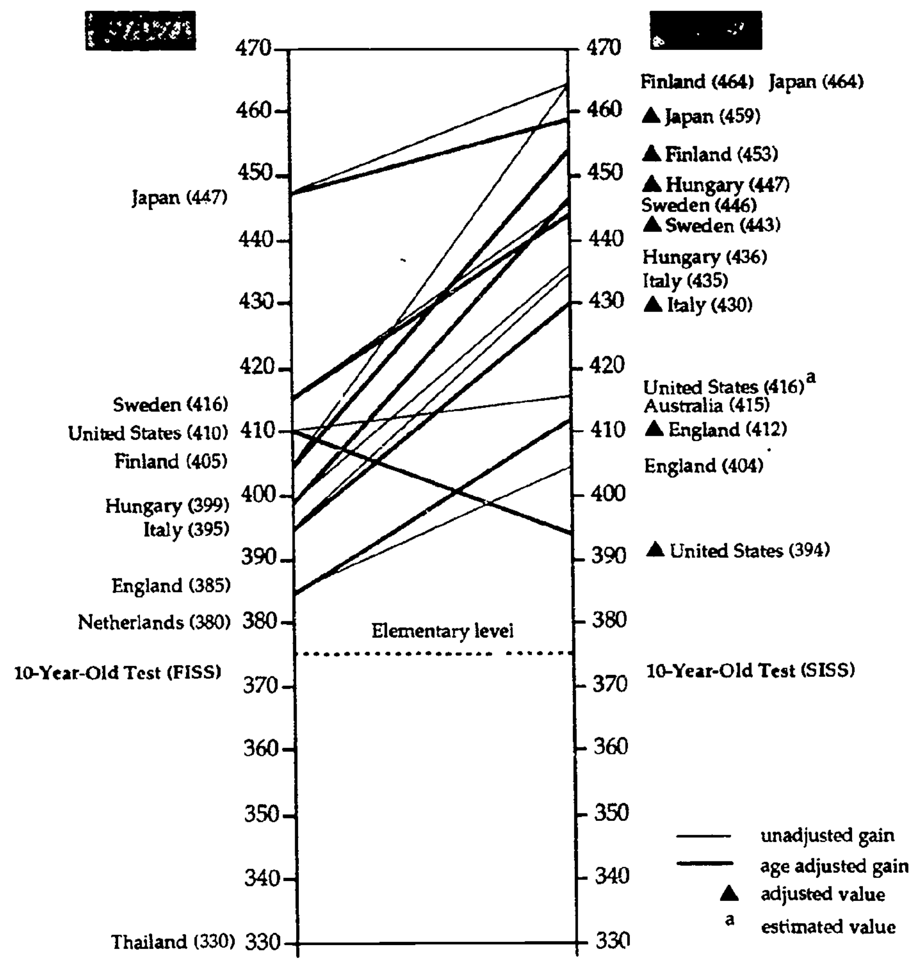


Figure 2.2 Mean Scale Scores for 10-Year-Old Level, 1970-71 and 1983-84

Elementary Level Test Item The Sun is the only body in our solar system that gives off large amounts of light and heat. Why can we see the Moon?

- *A It is reflecting the light from the Sun.
- B It is without an atmosphere.
- C It is a star.
- D It is the biggest object in the solar system.
- E It is nearer the Earth than the Sun.

The overall view obtained from these data is one of an increased emphasis on science teaching over the period from 1970-71 to 1983-84. Where it was possible for students to start learning science at a younger age or an earlier grade, a change was made. However, in Australia and Italy not all schools sampled were teaching science in the early grades although a majority were doing so. The evidence presented in Figure 2.3 also indicates very substantial increases in the proportions of students reporting that they did experiments in science lessons. In addition, the data in Figure 2.4 show a marked increase in the proportions of students reporting that they used a textbook in science lessons. These two aspects of science teaching in primary school classrooms suggest that over time there was a general and substantial increase in the extent to which science was taught in a purposeful and structured way. These two aspects together with the earlier introduction of science into the primary school curriculum in some countries help to account for the gains made over time in science achievement. [12]

Time Learning Science

For seven highly industrialized countries the data available were analyzed to examine the relationship between time spent learning science as reported by the students and science achievement test mean scores at the 10-year-old level. The data examined are given in Appendix 5. The relationship between time and science achievement is shown graphically in Figure 2.5. These countries differed substantially in the amount of time allocated to the study of science at the 10-year-old level. In those countries where more time was given to learning science, the level of achievement was higher. However, the straight line graph does not pass through the origin. This suggests that in industrialized countries scientific knowledge is also gained from reading books, magazines, and encyclopaedias, and from the mass media, particularly from television. [13]

Conclusion

The evidence presented indicates a striking general gain in the level of science achievement at the middle primary school level over the period from 1970-71 to 1983-84. This gain in achievement is due, in part, to the more formal introduction of science at an earlier grade level than previously. In addition, science would appear to be taught more purposefully in 1983-84 than in 1970-71 with students, in general, having greater access to a textbook and being more likely to do experiments by themselves in their science lessons. Nevertheless, in 1983-84, science was not being taught in all countries and in all schools from the first grade level. Furthermore, in a country, such as Australia, at the 10-year-old level more than half the students did not use a textbook and a substantial proportion, nearly 30 percent, did not do simple experiments themselves in science lessons. In addition, there were marked differences between countries in the time spent on teaching science at this stage. The evidence shows that time allocated to learning science was related to level of achievement.

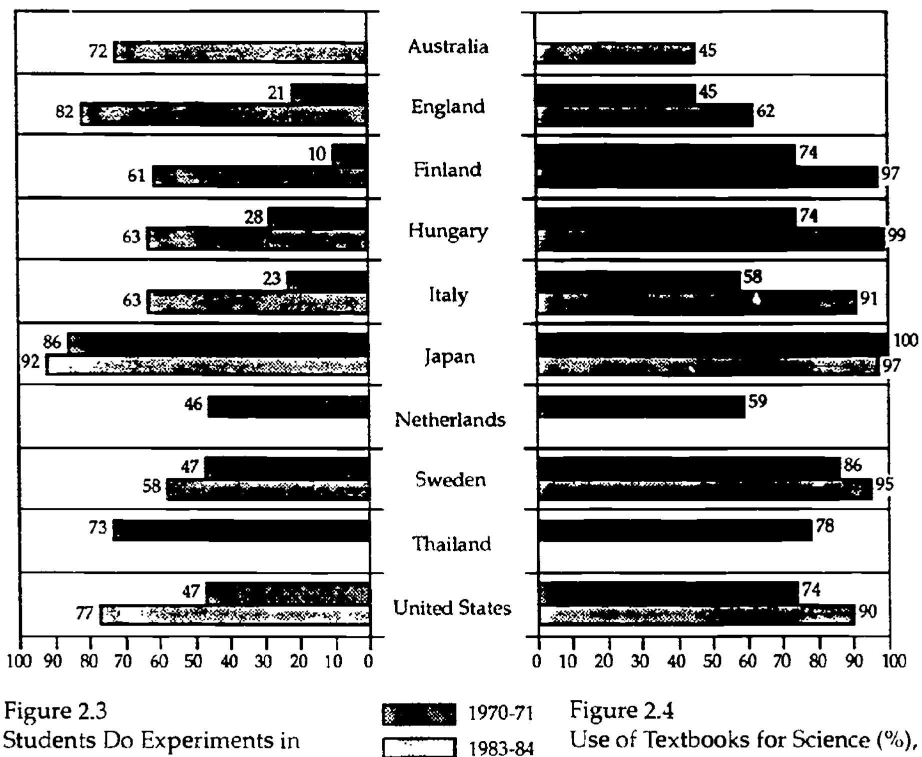


Figure 2.3
Students Do Experiments in Science (%), 1970-71 and 1983-84

Figure 2.4
Use of Textbooks for Science (%), 1970-71 and 1983-84

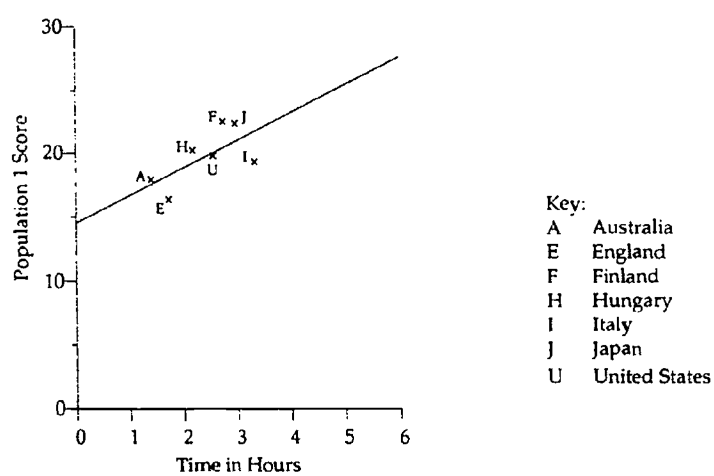


Figure 2.5 Time and Science Achievement, 10-Year-Old Level, 1983-84

3

Science for All in the Middle Secondary School

In 1983-84, in all countries taking part in this investigation at the lower secondary school level, the study of science in some form was obligatory. Countries, however, differed in the extent to which they required science to be studied as students progressed upward through the secondary school. The second stage at which the testing program was conducted was at that level where in most countries 100 percent of the age group was still in school. In addition, in most countries, it was found that up to and including this level the learning of some field of science was mandatory. The formal definition of the target population at this age level referred to as the '14-year-old level' is given below.

> **All students aged 14:0 to 14:11 years on the specified date of testing OR all students in the grade where most 14-year-old students were to be found on the specified date of testing.**

As at the 10-year-old level many countries preferred to use the second of the two alternative definitions and to test an intact class group from within each school. Furthermore, some countries considered that the tests were more appropriate for use at a grade level where some 14-year-olds were enrolled, but in which older students were also enrolled. Students in these countries performed, on average, poorly, even though an older group was tested.

Appendix 4 gives the percentage correct mean scores on the science tests and subtests, and the ages and grade levels of the students tested for each country. Figure 3.1 shows the mean scores for the different countries with an estimate of the error associated with each mean score. The countries were formed into five groups, after the errors of sampling were considered, with little overlap between groups. Within each group countries were ranked in order of achievement. [14]

Group 1	Group 2	Group 3	Group 4	Group 5
Hungary	The Netherlands	Canada (Eng.)	Thailand	Ghana
Japan		Korea	Singapore	Zimbabwe
		Sweden (Gr.8)	Sweden (Gr.7)	Nigeria
		Finland	England	Philippines
		China	Papua New Guinea	
		Italy (Gr.9)	Hong Kong	
		Poland	United States	
		Norway	Italy (Gr.8)	
		Australia		
		Canada (Fr.)		
		Israel		

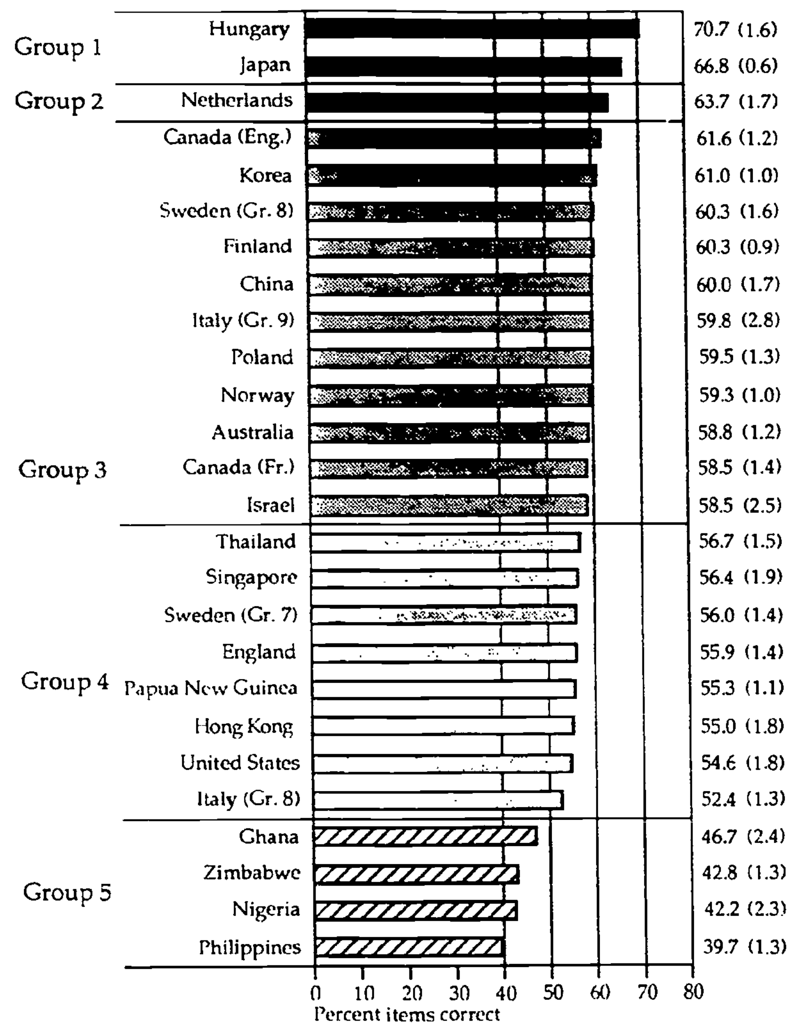
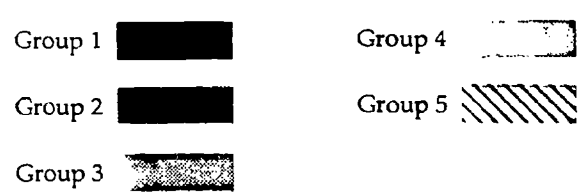


Figure 3.1 Science Performance at the 14-Year-Old Level, 1983-84
(the figures denote the mean scores and two standard errors [in brackets])



Hungary and Japan achieved a level well above the other countries tested. Four developing countries, namely Ghana, Zimbabwe, Nigeria, and the Philippines performed at a lower level than the other countries. The remaining countries bunched together into two groups with relatively small differences between the countries within each group. There were, however, quite large differences between countries in the proportions of the age group attending school. The proportions of the age group enrolled are given below in parentheses. Hungary (92%), the country performing at the highest level had lost eight percent of the age group from school by the 14-year-old stage. Ghana (6%), Zimbabwe (30%) and the Philippines (60%) tested at the Grade 9 level and had substantial proportions of the age group not attending school. These three countries still performed at the lowest level of achievement in science. Likewise Nigeria, with no data available on the proportion of the age group at school, and with testing carried out at Grade 10, was also included in the lowest group. Several other countries had substantial proportions who were not attending school, namely: Papua New Guinea (11%), Thailand (32%), Italy (Gr. 9) (72%) and Canada (Fr.) (84%). China, which tested in three provinces Beijing, Tianjin and Taiyuan had an estimated 37 percent enrolled at school in these provinces. A fall in the proportion enrolled at school associated with the group under survey, must be expected to give rise to a higher level of achievement than would be found if the whole age group were enrolled.

Changes in Achievement over Time

The data collected in the first and second science studies allowed comparisons in science achievement to be made over time in 10 countries. Appendix 6 provides the information on which these comparisons were based. The performance of the students on both occasions is shown on the common scale in Figure 3.2. The thin lines give the science achievement raw score gains made over time. [15]

In eight of the 10 countries there is evidence of gains between occasions. In Australia, the slight decline, is less than the errors of sampling, measurement and scaling and must be interpreted as no change in performance. For the United States there is evidence of a sizeable drop in level of achievement. These results suggest that between 1970-71 and 1983-84 across countries there had been an average gain of 17 score points on the science achievement scale. This is equivalent to approximately half a year of schooling in science.

The information provided in Appendix 6 also shows the differences between occasions in the 10 countries with respect to age and grade levels tested. In some cases the changes recorded were associated with a restructuring of the school system. Again in Sweden the change over time in grade composition was a consequence of earlier admission to schooling as is seen at the 10-year-old level. Some differences recorded were a consequence of changes between occasions in the design of samples from the defined target populations.

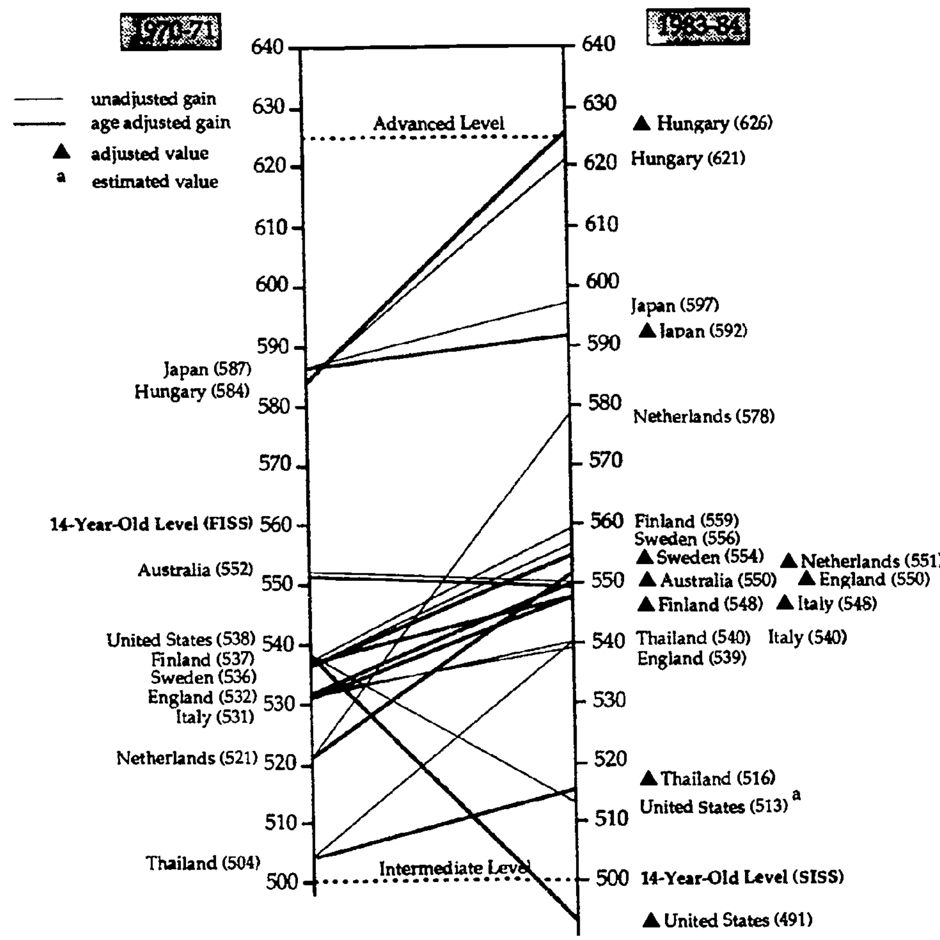


Figure 3.2 Mean Scale Scores for 14-Year-Old Level, 1970-71 and 1983-84

Advanced Level Test Item When 2 g (grams) of zinc and 1 g of sulphur are heated together, practically no zinc or sulphur remains after the compound zinc sulphide is formed. What happens if 2 g zinc are heated with 2 g of sulphur?

A Zinc sulphide containing approximately twice as much sulphur is formed.
*B Approximately 1 g of sulphur will be left over.
C Approximately 1 g of zinc will be left over.
D Approximately 1 g of each will be left over.
E No reaction will occur.

Adjustments were made to allow for these differences in the samples employed and the adjusted gain scores are shown in Appendix 6. The adjusted gains are indicated by heavy lines in Figure 3.2. The net effect of adjustment was to reduce slightly the sizes of the gains recorded, but not the pattern of results. Eight countries continued to show gain. The United States showed a greater decline in performance after adjustment and Australia continued to show no change. On average across countries there was a gain of about one-third of a year of schooling in science between 1970-71 and 1983-84.

In part it might be argued that the improved performance at the 14-year-old level reflected the gains recorded at the 10-year-old level. However, it is necessary to consider other possible sources of the improved performance in the different countries over time.

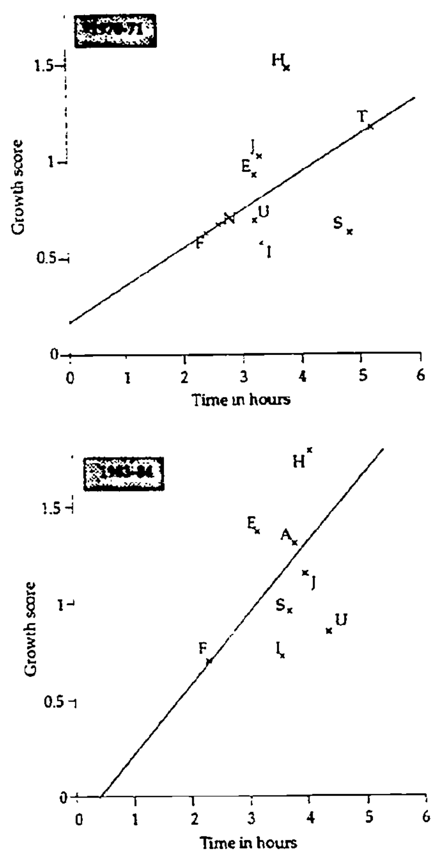
Time and Science Learning

Appendix 7 records the curricular time spent on the study of science for the 10 countries on both occasions. In addition, Appendix 7 gives the science achievement test scores, brought to a standard score scale, so that growth in science achievement between levels could be examined. In Figure 3.3, the growth scores on both occasions are plotted against time in hours. There is a general relationship between curricular time and growth in science achievement for both 1970-71 and 1983-84. However, other factors also act to influence science achievement. [16]

Achievement at the 10-Year-Old and the 14-Year-Old Levels

One possible influence in a country's performance at the 14-year-old level, is the average level of achievement within the country at the 10-year-old level. The data necessary to examine this relationship for the 10 countries under review are also given in Appendix 7. Figure 3.4 records the graphs of science achievement at the 14-year-old level plotted against science achievement at the 10-year-old level for both 1970-71 and 1983-84. On both occasions Hungary is an outlier performing well above expectation at 14 years of age given the level of achievement of its students at 10 years of age. In part, this above expectation performance in Hungary at the 14-year-old level is related to the greater time given to the study of science, more particularly in 1983-84 than in 1970-71. Japan also performed at a level above expectation at the 14-year-old level in spite of its relatively high level of achievement at the 10-year-old level on both occasions. [17]

This relationship between science achievement at the 10-year-old and the 14-year-old levels, indicates that the foundations laid in the primary grades are very important for learning science at the secondary level.



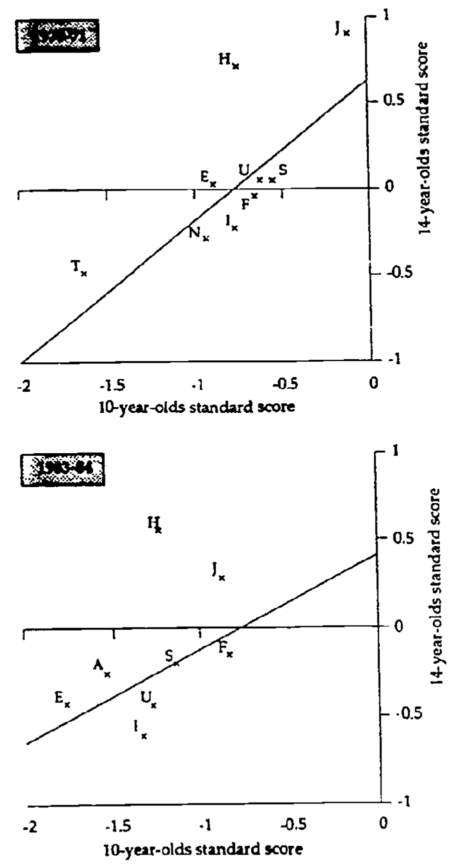


Figure 3.3
Time and Growth in Science Achievement Test Scores, 1970-71 and 1983-84

Figure 3.4
Standard Science Achievement Test Scores: 10-Year-Old Country Mean Plotted against 14-Year-Old Country Mean Scores, 1970-71 and 1983-84

Key:

A	Australia	J	Japan
E	England	N	Netherlands
F	Finland	S	Sweden
H	Hungary	T	Thailand
I	Italy	U	United States

outlier

Intensity of Learning Science

In a re-analysis of data collected in the first science study, Coleman (1986) drew attention to the fact that some countries taught science at a higher level of intensity at the lower and middle secondary school stage than did other countries. An examination of the growth scores between age levels recorded in Appendices 2, 6 and 7 for both 1970-71 and 1983-84 allowed countries to be classified into two such groups.

Group 1 - High Intensity	Group 2 - Low Intensity
Australia	Finland
England	Italy
Hungary	The Netherlands
Japan	Sweden
Thailand	United States

The consistency over time in the level of growth in science achievement between the 10- and the 14-year-old levels is quite striking. A detailed examination of evidence that might account for the differences between the two groups was undertaken in order to identify factors associated with the observed difference in intensity of science teaching. In the high intensity countries the three fields of science were taught either simultaneously as separate subjects, or as an integrated subject at the grade levels containing 14-year-old students. In the low intensity countries at the grade levels containing 14-year-old students, not all three fields of science were being taught to all students. In general, some alternation in the fields of science taught occurred for each semester or each year. Students in some countries learnt only one field of science as was common in the United States, or at most two fields of science during a semester as was common in Sweden. In Italy at the Grade 9 level, generally only one field of science was studied, while at the Grade 8 level, although general science was taught, there was limited emphasis on teaching all fields of science.

The effects associated with intensity in the learning of science would appear to lie in the fact that some students, during the period immediately prior to testing, had had an opportunity to learn aspects of science drawn from the three major fields of science - biology, chemistry and physics - whether science was taught as separate fields or as an integrated subject. However, other students were currently studying at the time of testing only one or at most two of the three major fields of science. Thus some students had less recent opportunity to learn content in one or more of the three fields. The former group of students had learnt science with a high level of intensity. The latter had learnt science with a low level of intensity. In part, this finding reflects the fact that the tests administered contained items drawn from the three major fields of science, together with some items from the field of earth science. The opportunity to learn the science content associated with the items included in the tests, was perhaps inevitably related to performance. [18]

Conditions of Learning Science

There are three further items of information on which data are available, that might serve to explain the changes in science achievement at the 14-year-old level over time.

First, there is the proportion of schools for which *Grade 8 was the last compulsory grade* for learning science. By implication the remainder of the schools for each country required that science was a compulsory subject at Grade 9. Secondly, there is the proportion of the age cohort studying science at the grade level under survey - the *participation rate*. This is the proportion of the age group enrolled at school, multiplied by the proportion of those at school studying science. Thirdly, there is the *time spent learning science* which involves both science curricular time in hours and time given to science homework.

Information on these three aspects of the conditions under which science was taught both in 1970-71 and 1983-84 is given in Appendix 8. There was a marked fall over time in several countries, namely, Australia, England, Finland, The Netherlands and United States in the proportion of schools that stated that Grade 8 or below was the last compulsory grade for learning science. Only in Australia (4% of schools) and the United States (1% of schools) was it possible in 1983-84 for students to cease learning science at the eighth grade level. The evidence presented in Appendix 8 indicates an increase over time in all countries in the mandatory requirements to study science at the 14-year-old level.

Appendix 8 shows that in all countries the proportion of the age cohort studying science, the participation rate, increased from 1970-71 to 1983-84. Appendix 8 also records class time, homework time and total time spent on learning science on the two occasions and shows that the time spent on studying science had increased. Only in Sweden and Thailand did the time spent on the study of science fall over time. In these two countries both the class time and the homework time declined. It should be noted that in Sweden part of this decline in curricular time spent on the study of science was taken up by the introduction into the curriculum at this level of a kindred subject of *Technology*. However, the noticeable decline in time spent on homework in science involved a different policy decision. Thailand recorded a marked gain in science achievement, presumably as a consequence of the reshaping of the science curriculum in the late 1960s and early 1970s. However, there was clearly a substantial reduction in curricular time for science in Thailand to the lowest level of time for the 10 countries under survey. [19]

Conclusion

The evidence presented in this chapter indicates an increasing recognition across most countries of the importance of the study of science by all students at the lower and middle secondary school stage. It is also clear that successful science teaching in the secondary school builds upon what is taught at the primary level. Moreover, there is strong evidence to support the teaching of all three major fields of science to all students in a concyclic or spiral curriculum during this period of schooling. Nevertheless, certain countries, such as the United States, show shortcomings in their provision for science teaching and learning at the middle or high school level that must be of concern to their science educators and administrators.

4

Graduating from High School

An important goal of school science programs is the preparation of high school graduates who will continue with the study of science-oriented courses at tertiary level and train to enter science-based occupations. Such students specialize in their final years at school in the study of one or more of the major fields of science - biology, chemistry and physics. There are, in addition, students specializing in areas other than science, who may or may not take alternative science courses that do not lead directly to the further study of science. As a consequence the students investigated at the upper secondary level were divided into the science specialist and the non-science specialist groups. The former group were further subdivided into biology, chemistry and physics specialists. The definitions used to identify these groups of students are given below.

Upper Secondary Level	**All students at the terminal or pre-university year of full-time secondary education.**
Science Specialists:	**All students in the terminal year of full-time secondary education studying science at a level which would permit them to proceed with the study of science related courses at an institution of higher education. These students were divided into several sub-populations as were appropriate in the different countries: (3B) all students studying Biology; (3C) all students studying Chemistry; (3P) all students studying Physics.**
Non-Science Specialists:	**All students in the terminal year of full-time secondary education not currently studying science subjects which would permit them to continue with the study of science related courses at an institution of higher education.**

The groups of students tested in different countries differed in several important respects:

- in age, depending largely on the age of entry to school;
- by number of years of schooling, or grade level;
- in the number of subjects studied for high-school graduation;
- in the time given to the study of each science subject;
- in the proportion of the age group studying each science subject;
- in the number of science subjects studied;
- in the relative abilities of students studying different science subjects; and
- in the relative proportions of male and female students studying the science subject.

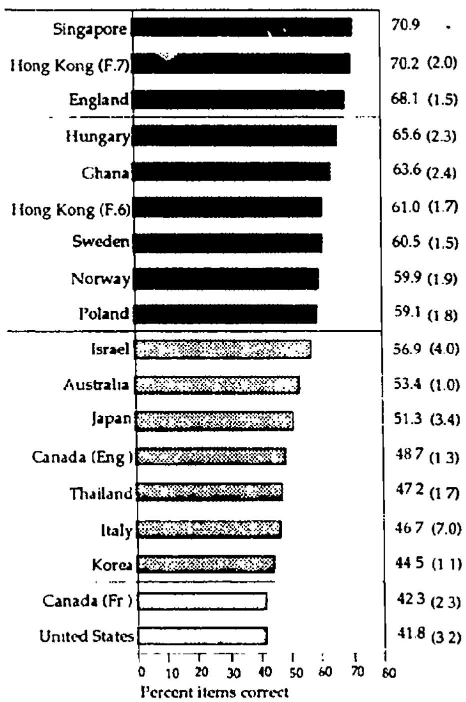


Figure 4.1 Performance in Biology of Science Specialist Students Upper Secondary Level, 1983-84

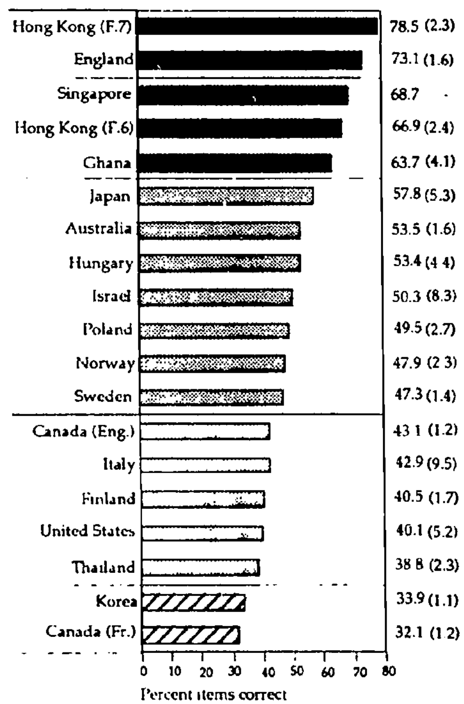


Figure 4.2 Performance in Chemistry of Science Specialist Students Upper Secondary Level, 1983-84

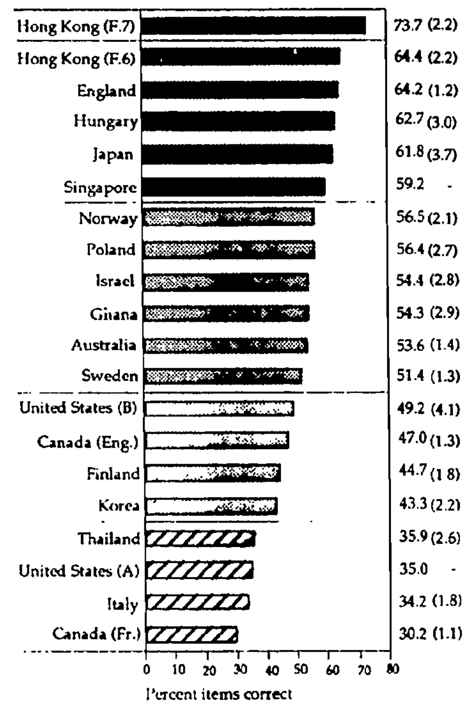
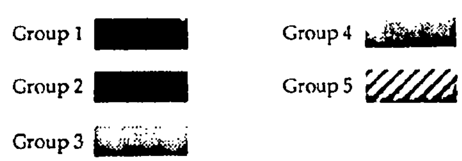


Figure 4.3 Performance in Physics of Science Specialist Students Upper Secondary Level, 1983-84

Note:
The figures on the right-hand side of each bar chart denote the mean scores and two standard errors [in brackets]



Such differences make it difficult to compare the performance of students from the different countries. In spite of these differences there are important comparisons that can be made and conclusions that can be drawn.

Achievement in Biology, Chemistry and Physics

Appendix 9 gives information on the achievement and the characteristics of the samples of students tested in biology at the upper secondary school level. [20]

The countries fall into four largely separate groups as is seen in Figure 4.1.

Group 1	**Group 2**	**Group 3**	**Group 4**
Singapore	Hungary	Israel	Canada (Fr.)
Hong Kong (F.7)	Ghana	Australia	United States (B)
England	Hong Kong (F.6)	Japan	
	Sweden	Canada (Eng.)	
	Norway	Thailand	
	Poland	Italy	
		Korea	

Appendix 10 records the results for the chemistry specialist students. Five groups were identified as is seen in Figure 4.2. [20]

Group 1	**Group 2**	**Group 3**	**Group 4**	**Group 5**
Hong Kong (F.7)	Singapore	Japan	Canada (Eng.)	Korea
England	Hong Kong (F.6)	Australia	Italy	Canada (Fr.)
	Ghana	Hungary	Finland	
		Israel	United States (B)	
		Poland	Thailand	
		Norway		
		Sweden		

Appendix 11 presents the data on the performance and characteristics of the students in physics, and five achievement groups are shown in Figure 4.3. [20]

Group 1	**Group 2**	**Group 3**	**Group 4**	**Group 5**
Hong Kong (F.7)	Hong Kong (F.6)	Norway	United States (B)	Thailand
	England	Poland	Canada (Eng.)	United States (A)
	Hungary	Israel	Finland	Italy
	Japan	Ghana	Korea	Canada (Fr.)
	Singapore	Australia		
		Sweden		

The consistently high levels of achievement of students in Hong Kong, England and Singapore and the low levels for students in the United States and Canada (Fr.) should be noted. It is necessary to ask why such consistent differences occur.

Achievement and Participation Rates

Appendices 9, 10 and 11 record the participation rates or the proportions of the age group studying biology, chemistry and physics respectively at the upper secondary level as specialist students. Figure 4.4 presents the graphs of achievement and participation rate. Linear relationships are found when particular countries are considered as outliers. In biology, Italy, Thailand, Canada (Fr.) and the United States are outliers performing below expectation. Again in chemistry and physics, Italy, the United States and Thailand are outliers performing below expectation. Hong Kong at both Forms 6 and 7 and in both chemistry and physics is an outlier achieving well above expectation. In general, where there is a higher proportion of the age group specializing in a science subject, the average level of achievement of the students is less. [21] However, it is important to recognize that the evidence available shows that the achievement of the better students does not suffer when more students are retained at school at the upper secondary level. [22]

Time and Achievement

Figure 4.5 shows the strong relationships between time spent learning biology, chemistry and physics at the upper secondary level and the average levels of achievement of the students. The data available are recorded in Appendix 12 and there is clear evidence that the time spent on the study of the science subject is a critical factor in influencing achievement. In biology, Sweden is an outlier achieving above expectation. In chemistry, Finland is an outlier, performing above expectation while Hungary is an outlier performing below expectation. In physics, Thailand is an outlier achieving below expectation, although the performance of the Italian sample is also low. Data were only available for the United States on time spent studying physics at the Year 12 level. These data indicate a marginally lower than expected level of achievement after allowance is made for the time spent studying physics. It is clear that in the United States, the teaching of science at the upper secondary level follows a very different arrangement to that occurring in other countries. This results in lower levels of participation, reduced time over the years of schooling spent on studying the specialist fields of science, and lower levels of achievement. Performance in chemistry in Hungary warrants further examination. [23]

Achievement of the Non-Science Specialists

Appendix 13 presents the achievement test scores for the non-science specialist students at the terminal secondary school level. Appendix 13 also records the percentage of the age group represented by the non-science specialist students tested, the proportion of the samples tested who were studying science, and the average time spent on learning science for the students tested, including those not studying science. The Hungarian students performed very well, in part because all were studying science. However, the English, Japanese and Swedish students also responded well, although none of these groups of students were at the time of testing taking any science courses. The United States students tested, who represented a substantial proportion of the age group, and who were not currently studying science, performed satisfactorily although not well. [24]

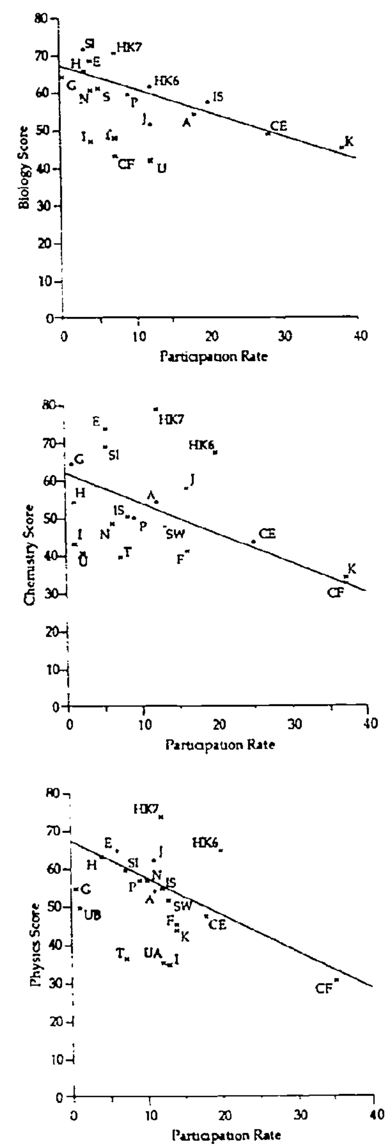


Figure 4.4
Participation Rates Plotted against
Science Achievement, 1983-84

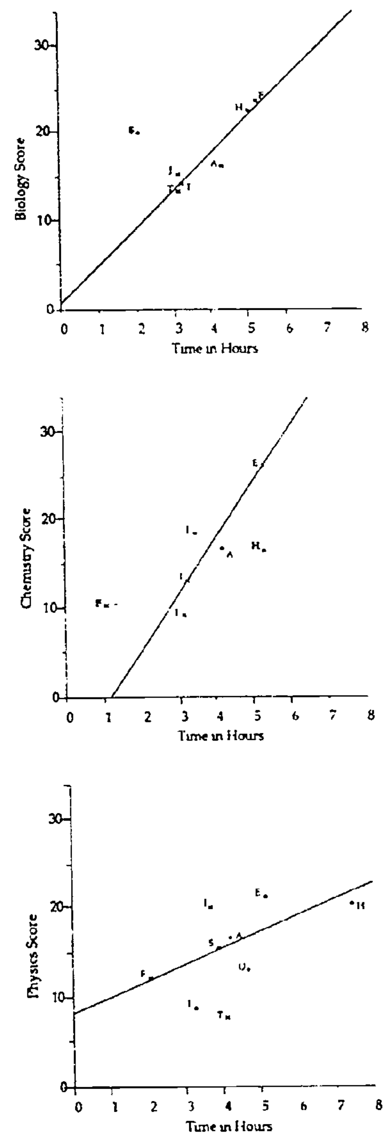


Figure 4.5
Time Plotted against Science
Achievement, 1983-84

Key:

A	Australia	HK7	Hong Kong (F.7)	N	Norway
CE	Canada (English)	H	Hungary	P	Poland
CF	Canada (French)	IS	Israel	SI	Singapore
E	England	I	Italy	S	Sweden
G	Ghana	J	Japan	T	Thailand
HK6	Hong Kong (F.6)	K	Korea	U	United States

Indexes of Yield

Three indexes of the scientific output of the high schools were examined.[25]

Science Achievement Yield. An index of yield of achievement in science was calculated by multiplying the mean test score, combined across all sub-groups by the retention rate. Yield indexes were obtained for 1983-84 for all students and for science specialist students. For 1970-71 similar indexes could only be calculated for all students. The scores for the two occasions are not on a common scale and are not directly comparable over time.

Science Educational Yield. Students in the samples tested at the terminal secondary school level were asked whether or not they expected to study any science subjects as part of their further education. The index of *science educational yield* is the proportion of the age group who expected to continue with the study of science at the tertiary level.

Science Occupational Yield. The students were also asked the type of course they planned to take at the post-secondary school level. The courses were classified into those leading to a science-based occupation, and those leading to a non-science based occupation. The former group comprised the following courses: agriculture, fishing, and forestry; applied science and science including mathematics; engineering and technology; and health sciences, including nursing and medicine. The proportion of the age group expecting to take courses leading to these four occupational groups is an index of the *science occupational yield*.

The estimated values of these indexes of yield for both **all students** and **science specialist students** are recorded in Appendix 14 and are presented graphically in Figure 4.6. From these results the following findings are noted.

1. Japan, the United States and Australia have relatively high levels of science achievement yield resulting from the relatively high proportions of the age group enrolled at school.

2. The yield in science achievement in Sweden and England relative to other countries would appear to have dropped over the period of 14 years as a consequence of the lack of growth in retention rates and participation rates in the study of science.

3. The low level of science achievement yield in Italy and Thailand must be a cause for concern in countries where there is a thrust for technological development.

4. The high levels of science educational and science occupational yield in Japan indicate that Japan is well placed to maintain scientific and technological development. In part, these high yield values arise from the plans of some non-science specialist students to continue with science based courses at the post-secondary school level.

5. Australia has a high level of science educational yield and science occupational yield. Students plan to continue with the further study of science if they are science specialist students.

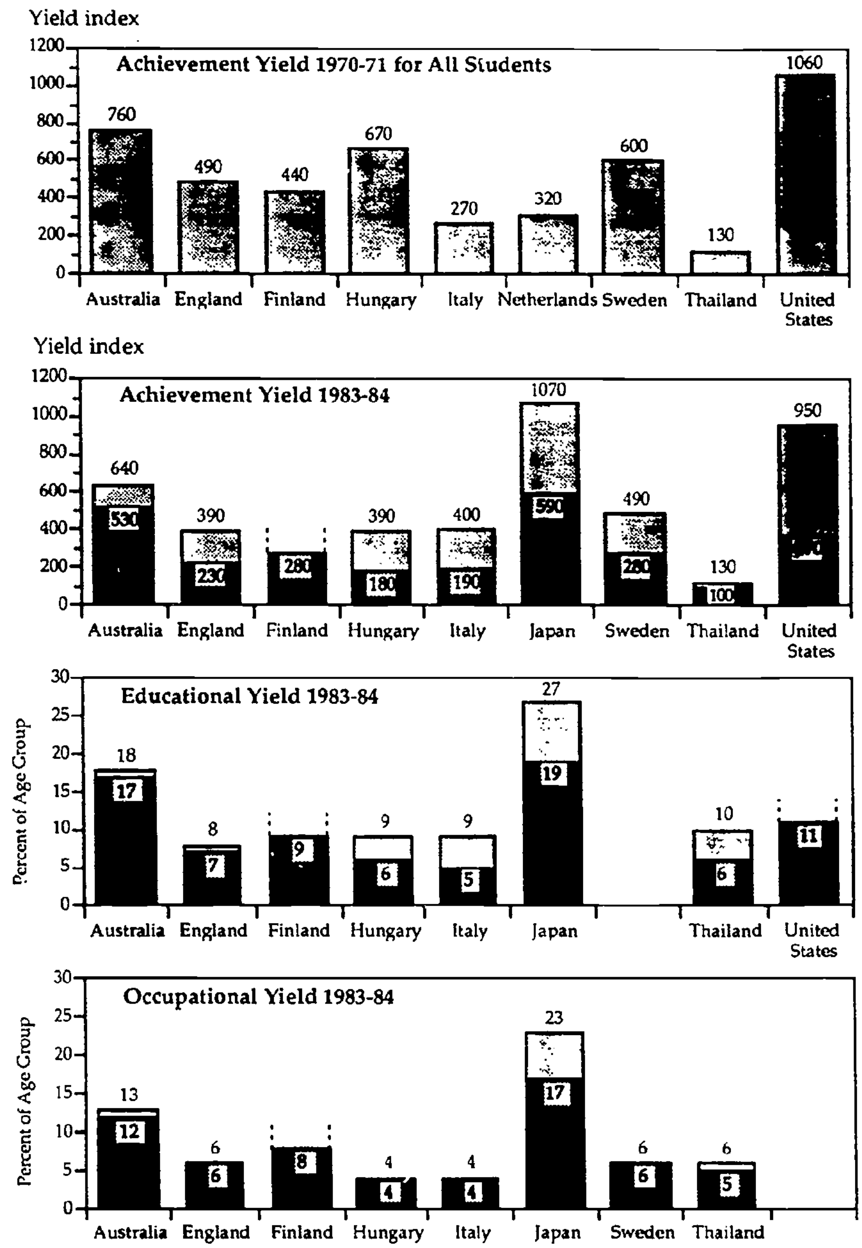


Figure 4.6 Science Achievement Yield (1970-71 and 1983-84), Educational and Occupational Yields (1983-84)

Science specialist students
Non-science specialist students

6. England has a relatively low level of science educational yield and science occupational yield, partly as a result of relatively low retention rates at the terminal secondary school level and as a result of polarization into science and non-science specialist programs at this level.

7. The science achievement yield index for Hungary fell between 1970-71 and 1983-84, and the educational yield and occupational yield were low in 1983-84. These results are in marked contrast with the high level of aspiration and achievement of the Hungarian students at the 14-year-old level. It would seem that although the Hungarian students recognized the importance of science for national development, the economic conditions within the country were so depressed in 1983-84, that the harsh realities of earning money and employment and the thrust on vocational training drew substantial proportions of students away from planning to take professional courses in science at the university level.

Factors Influencing Future Participation in Science

Analyses were undertaken to examine the factors influencing both directly and indirectly future participation in science courses after the completion of secondary schooling. Future study of science would appear to be influenced directly by:

- science values (career interest and beneficial aspects of science);
- aspirations (expected occupation and post-secondary education);
- amount of science studied (class time, courses and homework); and
- science attitudes (interest in science and ease of learning science).

Only in Hungary, does the sex of student (being a male) have a significant direct effect on future participation. Those boys in Hungary who remain in academic schooling are more likely than girls to continue with the study of science. However in five countries, sex of student has significant effects operating indirectly through values, attitudes, aspirations and amount of science studied to influence future participation. In most countries the effects of being a boy or a girl on future participation in science courses and preparation for a science-based occupation beyond the post-secondary level take place prior to the upper secondary school level. These gender effects have their influence on attitudes, values and science achievement well before the end of secondary schooling. [26]

Conclusion

The findings presented in this chapter indicate that the average levels of achievement of the science specialist students depend largely upon the proportions of the age group involved in the study of the different fields of science and the time given to the study of science at this level of schooling. However, the involvement of a higher proportion of the age group in the study of science does not lead to the better students doing worse. Nevertheless, the full picture of the yield of a school system in scientific training is not obtained unless the non-science specialist students are also taken into consideration.

5

Learning Science

Attitudes to Science and their Effects [27]

Five dimensions of attitudes and values to science were examined in the Second Science Study. Outcomes believed to be influenced by these attitudes and values were:

- achievement in science;
- choice of science subjects studied at school;
- further study of science after leaving school;
- preparation to enter a science-based occupation;
- performance on practical skills tests; and
- gender-related differences in performance.

The scales developed to measure these attitudes and values were:

1. *Interest in science at school.* The student likes science more than other school subjects, and considers science lessons to be interesting and enjoyable.

2. *Ease of learning science.* The student considers that science is not a difficult subject to learn, and that difficulties do not arise from handling apparatus, learning too many facts, or from undertaking calculations.

3. *Career interest in science.* The student expresses an interest in a scientific career in order to use the science learnt at school, to learn more about the world, and to work in a laboratory; and considers science to be a good field for creative people to enter. The student also considers that it is important to know science in order to get a good job; that people who understand science are better off in society; and that in future most jobs will require a knowledge of science.

4. *Beneficial aspects of science.* The student considers that science is useful for solving everyday problems; is important for a country's development; will make the world a better place in the future; and will raise standards of living. In addition, the student considers that it is worth spending public money on science and scientific research.

5. *Non-harmful aspects of science.* The student considers that science has not ruined the environment; has not increased tensions between people; has not caused the world's problems; has not made the world too complex; has not created anxiety; and that scientific discoveries do more good than harm.

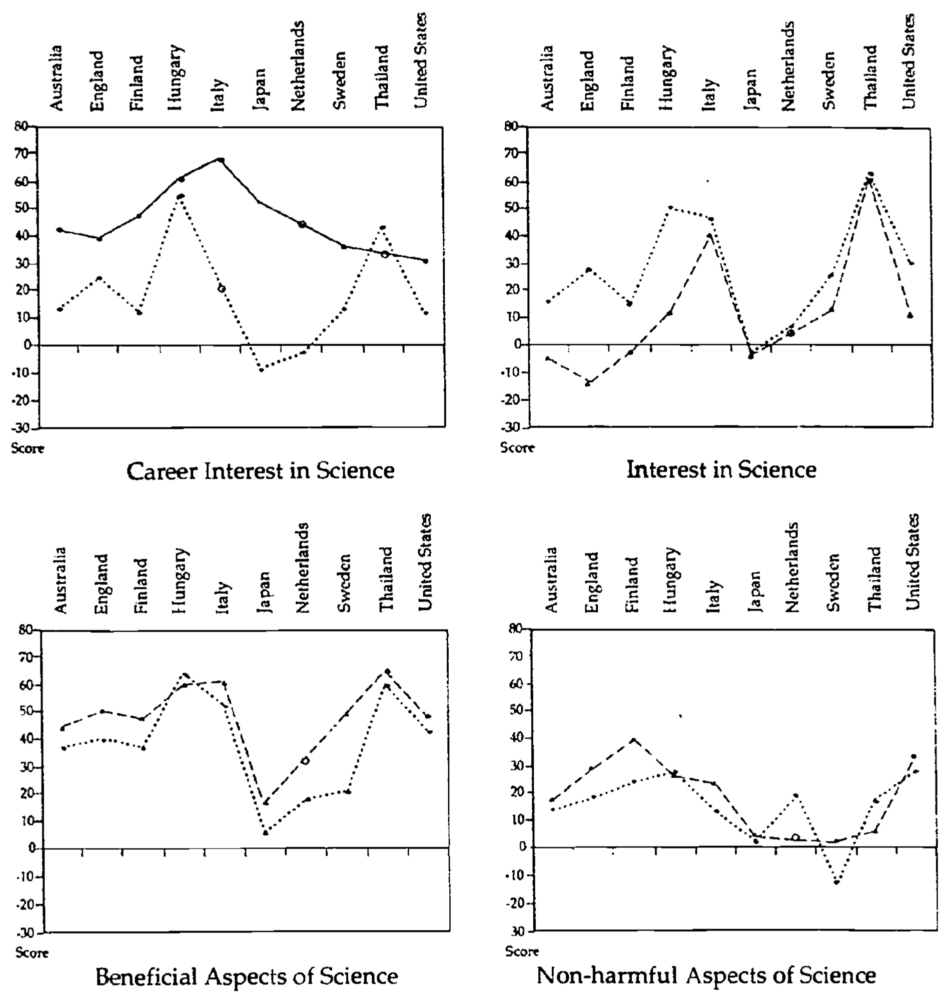


Figure 5.1 Attitudes Compared across Countries and Populations, 1983-84

Notes:
Attitude scale scores range from -100 to +100
—●— 10-year-old level
····◆··· 14-year-old level
- -▲- Upper secondary level
○ no data available

All five attitude scales were Likert-type scales with 'agree', 'disagree' or 'uncertain' response categories.

Figure 5.1 presents profiles where differences and similarities across countries and across age levels can be examined. The measured attitudes are recorded on scales that range from -100 to +100. Thus a value of zero represents a neutral level of attitude between highly favourable (+100) and highly unfavourable (-100) attitudes. No comparative results are presented for ease of learning science, or for population levels where comparisons are not valid. The following comments can be made from the four pairs of profiles presented.

1. Attitudes to science are, in general, favourable, indicating strong support for science and the learning of science.

2. There is consistency across countries and across population levels in the average level of attitudes towards science held by students.

3. There is a marked decline in attitudes of interest in school science between the 10-year-old level and the 14-year-old level. This decline is particularly noticeable in Japan, and is of concern to Japanese educators (Kida, 1991). [28]

4. In general, students in Hungary, Italy and Thailand hold very favourable attitudes to science. Students in Japan, The Netherlands and to a lesser extent Sweden, hold less favourable attitudes. This suggests that in those countries where there is an emerging thrust for industrial and technological development the attitudes to science of the students at school are highly favourable. In those countries where a high level of technological and industrial development has been achieved, attitudes to science are more neutral.

5. While Swedish students at both the 14-year-old and upper secondary school levels hold favourable attitudes towards the beneficial aspects of science, they also hold more neutral attitudes and express reservations about the non-harmful aspects of science. This is consistent with the widely acknowledged concern in Sweden for environmental issues. The same is generally true for other countries, particularly Thailand. It is less true for the United States.

6. In Australia, England, Finland and Hungary, there is evidence of a decline in career interest in science between the 14-year-old and upper secondary school levels. In the cases of Finland and Hungary this could be due to the high proportion of girls remaining at school to the terminal year and substantial proportions of boys transferring to vocational programs between the 14-year-old and the Year 12 levels. In England and Australia, the effects recorded could well be due to polarization by students into science oriented and non-science oriented courses in the upper secondary school.

The Effects of Attitudes to Science

One of the questions of interest is whether attitudes influence achievement or whether achievement influences attitudes. Work was carried out to examine this question using procedures which permitted reciprocal effects to be estimated. This work provided evidence for three findings. [29]

1. The effects of attitudes concerned with the beneficial aspects of science on achievement are approximately equal in magnitude to the effects of achievement on these attitudes (see Morgenstern, 1990).

2. The effects of interest in school science on achievement are greater than the effects of achievement on interest.

3. The effects of achievement on attitudes of ease of learning science, are greater than the effects of these attitudes on achievement.

There are two clusters of attitudinal measures. The first cluster is concerned with **attitudes to school science** and involves both *interest in science at school* and *ease of learning science.* These attitudes are assumed to influence directly achievement in science and not vice versa. The second cluster is concerned with **science values** and combines together the measures of *career interest in science, beneficial aspects of science,* and *non-harmful aspects of science.* These values are assumed to influence both attitudes to school science and science achievement.

Analyses were conducted at two levels. First, analyses sought to account for the differences in achievement that occurred between students **within** schools or classrooms. Secondly, analyses sought to account for differences in achievement **between** schools and classrooms. Table 5.1 shows in summary form the results of the analyses to examine the effects of attitudes on achievement. The following findings can be seen. [30]

1. In all countries and at both the 10-year-old and 14-year-old levels, attitudes to school science have a direct effect in accounting for differences in science achievement between students **within** classrooms.

2. At the 14-year-old level in all countries except Thailand, science values either acting directly or indirectly through other mediating factors account for differences between students **within** classrooms in their achievement in science. In Thailand the average level of science values of the students is very high.

3. At both age levels, with England the exception at the 10-year-old level and Australia the exception at the 14-year-old level, either the average level of attitudes of the students towards school science, or the average level of science values of the school or classroom group account for differences in the average levels of achievement **between** groups of students.

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Table 5.1 The Effects of Science Attitudes and Values on Science Achievement, at 10- and 14-Year-Old Levels, 1983-84

Results based on latent variable path coefficients	Australia	England	Finland	Hungary	Italy	Japan	Netherlands	Sweden	Thailand	United States
10-Year-Old Level										
Between students within classrooms										
Attitudes to school science [a]										
direct effects	÷	÷	÷	÷	÷	÷	nd	÷	nd	÷
Science values [a]										
direct effects			÷				nd	÷	nd	÷
total effects			÷				nd	÷	nd	÷
Between classrooms										
Attitudes to school science [b]										
direct effects			★	★		★	nd	★	nd	
Science values [b]										
direct effects	★		★		★		nd		nd	★
total effects	★		★		★		nd		nd	★
14-Year-Old Level										
Between students within classrooms										
Attitudes to school science [a]										
direct effects	÷	÷	÷	÷	÷	÷	÷	÷	÷	÷
Science values [a]										
direct effects	÷		÷	÷	÷		÷	÷		
total effects	÷	÷	÷	÷	÷	÷	÷	÷		÷
Between classrooms										
Attitudes to school science [b]										
direct effects				★	★		★		★	
Science values [b]										
direct effects		★	★	★				★		★
total effects		★	★	★		★	★	★		★

a Coefficients greater than 0.05 are shown with ÷.

b Coefficients greater than 0.10 are shown with ★.

nd No data collected.

These findings are of particular importance for teachers who are in a position to influence the attitudes and values of the students within their classrooms. The science attitudes and values held by individual students influence the level of achievement of those students in science, after other factors such as the home background and aptitude of the students are taken into account. Likewise, the average levels of attitudes and values held by the classroom group of students also have an influence to change the level of achievement in science of the classroom group after allowances are made for home background and aptitude effects.

Teachers can influence students' attitudes and values, and can have both direct and indirect effects on their students' achievement in science. As a consequence science teachers should create a climate in their classrooms where students become interested in science, see the beneficial aspects of science, recognize that science is not necessarily harmful or difficult to learn, and seek a career in a science-based occupation.

Towards Equality between the Sexes

The existence of differences between boys and girls in achievement in science is well known. However, the origins of such differences in science achievement are based on speculation and have not been firmly established.

Societal Changes in Equality between the Sexes [31]

Several indexes of the roles of women in society show change across countries between 1970-71 and 1983-84.

- There was an increase in the proportion of women engaged in the labour force in all countries except Japan.
- There was an increase in the age of first marriage in all countries.
- There was a substantial drop in total fertility rates in all countries.
- There were substantial falls in family size in all countries.

Several indexes associated with equality between the sexes in educational participation and provision showed clearly identifiable change.

- In all countries, there were substantial falls in the ratio of male to female students at the terminal year of secondary schooling.
- In nearly all countries there were falls in the ratio of male to female teachers both at the secondary school and university levels.
- In all countries where single-sex schools formerly existed, there was a substantial decline in the ratio of single-sex to coeducational schools.

These results indicate a changing role of women in society with reduced involvement in child rearing and greater participation in employment. In addition, they also indicate a change in educational provision and participation with a marked decline in single-sex schools, with greater retention of girls in schooling, and with greater involvement of women in teaching at school and university. Australia and England are among the few countries in the group where single-sex schools still exist, and Australia is the only country where there was an increase in the proportion of male teachers in secondary schools over the 14 year period.

Since the late 1960s and early 1970s there would appear to have been a climate established in which there has been pressure for greater equity in educational and occupational participation between the sexes. One way in which this might be accomplished is through improved performance by girls in science and in particular, the physical sciences.

Changes in Science Achievement over Time

The undertaking of two parallel studies 14 years apart provided a unique opportunity to make comparisons over time. Figure 5.2 shows these results averaged across countries. The index of difference between boys and girls is called an *effect size*.

It can be seen that the effect sizes are larger in physics, than in chemistry and again larger than in biology. Furthermore, the effect sizes are larger at the upper secondary level, than at the 14-year-old level, and again larger than at the 10-year-

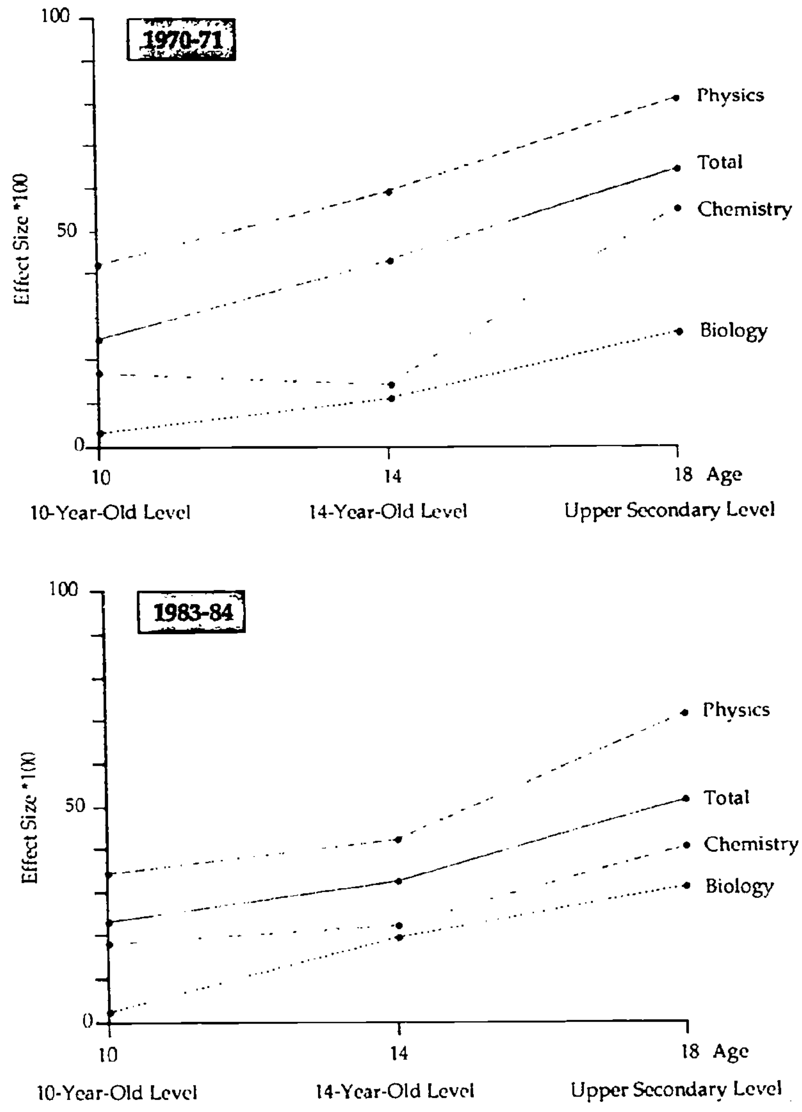


Figure 5.2 Sex Differences in Science Scores and Subscores at Different Ages, 1970-71 and 1983-84

Note: The difference recorded is called an *effect size* and is obtained from:

$$\text{Effect size} = \frac{(\text{boys score - girls score}) \times 100}{\text{pooled standard deviation across countries}}$$

old level. Thus the effect size is influenced by time in schooling, and by the content of the field of science being studied. However, the influence of selection must also be considered at the levels of schooling beyond which enrolment is compulsory, or the study of a particular field of science is mandatory, since different proportions of boys and girls are drawn to studying science or a particular field of science. Inspite of the effects of selection at the upper secondary level boys outperform girls in science.

At the 10-year-old level there was little change in the effect size over time. At the 14-year-old level there was a significant reduction in the effect sizes in five countries, and on average across all countries, with one exception, namely England. The countries showing a significant decline were Australia, Finland, Hungary, Japan and Sweden. At the upper secondary level, there was a significant reduction in four countries - Australia, England, Finland and Sweden. Three of these countries were common between the 14-year-old and upper secondary levels. The significant differences reported are associated with a drop in the effect sizes in achievement in the physical sciences, more particularly in physics. Such relationships are seen clearly in Figure 5.2. The programs introduced to encourage girls to become involved in science and technology in such countries as Australia and Sweden would appear to have produced these results. [32]

Nevertheless, there are disturbing effects emerging at the terminal secondary school level in many countries and in particular, in Finland and Hungary where the ratio of male to female students in academic schooling have fallen between 1970-71 and 1983-84 from 0.8 to 0.6 and 0.8 to 0.5 respectively. In these two countries, for various reasons boys have opted out from formal academic education, preferring to move more rapidly towards employment and the earning of money, through educational programs in vocational schools. As specific vocational skills become more difficult to identify, the more general education provided in academic schools would appear to have increasing value. Consequently, the question must be raised as to whether it is becoming necessary to establish more effective programs for boys in academic schools particularly in the field of technology. [33]

Differences between the Sexes in Participation in Science Courses

At levels of schooling where the study of science ceases to be mandatory, differences emerge between the sexes in participation in science courses in the fields of biology, chemistry and physics. Figure 5.3 shows the profiles by country of the percentage of male students studying biology, chemistry and physics respectively at the terminal secondary school level. The star profiles cross for only one country, Italy, although they touch in several places. Thus, in general, the percentage of male students enrolled in physics, exceeds the percentage of male students enrolled in chemistry, which also exceeds the percentage of male students enrolled in biology. This ordering of subject fields is the same as that recorded for differences between the sexes in science achievement. Thus it would appear that relative levels of achievement in the fields of science may be related to subsequent participation. [34]

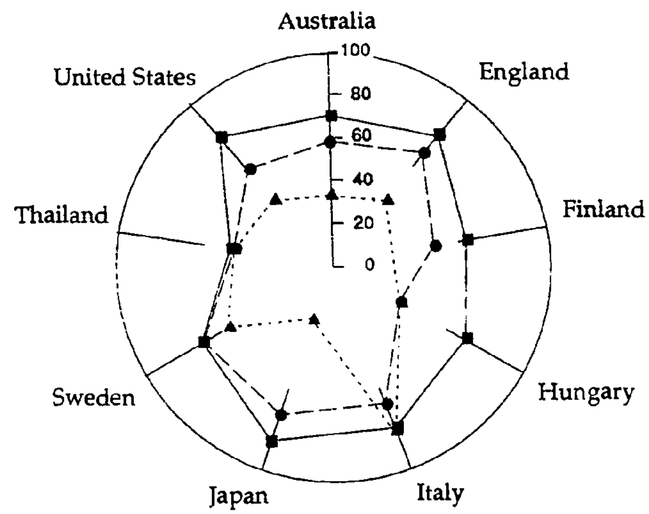


Figure 5.3 Percentage Male of Total Group of Science Specialist Students Studying Biology, Chemistry and Physics at the Pre-university Level, 1983-84

Biology
Chemistry
Physics

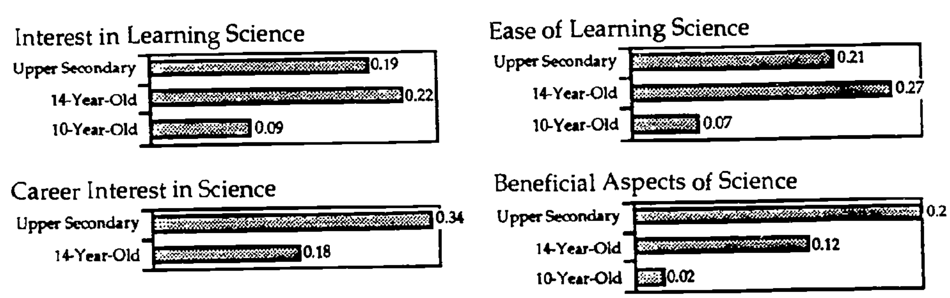


Figure 5.4 Effect Sizes of Sex Differences in Attitudes to Science, 1983-84

Note: The difference recorded is called an *effect size* and is obtained from:

$$\text{Effect size} = \frac{\text{(boys score - girls score)} \times 100}{\text{pooled standard deviation across countries}}$$

Attitudes to Science and their Effects [35]

Figure 5.4 records the average effect sizes for differences between boys and girls in their attitudes to science. At the 14-year-old and upper secondary levels information on four key attitudes is presented:

- beneficial aspects of science,
- interest in learning science,
- ease of learning science, and
- career interest in science.

At the 10-year-old level the attitude of career interest in science was not assessed, and the scale measuring the beneficial aspects of science was replaced by a scale concerned with the *importance of science*. The pattern of results is very clear. Even at the 10-year-old level, male students hold more favourable attitudes to science.

The second finding shown in the data and in Figure 5.4 is that differences between the sexes in attitudes to science increase with age. This result parallels the increase in effect sizes in achievement in science. Attitudes and achievement appear to be linked together in the development of such differences as students progress through the years of schooling.

Causal analyses show that the sex of the student has a direct influence on:

- science achievement, and
- attitudes and values towards science held by the students.

However, sex of student acting through attitudes and values has only weak indirect effects on science achievement.

Moreover, there is no clear evidence to indicate that attitudes and values operate differently for male and female students in their influence on science achievement. Nevertheless, Kotte (1991) has shown that in two countries, Australia and England, where there are sufficient numbers of single-sex schools for effective analyses, that science attitudes and values operate differently in single-sex boys schools, single-sex girls schools and coeducational schools to influence science achievement.

These results add to our understanding of how with increasing age, attitudes and values may contribute to the emergence of gender differences in achievement. Moreover, they suggest that the attitudes and behaviours of teachers within classrooms may have a strong influence on the engendering of differences between boys and girls in their attitudes and achievement in science.

The fact that sex differences in achievement have been reduced significantly over time between 1970-71 and 1983-84 in several countries makes it clear that the influence of this factor is, at least in part, societal rather than biological. However, the manner in which the sex of the student operates to influence science achievement is not completely clear from the analyses undertaken. Attitudes are involved and effects also differ for the field of science being considered.

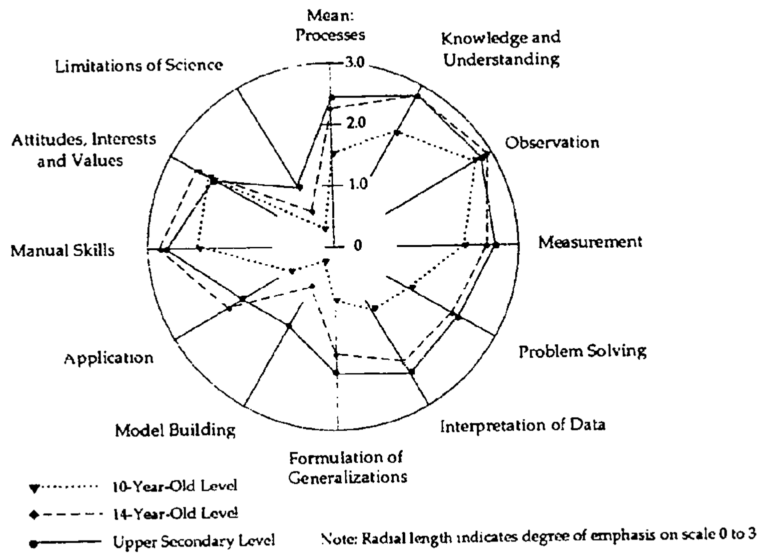


Figure 5.6 Emphasis on Process Objectives in Science Curricula for 10-Year-Old, 14-Year-Old and Upper Secondary Level, 1983-84

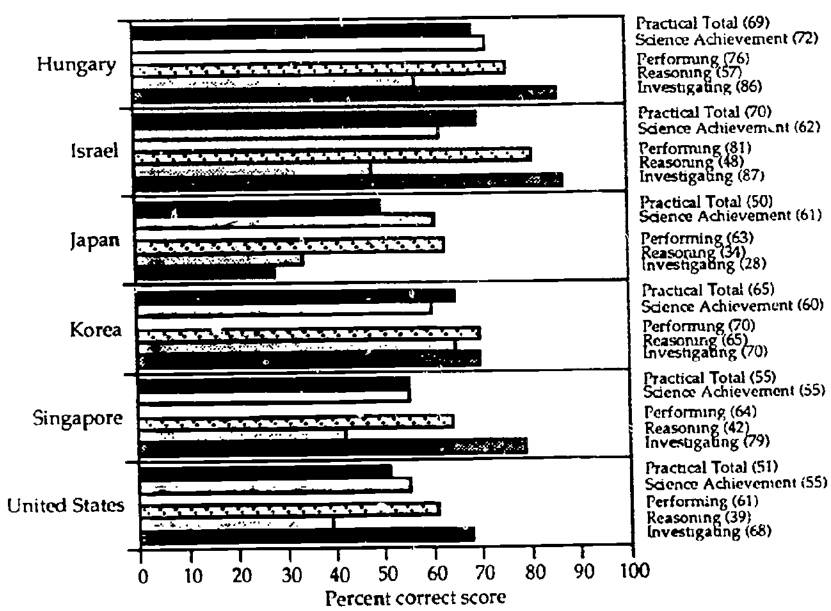


Figure 5.7 Performance on Practical Skills Test, 14-Year-Old Level, 1983-84

Science is Inquiry [36]

Not only does the learning of science involve the mastery of ideas and principles, but it also involves the acquisition of the skills of inquiry. These skills are taught primarily in the school science laboratory and through practical work. The teaching of these skills was examined by asking the countries participating in the second science study to provide ratings on the emphasis on this aspect of the science curriculum using a four-point scale. Eleven general activities of science as inquiry were identified.

- **Processes**
  - **Knowledge and understanding,**
  - **Observation,**
  - **Measurement,**
  - **Problem solving,**
  - **Interpretation of data,**
  - **Formulation of generalizations,**
  - **Model building,**
- **Applications of science,**
- **Manual skills,**
- **Attitudes, interest and values,** and
- **Limitations of science and scientific methods.**

Figure 5.6 gives the mean ratings averaged across countries for those countries that responded and for each population level. Generally, there is increased emphasis as students progress through the stages of schooling. There is strong emphasis on knowledge, observation, measurement, problem solving, the interpretation of data, manual skills and attitudes, interests and values. There is noticeably less emphasis on the formulation of generalizations, model building, application and the limitations of science. Some assessment of these objectives was warranted.

Practical Skills Testing Program [37]

Practical skills tests were developed for use at the 10-year-old and 14-year-old levels and six countries took part in the program - Hungary, Israel, Japan, Korea, Singapore and the United States.

For the practical skills tests at the 14-year-old level in addition to a total score three subtest scores were obtained, which assessed the skills of *performing, reasoning* and *investigating*. The results for the six countries and for the same samples of students on the science achievement tests (paper and pencil tests) are given in Figure 5.7. In all countries the students achieve less well on the reasoning subtest than on the performing subtest.

It should be noted in Figure 5.7 that the Japanese students achieve at a much lower level on the practical skills test. This is particularly true for their achievement in reasoning and investigating in the practical situation, but not for their skills of performing in a practical setting. Furthermore, there is no evidence of a lower level of achievement by Japanese students on understanding or application in pencil and paper science achievement tests.

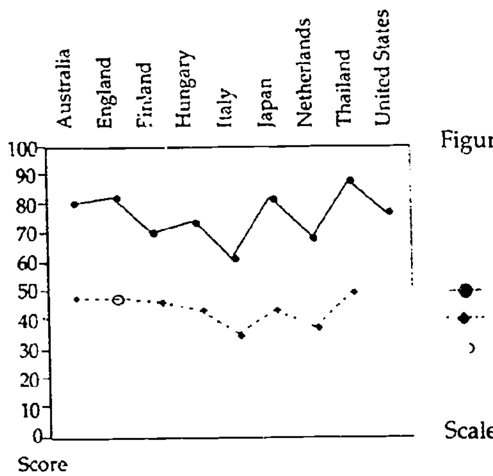


Figure. 5.8 Dimensions of Science Teaching, 14-Year-Old Level, 1983-84

Scale scores range from 0 to 100.

In contrast, although the students from the United States perform less well on both the practical skills tests and the science achievement test than students from other countries, they achieve at a relatively higher level on the investigating subtest. These results suggest that while there are deficiencies in the in the knowledge of content in learning science in the United States, there may be relative gains being made in investigating or inquiry skills.

The Hungarian, Israeli, and Korean samples perform relatively well on the practical skills tests as well as on the science achievement tests. These results raise questions about the manner in which science is taught in different countries to 14-year-old students.

Emphasis on Inquiry in Science Teaching [38]

Information was obtained from students and teachers at the 14-year-old level on the provision made for inquiry in science teaching. A scale was developed to assess the emphasis placed by teachers on inquiring and investigating. This scale was specified in the following terms:

> *Scientific investigation.* The teacher thinks that developing the ability of the students to think scientifically and the understanding of scientific concepts to be important. Towards these ends the teacher spends much of the time teaching science in a laboratory, with the students doing practical work on their own or in small groups. In assessing student performance the teacher makes frequent use of project work including practical and laboratory exercises.

A corresponding scale was constructed to assess the students' views of science teaching, and this scale was defined in the following terms:

> *Student practical work.* The student reports doing practical work in small groups during science lessons, with written instructions, or with instructions given by the teacher. Reports of practical work are written up for home work.

Percentage scores on the degree of emphasis on each of these two dimensions of science teaching and learning were calculated with 'often' scored 1, 'sometimes' scored 0.5, and 'never' scored 0.

Figure 5.8 records the profiles for this pair of scales so that the average views of the teachers for a country are compared with the average views of the students. There is a strong indication of correspondence between students' and teachers' views across countries. This evidence indicates that practical work and an investigatory approach are seen to be generally higher in Japan and Thailand, and lower in Italy and The Netherlands. Unfortunately complete data are not available for the views of teachers in England and the United States with respect to this dimension. However, there is evidence to show that for students' views on practical work there is wide variation across class groups and schools in the United States (ROH=0.66) and markedly less variation in England (ROH=0.12).

Factors Influencing Science Achievement [39]

Scientific Investigation. In two out of 10 countries at the 14-year-old level, namely Italy and Thailand, where the science teachers place a greater emphasis on investigation, the students in the class group do better on the science achievement tests after other factors have been taken into account.

Student Practical Work. In six countries at the 14-year-old level, namely England, Finland, Hungary, The Netherlands, Thailand and the United States, the total effects of the students' views are found to be important. In all these countries, except Hungary, the direct effects of this factor are also found to be important accounting for at least one percent of the between school variance. Thus in six out of 10 countries, those students who view their science classes as having a greater emphasis on practical work perform better than do students who view their science classes as having little emphasis on practical work.

The development of investigating skills is seen to be an area of growing importance in science education. However, this does not imply that traditional science practical work in the laboratory should continue unchanged, although it does involve an increased emphasis on the processes of inquiry in science teaching. This requires that teachers should stress investigatory activities and that students should view the learning of science as being involved with inquiry. The evidence from this study indicates that in the mid-1980s, where students saw science teaching as being associated with a greater emphasis on practical work, in general, they achieved at a higher level. In addition, the performance of the Japanese students on the practical skills tests indicates that there are skills of reasoning and investigating in the practical situation, that differ in kind from those skills involved in responding to pencil and paper tests. There is no evidence to suggest that Japanese students lack opportunities to carry out practical work, and their results on the performing subtests and their views on student practical work indicate that such opportunities are provided. Yet, it is probable that the pressure for examination success requires Japanese teachers and students to place such a strong emphasis on knowledge, that deficiencies arise in the development of the inquiry skills of reasoning and investigation. This area of science teaching and learning warrants further consideration.

6

The Science Curriculum

The achievement in science of students in any particular country, school or classroom must be seen in terms of the science curriculum studied and opportunity to learn the topics tested.

The Planned Curriculum [40]

In both the First and the Second IEA Science Studies a detailed examination of the *planned* or *intended* science curriculum was carried out. The domain of science was divided into four fields - earth science, biology, chemistry, physics, and a total of 57 topics was identified within these four areas. Countries provided ratings at each of the age and grade levels tested on the degree of emphasis given to each topic. There are four findings of particular interest.

- In many countries science is a school subject that is developed across grade levels in a concyclic or spiral way. For most topics there is an increased emphasis from one grade level to the next. Thus the teaching of the four fields of science in separate layers in separate years does not provide for a gradual and planned development across the stages of schooling.

- By the final grade of secondary schooling in most countries most topics are taught with a major emphasis to the science specialist students in the fields of biology, chemistry and physics, but not in earth science. Thus across these three major fields of science there is a largely common body of scientific content that is taught to students in different countries by the end of secondary schooling. What is taught in lower grades, and how it is taught may differ between countries, but during the 12 years of schooling the science taught progresses towards this common body of content.

- The topics that receive least emphasis in the physical sciences at the terminal secondary school level are those that involve the application of scientific ideas and principles. These topics are concerned with the use of science in technology and everyday life. The curriculum reforms of the 1960s and 1970s placed less emphasis on the applications of science. Today the demand to raise the standards of science teaching in the schools comes from a thrust for technological development. A strong case can thus be argued for greater emphasis in science courses on how scientific knowledge is applied in industry, commerce and daily life, together with the interrelations between science, technology and society.

- At all three levels tested, only moderate emphasis is placed on topics in the field of earth science. Moreover, at the terminal secondary school level, only in four countries - Australia, Italy, Japan and Korea - is earth science formally taught. In some countries, mainly those in Eastern Europe, geography was originally introduced into schools and universities with a strong emphasis on physical geography and with earth science and geology included. Today, the emphasis is changing towards social and economic geography. As a consequence, the field of geography is becoming increasingly recognized as a social science, and not as a natural science.

  It should be noted that three of the four countries teaching earth science or geology at the terminal secondary school level lie within active volcanic zones. The fourth country, Australia, is heavily dependent on its mineral resources, and has major problems of land usage and desertification.

Changes in Content [41]

Thought was given to new science content that might have been introduced between 1970 and 1984. Three general areas were considered to be important in developed countries:

- the history and philosophy of science,
- environmental science, and
- technical and engineering science.

In addition, it was argued that developing countries might emphasize two further content areas:

- rural science, and
- health science.

Topics within these areas were identified, and the degree of emphasis on these topics assessed. However, there was little evidence of concyclic development of these topics across the stages of schooling. Only for the topics of *Environmental Impact* and *Habitats* was there a strong degree of emphasis. The remaining 13 new topics examined received only limited emphasis in science teaching at any level. It is clear that the science curriculum of the schools evolves slowly, although some change has taken place over time.

Opportunity to Learn [42]

From the curriculum analysis it was possible to identify topics that had high, moderate or low ratings across most if not all countries. This information was used in the construction of tests that would be fair across countries. It was, however, also important to examine the extent to which the *planned* or *intended* curriculum was implemented in schools. The science teachers of the students tested were asked to assess the extent to which their students had had an opportunity to learn the content of each of the items in the tests.

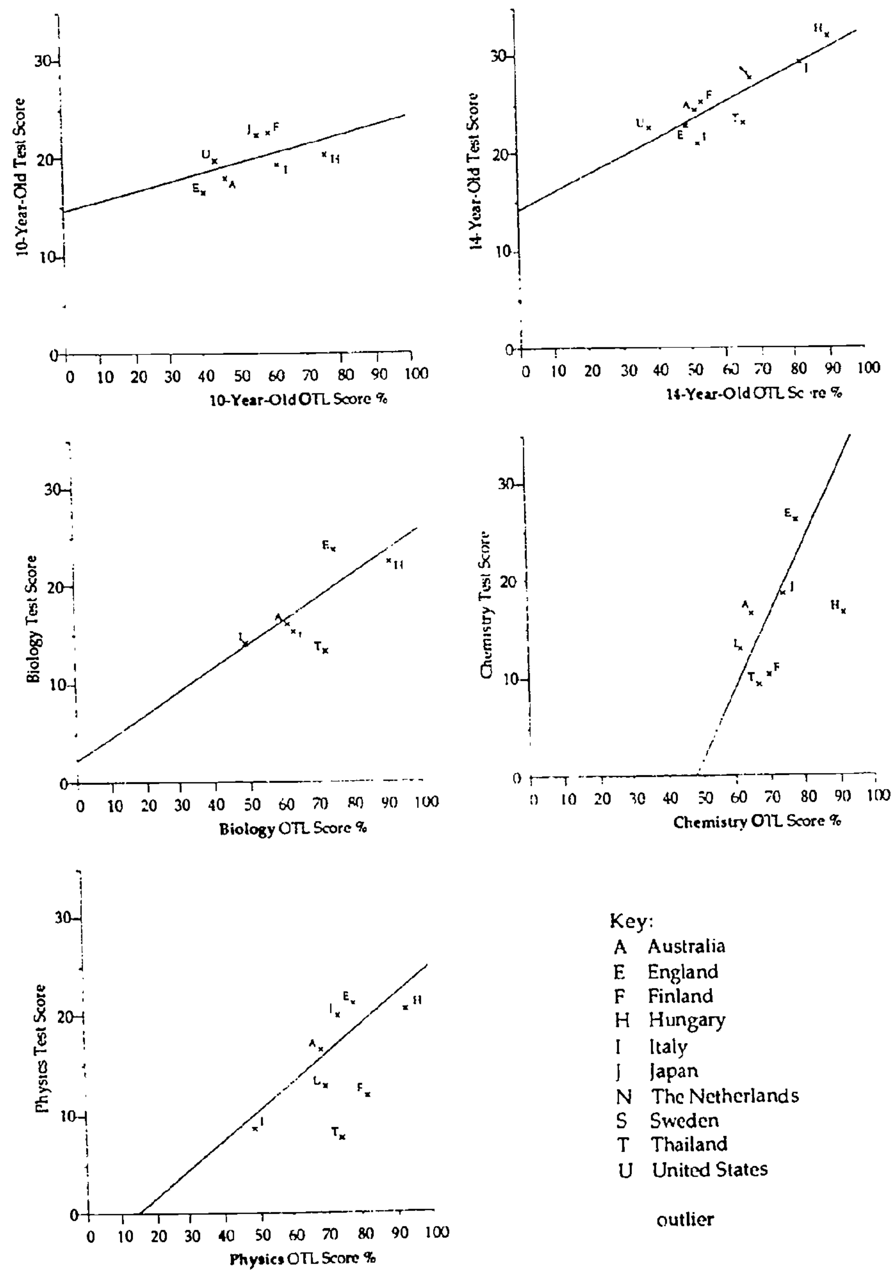
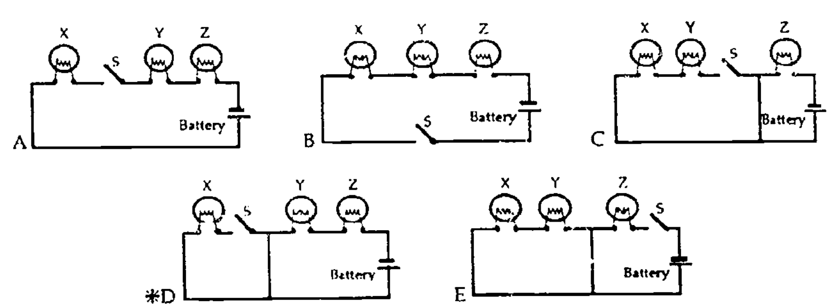


Figure 6.1 Opportunity to Learn Science Plotted against Science Achievement, 1983-84

The mean opportunity to learn rating for each country on each of the main tests is plotted against the average level of achievement of the students in that country in Figure 6.1. For each of the five tests there is a general linear relationship. Where a country has performed at a high or low level on the science tests its achievement depends on the opportunity to learn provided. At the upper secondary school level, Thailand is an outlier in biology, Hungary in chemistry, and Finland and Thailand in physics with students in these countries performing well below expectation.

Since the data on opportunity to learn were supplied for each school within each country it is possible to examine the effects of opportunity to learn on the average level of achievement of each school. Such relationships are more likely to be found where schools have greater freedom to determine their science curricula. Where there is a centrally prescribed curriculum for all schools in a country, it is unlikely that strong relationships are found when other factors are taken into account. At the 10-year-old level, small effects are found for Australia and England. Likewise at the 14-year-old level in three countries, Australia, England and Italy, small effects are found in association with the time spent on the study of science and time spent on science homework. These were the countries where schools had greater freedom to decide what was taught to students in science courses. It is between countries, rather than between schools within countries that opportunity to learn has more substantial effects.

Intermediate Level Test Item X, Y and Z represent three lamps in a circuit, which also includes a battery and a switch S. When the switch is open X fails to light while Y and Z do. Which of the following circuits is it?



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7

Teachers of Science and their Influence

It is generally acknowledged that the competence of the teachers plays a critical role in the learning of science in the schools. Furthermore, the expansion of secondary education has led to a serious shortage of science teachers, particularly in the physical sciences. As a consequence, it is of interest to examine whether the characteristics of science teachers have changed over time at the 14-year-old level. Likewise, with increased emphasis on science teaching in primary schooling, it is also of interest to examine whether the characteristics of the teachers of science have changed from 1970 to 1984 at the 10-year-old level. Table 7.1 records data on five characteristics of science teachers which were obtained both in 1970-71 and in 1983-84.

Changes over Time [43]

Several changes in the characteristics of science teachers are worthy of note.

1. At the 10-year-old level, the proportions of teachers of science who were male increased in Finland (from 30% to 50%) and decreased in Italy (from 45% to 13%) and Sweden (from 22% to 3%).

2. At the 14-year-old level the proportions of science teachers who were male decreased in Finland (from 66% to 49%), Hungary (from 46% to 30%) and Thailand (from 67% to 50%). Finland and Hungary are two countries where girls now dominate the Year 12 classrooms.

3. Only in Sweden has the average age of teachers changed substantially over time. At the 10-year-old level in the 13-year period from 1970 to 1983, the average age of teachers increased by 13 years from ages 36 to 49. Sweden must shortly be facing formidable problems in the education and replacement of an ageing teaching service. At the 14-year-old level over the same period, the average age of Swedish teachers increased from 35 years in 1970 to 45 years in 1983. There are thus opportunities arising in the next decade to reshape the teaching of science in Sweden with more highly and more appropriately trained science teachers.

4. In several countries at the 10-year-old level, namely England, Finland, and Hungary, between 1970-71 and 1983-84 teachers increased, by one or more years on average, the length of their post-secondary education.

5. Likewise at the 14-year-old level, science teachers between 1970-71 and 1983-84 had on average an additional year of education in Australia, England, Finland, The Netherlands and Thailand.

Table 7.1 Changes in Characteristics of Science Teachers from 1970-71 to 1983-84

		[illegible]	England	Finland	Hungary	Italy	Japan	[illegible]	[illegible]	[illegible]	United States
10-Year-Old Level											
Sex of Teacher (% Male)	1970-71	n	45	30	12	45	49	80	22	46	21
	1983-84	22	40	50	16	13	50	n	3	n	30
Age of Teacher (years)	1970-71	n	36	41	38	48	36	31	36	28	36
	1983-84	33	39	42	38	45	36	n	49	n	39
Years Teaching Experience	1970-71	n	13	17	18	18	16	11	14	8	11
	1983-84	11	13	18	17	21	14	n	nd	n	15
Years Post-Secondary Education	1970-71	n	2.0	3.0	1.0	1.0	3.0	3.6	2.2	2.3	4.5
	1983-84	4.0	4.0	4.0	3.0	1.0	3.0	n	2.0	n	5.4
Days Inservice Science Education	1970-71 a	n	1.0	1.0	4.0	n	3.0	0.7	0.4	3.4	3.6
	1983-84 b	1.0	1.0	1.0	4.0	1.0	2.0	n	1.3	n	1.8
14-Year-Old Level											
Sex of Teacher (% Male)	1970-71	68	66	66	46	38	90	85	76	67	70
	1983-84	74	69	49	30	30	85	89	73	50	70
Age of Teacher (years)	1970-71	30	34	37	36	40	36	41	35	29	35
	1983-84	34	31	39	38	41	38	37	45	28	38
Years Teaching Experience	1970-71	8	11	11	13	14	15	14	10	8	11
	1983-84	11	12	13	16	15	16	12	nd	7	14
Years Post-Secondary Education	1970-71	4.0	3.0	4.0	4.0	4.0	4.0	2.8	3.7	2.1	4.8
	1983-84	5.0	4.0	6.0	4.0	4.0	4.0	5.3	nd	4.0	5.6
Days Inservice Science Education	1970-71 a	3.0	3.0	4.0	3.0	2.0	6.0	4.2	3.6	6.0	9.2
	1983-84 b	2.0	2.0	3.0	4.0	3.0	4.0	2.0	1.9	2.2	3.0

a Data collected as number of weeks over past five years.
b Data collected as number of days over past year.
n Country did not test at this level.
nd Data on item not collected or clearly erroneous.

6. The early 1970s was a period of science curriculum reform. In several countries more extensive provision was made at that time for inservice education programs than in the mid-1980s. As a consequence, Australia, England, Finland, Japan, The Netherlands, Sweden, Thailand and the United States, all show a decline in the number of days of inservice education provided for teachers at the 14-year-old level. Only in Hungary at the 14-year-old is there a marked increase over time in participation in inservice education. Likewise at the 10-year-old level, the opportunities for inservice education declined between 1970-71 and 1983-84 in Japan and the United States, but increased in Sweden from 0.4 days to 1.3 days. In Sweden the greater provision of inservice education was in response to a recognized need for re-equipping an ageing teaching service.

The Effects of Teacher Characteristics on Science Achievement [44]

In examining the effects of teacher characteristics on science achievement it is necessary to recognize that policies and practices within a country have served to reduce the variation among teachers. In addition, where an incompetent teacher has existed, forces have worked to remove that teacher from the teaching service. Furthermore, to understand why some characteristics contribute in certain countries and others do not, it is necessary to examine carefully the variation in those characteristics in a particular country.

The overall findings are that in five out of eight countries examined at the 10-year-old level and five out of 10 countries at the 14-year-old level, there is evidence of a cluster of teacher characteristics that have a recognizable effect after other significant factors have been taken into consideration. These characteristics involve the general level of competence of the teachers.

10-Year-Old Level (five out of eight countries involved)	Age (2 countries) Years of post-secondary education (1 country) Years of experience (2 countries) Reads science journals (2 countries) Days of inservice education (1 country) Science specialist teacher (1 country)
14-Year-Old Level (five out of 10 countries involved)	Sex of teacher (a woman not a man) (1 country) Years of post-secondary education (3 countries) Years of post-secondary science education (2 countries) Years of experience (2 countries) Member of a science teachers association (2 countries) Reads science journals (1 country) Science specialist teacher (4 countries)

There is no simple solution to the lack of scientific knowledge, interest, and competence of teachers through adopting special arrangements for the teaching of science. [45]

8

Planning Science Education for the Future

In considering changes which might improve the learning of science in schools it is necessary to consider four issues:

- how changes are introduced;
- changes in emphasis on the processes of science;
- changes in emphasis on content; and
- changes in teaching and learning.

How Changes are Introduced

In several of the countries that took part in both the First and Second IEA Science Studies responses to the findings of these studies can be noted.

- In Hungary, a major program of reform was introduced in the late 1970s. The results are clearly seen in the evidence presented above.
- In Italy, the disparities in performance between north and south were made clear in the first study and major reforms were undertaken.
- In Thailand, the Chairman of the Science Committee for the 1970-71 study, L. C. Comber, was invited to help with the development of the school science curriculum, particularly in biology.
- Japan has, since 1984, planned a reshaping of science teaching at the upper secondary school-level to remedy problems that are evident from the analysis of the data collected in the second study.
- England in the late 1980s planned the introduction of new curricular policies and programs at all levels of schooling.These changes include more purposeful teaching of the less able. At the upper secondary level a wider range of subjects are to be studied, and retention rates are to be increased. IEA findings have exposed these issues.
- In the United States, the President has called for major reforms in the teaching of Science in recognition of the evidence revealed in cross-national studies. *Project 2061* is an important response. (see AAAS, 1989)

The systematic monitoring of reform in the teaching and learning of science is a critical step for the future. Those countries that took part in the Second IEA Science Study are well placed to monitor such change.

In countries, such as Australia and The Netherlands, where schools and teachers have a major say in what science is taught, it is difficult to introduce widespread change. Likewise, in the United States, where school boards have a key role in such decisions, change is even more difficult to make. However, in centrally directed systems, research can be conducted, public debate on reform can take place, and change can be prescribed. The danger in a centrally controlled system is that change can be oriented in unprofitable directions. Thus the introduction of change must be considered in each system as well as the nature of changes to be implemented. [46]

Changes in Emphasis on Processes

With the rapid growth of scientific knowledge, there is growing recognition of the importance of problem solving skills and the processes of investigation and inquiry. Science is the subject in the school curriculum best suited for the development of such skills. Some weaknesses in the teaching and learning of these skills have been shown in the evidence presented. The manner in which these skills are taught and the tasks employed to provide opportunities for the development of these skills must be changed. Moreover, new technology is improving the ways in which observations and measurements are made, recorded, and analyzed. As a consequence, laboratory work in science must take account of such developments, and be modified accordingly. The skills to be learnt remain. the approaches to their teaching must change.

Changes in Emphasis on Content

In the years between 1970 and 1984 limited change occurred in the content of the science curriculum. Little emphasis was found to have been placed on the new topics investigated other than for the topics of *Environmental Impact* and *Habitats*. However, the science curriculum must continue to evolve in response to new scientific knowledge and new technological applications of science. Lack of emphasis on application is considered to be a serious shortcoming of the reforms of the 1960s, and with the growing thrust on technological development redress is required. In developing countries, the areas of *Rural Science* and *Health Science* must be given greater attention, since problems of famine and disease are widespread.

With increased retention of students at the upper secondary school level, there is a strong case for teaching all students some science during these years. The non-science specialists might well study a course in *Science, Technology and Society*, that considers the historical development of science, its interactions with technology and its interrelations with societal change. At the lower and middle secondary school stage all students were, in 1983-84, required to learn some science. However, not all students in all countries were required to learn content from all major fields of science. This needs to be rectified.

Changes in Teaching and Learning

In making recommendations for change in the teaching and learning of science, it is of value to summarize the key findings of this study.

1. Except in the United States and Australia, there has been substantial growth in the average levels of science achievement at both the 10- and 14-year-old levels. This is believed to be a result of the more formal teaching of science.

2. At the upper secondary school stage the average level of achievement in science drops, where a higher proportion of the age group is retained at school and studies science. However, the performance of the better students does not decline.

3. In the 14 years under survey in several countries the difference between boys and girls in science achievement at both the 14-year-old and the upper secondary school levels has been reduced; particularly in the physical sciences. This is believed to be the result of societal factors and of programs designed to produce such changes.

4. At all age levels, the time given to the study of science in a country is related to the average level of achievement in science. Within countries, time spent on homework is found to be important.

5. At all age levels, the opportunity provided in the curriculum for students to learn the content tested is related to the average level of science achievement of a country. Likewise, where differences occur between schools within a country, opportunity to learn is related to the average level of achievement of the school or classroom group.

6. Attitudes and values towards science account in part for the differences that exist between students within classrooms in their science achievement as well as the differences that occur between school and classroom groups, after other factors have been taken into consideration.

7. At the 14-year-old level, in six out of 10 countries, the students' views of emphasis on practical work in the teaching of science account, in part, for differences between school and classroom groups in their science achievement.

8. At both the 10- and 14-year-old levels the evidence from a majority of countries shows that students perform better where they are taught by teachers who are experienced and competent in science.

9. Between the primary and middle secondary school stages the average growth in level of achievement in science is greater where all major fields of science - biology, chemistry, physics and earth science - are taught simultaneously. It is not found to be necessary for science to be taught as an integrated subject.

10. The scientific and technological progress of a country depends on the proportion of its youth who are willing and able to continue with the study of science at the post secondary stage and to train for a science-based occupation. Countries differ markedly in their yield of science students graduating from high school. Japan is very well placed in this respect relative to other countries.

IEA is committed to conducting surveys at regular intervals in key areas of the curriculum to provide a systematic monitoring of change in the outcomes and effects of teaching and learning. An interval of 14 years would appear to be an appropriate period in the longitudinal study of change in science teaching and learning within school systems.

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Notes:

1 See Postlethwaite: pp. 187-194.
2 See Comber: p. 45.
3 See Doran: pp. Art. 4.
4 See Keeves: pp. 24-36.
5 See Husén: pp. 7 *et. seq.*
6 See Keeves. pp. 53-55.
7 See Keeves: pp. 58-63, 369-374.
8 See Keeves: p. 3.
9 See Postlethwaite: pp. 55-57, 199.
10 See Keeves: pp. 271-275.
11 See Keeves: pp. 273-284.
12 See Keeves: pp. 208-210.
13 See Keeves: pp. 110-114.
14 See Postlethwaite: pp. 57-62, 200.
15 See Keeves: pp. 273-284.
16 See Keeves: pp. 110-115.
17 See Keeves: pp. 228-230. See Postlethwaite: pp. 59-60.
18 See Keeves: pp. 77-82, 236-241.
19 See Keeves: pp. 100, 105-106, 110-114.
20 See Postlethwaite: pp. 63-70.
21 See Postlethwaite: pp. 71-73. See Keeves: pp. 101,109, 241-243.
22 See Keeves: pp. 248-250.
23 See Keeves: pp. 110-115.
24 See Keeves: pp. 244-246. See Postlethwaite: p. 195. See IEA: pp. 48, 54.
25 See Keeves: pp. 246-248, 250-254. See Husén: pp. 84-86.
26 See Keeves: pp. 255-262.
27 See Keeves: pp. 122-140, 353-359.
28 See Husén: pp. 195-196.
29 See Keeves: pp. 136-140.
30 See Keeves: pp. 159-163, 180-184, 201-202, 216-220, 226-228.
31 See Keeves: pp. 141-147.
32 See Keeves: pp. 147-151.
33 See Keeves: pp. 145-147.
34 See Keeves: pp. 151-156.
35 See Keeves: pp. 156-163.
36 See Rosier: pp. 38-42. See Keeves: pp. 88-90.
37 See Doran: pp. Art. 5.
38 See Keeves: pp. 188-195, 360-365.
39 See Keeves: pp. 196-207.
40 See Rosier: pp. 30-38. See Keeves: pp. 42-44, 90-92.
41 See Rosier: pp. 67-71. See Keeves: pp. 85-87, 90-94.
42 See Keeves: pp. 115-119, 203-204, 225-227. See Postlethwaite: pp. 91-107.
43 See Postlethwaite: pp. 25, 28-30. See Keeves: pp. 210-212.
44 See Keeves: pp. 204, 224.
45 See Keeves: pp. 212-214.
46 See Keeves: pp. 59-67.

Appendices

Appendix 1 Science Performance[c] at the 10-Year-Old Level, 1983-84

Country	Age in Years	Grade	% in School	Core Test Mean	Core + Rotated Tests Mean	Core + Rotated Tests sd	Core + Rotated Tests se	Biology Mean	Chemistry Science Mean	Earth Mean	Physics Mean
Australia	10:6	4,5,6	99	53.5	56.9	17.2	0.68	58	49	59	56
Canada (Eng.)	11:1	5	99	57.2	61.7	15.8	0.48	63	58	63	61
Canada (Fr.)	11:1	5	99	60.4	61.4	15.4	0.60	63	60	61	61
England	10:3	5	99	48.8	53.8	17.0	0.64	56	47	57	52
Finland[a]	10:10	4	99	63.8	66.0	14.9	0.55	68	69	65	64
Hong Kong	10:5	4	99	46.6	50.9	15.8	0.72	56	48	51	46
Hungary	10:3	4	99	60.2	61.7	16.3	0.85	65	69	66	55
Israel	10:9	5	99	49.6	52.2[e]	17.8[b]	1.00[b]	nd	nd	nd	nd
Italy	10:9	5	99	55.8	59.2	17.6	1.00	63	69	64	51
Japan	10:7	5	99	64.3	66.4	14.7	0.24	69	51	67	68
Korea	11:2	5	99	64.0	65.7	16.0	0.59	66	62	64	67
Nigeria	12:1	6	92	32.9	35.1	15.6	1.53	36	35	36	34
Norway[a]	10:11	4	99	52.9	55.5	16.3	1.14	54	63	57	55
Philippines[a]	11:1	5	97	39.6	42.3	16.7	0.59	44	38	46	39
Poland[a]	10:11	4	99	49.7	52.5	17.2	0.62	58	55	52	46
Singapore	10:10	5	99	46.8	51.8	16.0	0.73	54	40	52	52
Sweden (Gr.3)[a]	9:10	3	99	53.4	55.9	15.9	0.78	59	56	61	51
Sweden (Gr.4)[a]	10:10	4	99	61.1	62.8	14.6	0.60	65	64	67	59
United States	11:3	5	99	54.8	57.6[e]	19.0[b]	0.75[b]	nd	nd	nd	nd
Mean				53.4	56.3			58.6	54.9	58.1	53.9
No. of items				24	40			22	5	8	21

a Students start school at age seven years.
b Value applies to core test.
c % correct recorded.
e Estimated value.
nd No data available.
sd Standard deviation of student scores.
se Standard error of mean.

Appendix 2 Change in Science Achievement, 10-Year-Old Level, 1970-71 to 1983-84

Country	Mean Scale Score FISS	Mean Scale Score SISS	Gain Raw	Gain Adj.	Age Y:M FISS	Age Y:M SISS	Enrolment Rate FISS	Enrolment Rate SISS	Percent Enrolled in Grade FISS 3	FISS 4	FISS 5	FISS 6	SISS 3	SISS 4	SISS 5	SISS 6
Australia	*	415	*	*	*	10:6	99	99	*	*	*	*		21	51	28
England	385	404	19	27	10:6	10:3	99	99			48	52			100	
Finland	405	464	59	48	10:6	10:10	99	99	23	77				100		
Hungary	399	436	37	48	10:7	10:3	99	99		71	29			100		
Italy (Gr.5)	395	435	40	35	10:7	10:9	99	99		4	96				100	
Japan	447	464	17	12	10:5	10:7	99	99			100				100	
Netherlands	380	*	*	*	10:6	*	99	99	5	37	58		*	*	*	*
Sweden	416	446	30	27	10:5	10:6	99	99	47	53			27	73		
Thailand	330	*	*	*	10:7	*	90	90	2	52	42	3	*	*	*	*
United States	410	416e	6	-16	10:7	11:3	99	99	2	37	60				100	
Mean Gain			30	26												

e Estimated value.
* no data available.

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Appendix 3 Conditions of Learning Science, 10-Year-Old Level, 1970-71 and 1983-84

Country	Beginning Science Age		Beginning Science Grade		% Schools teaching Science in 1983-84			Use textbook in Science (%)		Do experiments in Science (%)	
	FISS	SISS	FISS	SISS	Gr. 1	Gr. 2	Gr. 3	FISS	SISS	FISS	SISS
Australia	8	6	3-4	1	87	87	94	-	45	-	72
England	9	5	4	1	nd	nd	nd	45	62	21	82
Finland	7	7	1	1	100	100	100	74	97	10	61
Hungary	6	6	1	1	100	100	100	74	99	28	63
Italy	8	v	3	v	55	60	89	58	91	23	63
Japan	6	6	1	1	100	100	100	100	97	86	92
Netherlands	8	v	2	v	-	-	-	59	-	46	-
Sweden	10	10	4	4	nd	nd	nd	86	95	47	58
Thailand	8	7	1	1	-	-	-	78	-	73	-
United States	6	6	1	1	nd	nd	nd	74	90	47	77

nd No data available.
v Various.
FISS First IEA Science Study
SISS Second IEA Science Study

Appendix 4 Science Performance[c] at the 14-Year-Old Level, 1983-84

Country	Age in Years	Grade	% in School	Core Test Mean	Core + Rotated Tests Mean	Core + Rotated Tests sd	Core + Rotated Tests se	Biology Mean	Chemistry Mean	Earth Science Mean	Physics Mean
Australia	14.5	8.9.10	98	59.5	58.8	16.0	0.62	59	50	65	61
Canada(Eng.)	15·0	9	99	61.9	61.6	14.9	0.58	64	55	65	62
Canada (Fr.)	15.3	9	84d(94)	60.2	58.5	13.5	0.69	61	49	61	60
China	15.8	9	37	58.7	60.0	15.1	0.85	53	64	60	66
England	14.2	9	98	55.8	55.9	15.7	0.72	55	49	59	60
Finland[a]	14.10	8	99	61.7	60.3	13.9	0.44	61	55	65	61
Ghana	16:1	9	6d(43)	45.5	46.7	15.6	1.19	48	45	48	46
Hong Kong	14:7	8	99	54.6	55.0	14.4	0.88	53	47	64	57
Hungary	14:3	8	92	72.2	70.7	15.1	0.81	69	68	76	72
Israel	14·9	9	99	61.9	58.5	17.0	1.25	59	57	67	56
Italy (Gr.8)	13:11	8	99	52.4	52.4	15.3	0.66	54	44	58	53
Italy (Gr.9)	14:8	9	72	59.6	59.8	14.9	1.38	62	52	66	60
Japan	14.7	9	99	67.3	66.8	16.1	0.28	65	59	69	73
Korea	15·0	9	99	60.2	61.0	15.3	0.49	60	53	65	65
Netherlands	15.4	9	99	65.8	63.7	16.1	0.83	60	61	68	68
Nigeria	16:2	10	nd	40.8	42.2	13.8	1.16	46	37	41	42
Norway[a]	15·10	9	99	59.8	59.3	14.7	0.48	58	55	63	61
Pap. New Guinea	17.1	10	11	54.5	55.3	11.4	0.56	57	46	60	57
Philippines[a]	16·1	9	60	38.2	39.7	14.4	0.65	41	36	43	39
Poland[a]	15:0	8	91	60.4	59.5	15.9	0.66	61	60	64	56
Singapore	15:3	9	91	54.9	56.4	15.9	0.96	56	50	60	59
Sweden (Gr.7)[a]	13·10	7	99	57.7	56.0	15.1	0.70	54	51	64	57
Sweden (Gr.8)[a]	14:10	8	99	61.4	60.3	16.0	0.81	59	57	66	62
Thailand	15.4	9	32	55.1	56.7	12.5	0.74	60	48	59	57
United States	15:3	9	99	54.8	54.6[e]	16.7[b]	0.91[b]	nd	nd	nd	nd
Zimbabwe	16·1	9	30	41.3	42.8	11.6	0.66	45	37	46	42
Mean				56.9	56.7			57	51	61	58
No. of items				40	56			23	15	9	23

a Students start school at age seven years.
b Value applies to core test.
c % correct recorded
d Figure given as proportion of age group tested, percent in school given in parentheses.
e Estimated value.
nd No data available.
sd Standard deviation of student scores.
se Standard error of mean.

Appendix 5 Time and Science Achievement, 10-Year-Old Level, 1983-84

Country	Time in hours		Science achievement	
Australia	1.36		18.0	
England	1.70		16.4	
Finland	2.71		22.6	
Hungary	2.16		20.4	
Italy	3.28		19.4	
Japan	2.93		22.4	
United States	2.50		19.9	
Regression constants	a	b	r	outlier
Achievement on time	14.7	2.2	0.67	-

Appendix 6 Change in Achievement, 14-Year-Old Level, 1970-71 to 1983-84

Country	Mean Scale Score FISS	Mean Scale Score SISS	Gain Raw	Gain Adj.	Age Y:M FISS	Age Y:M SISS	Enrolment Rate FISS	Enrolment Rate SISS	Percent Enrolled in Grade FISS 7	FISS 8	FISS 9	FISS 10	SISS 7	SISS 8	SISS 9	SISS 10
Australia	+	415	+	+	+	10:6	99	99	+	+	+	+		21	51	28
Australia	552	550	-2	-2	14:5	14:5	99	98	2	26	60	12		20	69	12
England	532	539	7	18	14:7	14:3	99	98			48	52			100	
Finland	537	559	22	11	14:6	14:10	99	99	40	60				100		
Hungary	584	621	37	42	14:5	14.3	83	92		77	23			100		
Italy ▲	531	540	9	17	14:10	14:7	55	86		45	53			58	42	
Japan	587	597	10	5	14:5	14:7	99	99			100				100	
Netherlands	521	578	57	30	14:6	15:4	98	99	18	71	10				100	
Sweden ▲	536	556	20	18	14:6	14.7	99	99	49	51			27	73		
Thailand	504	540	36	12	14:6	15.3	22	32	5	33	55	6			100	
United States	538	513	-25	-47	14.8	15:4	99	99	2	26	72				100	
Mean Gain			17	10												

▲ The grade samples in the second study for Italy and Sweden were combined to provide a 14-year-old age sample, as in the first study.

FISS First IEA Science Study
SISS Second IEA Science Study

Appendix 7 Time and Growth in Science Achievement Scores, 1970-71 and 1983-84

Country	1970-71 Time[a]	1970-71 10-Yr.-Olds	1970-71 14-Yr.-Olds	1970-71 Growth	1970-71 Intensity	1983-84 Time[a]	1983-84 10-Yr.-Olds	1983-84 14-Yr.-Olds	1983-84 Growth	1983-84 Intensity
Australia	3.5	-	0.31	-	-	3.8	-1.55	-0.25	1.30	H
England	3.2	-0.90	0.02	0.92	H	3.2	-1.78	-0.43	1.36	H
Finland	2.4	-0.66	-0.05	0.62	L	2.3	-0.85	-0.15	0.70	L
Hungary	3.8	-0.76	0.71	1.47	H	4.1	-1.23	0.55	1.78	H
Italy (Gr. 8)	3.3	-0.78	-0.23	0.56	L	3.6	-1.33	-0.62	0.71	L
Japan	3.3	-0.12	0.89	1.01	H	4.0	-0.88	0.27	1.15	H
Netherlands	2.6	-0.94	-0.29	0.66	L	5.9	-	0.84	-	-
Sweden	4.8	-0.56	0.05	0.62	L	3.7	-1.15	-0.20	0.95	L
Thailand	5.2	-1.64	-0.49	1.16	H	3.0	-	-0.41	-	-
United States	3.2	-0.63	0.04	0.68	L	4.4	-1.28	-0.44	0.84	L
Regression constants	a	b	r	outlier		a	b	r	outlier	
Growth on time	0.17	0.19	0.76	Hungary, Sweden		-0.13	0.36	0.57	United States	
Achievement at 14 on achievement at 10	0.63	0.82	0.86	Hungary		0.42	0.54	0.64	Hungary	

a Time in hours for 14-year-old students

Appendix 8 Conditions of Learning Science, 14-Year-Old Level, 1970-71 and 1983-84

Country	Grade 8, last compulsory grade % Schools		Participation Rate		Time Learning Science					
					Class time		Homework		Total time	
	FISS	SISS	FISS	SISS	FISS	SISS	FISS	SISS	FISS	SISS
Australia	22	4	93	98	3.5	3.8	1.3	1.4	4.8	5.2
England	31	0	91	98	3.2	3.2	1.3	1.5	4.5	4.7
Finland	16	0	72	99	2.4	2.3a	1.3	1.5	3.7	3.8
Hungary	0	0	81	92	3.8	4.1	2.2	4.1	6.0	8.2
Italy (Gr. 8)	nd	0	43	99	3.3	3.6	2.0	2.5	5.3	6.1
Japan	1	0	100	99	3.3	4.0a	1.3	1.5	4.6	5.5
Netherlands	36	0	97	nd	2.6	5.6	1.9	4.0	4.5	9.6
Sweden	7	0	99	99	4.8	3.7a	2.2	0.8	7.0	4.5
Thailand	0	0	19	32	5.2	3.0a	3.0	2.5	8.1	5.5
United States	13	1	86	99	3.2	4.4	0.4	1.8	3.6	6.2

a Data from official sources.
nd No data available.
FISS First IEA Science Study
SISS Second IEA Science Study

Appendix 9 Performance in Biology, Upper Secondary Level, 1983-84

Country	Grade Level	Age in Years ◆	% Male	Partici-pation Rate	Biology Scores			Subtest Scores		
					Mean	sd	se	Infor-mation	Compre-hension	Appli-cation
Australia	12	17:1	33	18	53.4	13.3	0.50	53	51	57
Canada (Eng.)	12/13b	18:2	37	28	48.7	14.3	0.63	47	47	54
Canada (Fr.)	11/12c	17:2	26	7	42.3	12.7	1.14	39	40	51
England	13	18:0	40	4	68.1	11.9	0.74	70	66	68
Ghana	13	18:8	82	0.2	63.6	11.5	1.20	69	60	62
Hong Kong (F.6)	12	18:5	68	12	61.0	12.1	0.83	65	59	59
Hong Kong (F.7)	13	19:2	68	7	70.2	13.0	0.98	75	68	68
Hungary	12	18:0	36	3	65.6	12.3	1.13	67	64	66
Israel	12	17:7	40	20	56.9	19.6	1.98	57	54	62
Italy	13	19:5	82	4	46.7	14.1	3.49	50	41	52
Japan	12	18:1	27	12	51.3	15.4	1.70	47	55	52
Korea	12	17:11	52	38	44.5	14.1	0.56	44	44	47
Norway	12	18:11	26	4	59.9	13.9	0.96	61	56	65
Poland	12	18:7	24	9	59.1	12.3	0.90	67	52	60
Singapore	12/13	18:0	51	3	70.9	11.3	d	71	71	70
Sweden	12	18:11	56	5	60.5	14.0	0.77	57	61	64
Thailand	12	18:3	46	7	47.2	12.7	0.83	44	46	54
United States (B)	12	17:5	41	12	41.8e	15.5	1.62	-	-	-
Mean					57.1			58	55	59
No. of test items					39			13	16	10

Regression constants	a	b	r	outlier
Achievement on participation	66.8	-0.62	-0.85	Canada (Fr.), Italy, Thailand, United States

◆ Mean age given in years and months.
b In Ontario, students were in Grade 13.
c In Quebec, students were in Grade 11.
d Singapore tested all students and not a sample.
e Estimated value.
s.d. Student standard deviation.
s.e. Standard error of mean score.

Appendix 10 Performance in Chemistry, Upper Secondary Level, 1983-84

Country	Grade Level	Age in Years ◆	% Male	Participation Rate	Chemistry Scores Mean	sd	se	Subtest Scores Information	Comprehension	Application
Australia	12	17:3	56	12	53.5	16.7	0.81	49	57	53
Canada (Eng.)	12/13b	18:4	53	25	43.1	14.6	0.62	36	48	43
Canada (Fr.)	11/12c	17.1	44	37	32.1	11.3	0.60	24	36	33
England	13	18:0	67	5	73.1	15.0	0.82	71	76	71
Finland	12	18:6	48	16	40.5	13.3	0.87	34	44	41
Ghana	13	18:10	88	0.6	63.7	16.6	2.07	69	67	56
Hong Kong (F 6)	12	18:4	76	20	66.9	14.7	1.20	64	75	60
Hong Kong (F 7)	13	19:3	77	12	78.5	11.6	1.15	75	85	74
Hungary	12	18:1	76	1	53.4	16.7	2.19	52	57	50
Israel	12	17:7	51	8	50.3	19.5	4.13	44	58	46
Italy	13	19:2	69	1	42.9	22.4	4.76	43	46	39
Japan	12	18:2	74	16	57.8	20.2	2.66	47	65	57
Korea	12	17:10	52	37	33.9	13.8	0.56	30	35	36
Norway	12	18:11	41	6	47.9	15.7	1.16	39	54	46
Poland	12	18:7	24	9	49.5	15.8	1.34	49	57	42
Singapore	12/13	18:0	60	5	68.7	15.7	d	67	74	64
Sweden	12	19:0	70	13(6)d	47.3	15.0	0.71	45	50	46
Thailand	12	18:3	46	7	38.8	15.7	1.17	37	40	39
United States (B)	12	17.8	59	2	40.1e	18.2	2.60			
Mean					51.7			49	57	50
No. of test items					39			9	16	14

Regression constants	a	b	r	outlier
Achievement on particip.	61.8	-0.79	-0.78	Hong Kong (F 6 and F.7), Italy, Thailand, United States

Notes: see Appendix 9; dSweden tested 13% of age group; only 6% were studying Chemistry

Appendix 11 Performance in Physics, Upper Secondary Level, 1983-84

Country	Grade Level	Age in Years ◆	% Male	Participation Rate	Physics Scores Mean	sd	se	Subtest Scores Information	Comprehension	Application
Australia	12	17.3	69	11	53.6	14.6	0.68	49	52	63
Canada (Eng.)	12/13b	18:4	70	18	47.0	14.5	0.67	40	47	54
Canada (Fr.)	11/12c	17.1	51	35	30.2	10.7	0.57	27	27	40
England	13	18:0	78	6	64.2	13.3	0.60	57	64	74
Finland	12	18:7	63	14	44.7	13.5	0.90	38	43	57
Ghana	13	18:11	89	0.6	54.3	13.5	1.43	53	55	55
Hong Kong (F 6)	12	18:4	77	20	64.4	13.0	1.08	55	64	76
Hong Kong (F 7)	13	19:3	78	12	73.7	12.6	1.10	67	73	81
Hungary	12	18.0	71	4	62.7	15.3	1.50	55	61	74
Israel	12	17.7	69	12	54.4	17.0	1.42	47	53	66
Italy	13	19:2	81	13	34.2	13.4	0.89	27	30	52
Japan	12	18.2	87	11	61.8	16.1	1.85	53	61	73
Korea	12	17:11	75	14	43.3	17.2	1.10	39	41	54
Norway	12	18:11	68	10	56.5	15.5	1.06	58	53	64
Poland	12	18.7	46	9	56.4	16.5	1.33	58	52	63
Singapore	12/13	18.0	68	7	59.2	12.8	d	51	59	68
Sweden	12	19.0	70	13	51.4	14.5	0.63	48	49	61
Thailand	12	18.2	48	7	35.9	16.9	1.31	34	33	44
United States (A)	12	17.9	63	12	35.0e	.	.	.	.	.
United States (B)	12	17:10	78	1	49.2e	15.9	2.07	.	.	.
Mean					52.5			48	51	62
No. of test items					38			9	20	9

Regression constants	a	b	r	outlier
Achievement on participation	66.9	1.13	-0.91	Ghana, Hong Kong (F 6 and F 7) Italy, Thailand, United States (A and B)

Notes: see Appendix 9

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Appendix 12 Time and Science Achievement, Upper Secondary Level, 1983-84

Country	Biology Time	Biology Mean score	Chemistry Time	Chemistry Mean score	Physics Time	Physics Mean score
Australia	4.25	16.06	4.11	16.57	4.15	16.61
England	5.18	23.53	5.22	25.99	5.11	21.16
Finland	-	i	1.00	10.28	1.95	11.98
Hungary	4.98	22.38	5.23	16.46	7.36	20.60
Italy	3.2d	14.12	3.2d	12.93	3.2d	8.73
Japan	3.09	15.28	3.40	18.49	3.63	20.00
Sweden	2.0d	19.91	-	f	3.8d	15.46
Thailand	3.07	13.28	3.08	9.18	4.02	7.60
United States	g	-	g	-	4.6	12.95e

Regression constants		a	b	r	outlier
Achievement on time	Biology	0.6	4.3	0.94	Sweden
	Chemistry	-7.7	6.4	0.90	Finland, Hungary
	Physics	8.2	1.8	0.65	Thailand

d Data from official sources.
e Estimated value.
f More than half the students tested were not studying chemistry.
g Information was not available.
i Students specializing in the study of biology could not be identified.

Appendix 13 Science Achievement of the Non-Science Specialists, Upper Secondary Level, 1983-84

Country	% of Age Group	% Taking Science	Average Time in Hours	Mean Score (60 Items)
Australia	10	27	1.2	24.4
England	10	0	0	30.1
Hungary	10	100	5.0	36.2
Italy	21	78	4.0	22.4
Japan	35	0	0	29.1
Sweden	15	0	0	29.0
Thailand	7	79	2.4	14.6
United States (A)	49	0	0	21.5e

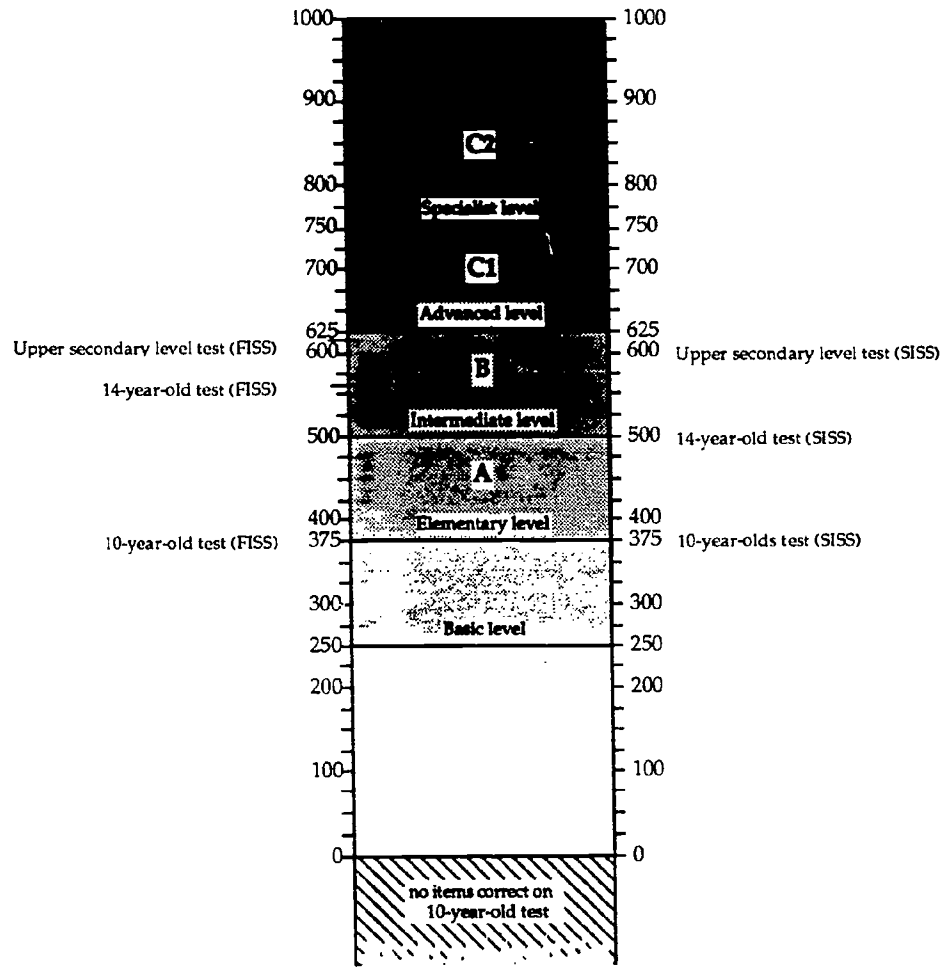
e Estimated value.

Appendix 14 Indexes of Scientific Yield, Upper Secondary Level, 1970-71 and 1983-84

Country	1970-71 Retention Rate All	1970-71 Achievement All	1983-84 Retention rate All	1983-84 Retention rate Science	1983-84 Achievement Yield All	1983-84 Achievement Yield Science	1983-84 Educational Yield[p] All	1983-84 Educational Yield[p] Science	1983-84 Occupational Yield All	1983-84 Occupational Yield Science
Australia	29	760	39	29	640	530	18	17	13	12
England	20	490	20	10	390	230	8	7	6	6
Finland	21	440	41	14	na	280e	na	9	na	8
Hungary	28	670	18	8	390	180	9	6	4	4
Italy	16	270	34	13	400	190	9	5	4	4
Japan	70	-	63	28	1070	590	27	19	23	17
Netherlands	13	320	14	-	-	-	-	-	-	-
Sweden	30	600	28	13	490	280	na	na	6	6
Thailand	10	130	14	7	130	100	10	6	6	5
United States	75	1060	80e	21e	950	370	na	11	na	na

e Estimated value
p Percent of age group.
na Data not available.

The Science Achievement Scale



The procedure of scaling and equating the achievement tests used in the two science studies aimed at developing a scale of science achievement that would enable the performances of students from different countries at different age and grade levels and on different occasions to be compared. This required that one particular test should be used as the basic measuring instrument and the 14 year-old test employed in the second study was chosen for this purpose. The mean difficulty level of the items in this test provided the one fixed point necessary to locate the scale and was set at 500 with a scale logic of 100 units. The international scale was so constructed that the scale value for no measurable knowledge of science was below the zero point, and the scale value for slight knowledge was above the zero point. Then all tests for the two occasions, including the 10 year-old tests for 1970-71 and 1983-84 and the 14 year-old test for 1970-71, were linked to this scale. The addition of all tests for the two occasions indicates that the upper end of the scale has meaning and is useful.

(For information about construction of The Science Achievement Scale, see Keeves (1992), pp. 271-275.)

This volume summarizes information published in a series of international reports which present the findings of the First and Second IEA Science Studies.

First IEA Science Study

Comber, L.C. and Keeves, J.P. (1973) *Science Achievement in Nineteen Countries.* Almqvist and Wiksell, Stockholm and Wiley, New York.

Second IEA Science Study

IEA (1988) *Science Achievement in Seventeen Countries. A preliminary report. Pergamon.* New York and Oxford.

Rosier, M.J. and Keeves, J.P. (1991) *The IEA Study in Science I:Science Education and Curricula in Twenty-Three Countries.* Pergamon, Oxford.

Postlethwaite, T.N. and Wiley, D.E. (1991) *The IEA Study in Science II: Science Achievement in Twenty-Three Countries.* Pergamon, Oxford.

Keeves, J.P. (ed.) (1992) *The IEA Study in Science III: Changes in Science Education and Achievement: 1970 to 1984.* Pergamon, Oxford.

Doran, R.L. and Tamir, P. (eds.) (1992) An international assessment of science practical skills. *Studies in Educational Evaluation.* 18(1), pp. 1-102.

There are, in addition, a large number of national reports which have been prepared to provide information on the findings of these studies within particular countries.