DOCUMENT RESUME

ED 275 534 SE 047 516

AUTHOR	Miller, June K.
TITLE	An Analysis of Science Curricula in the United States. Second IEA Science Study (SISS), United States.
INSTITUTION	Columbia Univ., New York, N.Y. Teachers College.; International Association for the Evaluation of Educational Achievement, New York, NY.
SPONS AGENCY	National Science Foundation, Washington, D.C.
PUB DATE	86
CONTRACT	SPA-8470382
NOTE	110p.
PUB TYPE	Information Analyses (070)
EDRS PRICE	MF01/PC05 Plus Postage.
DESCRIPTORS	Case Studies; Curriculum Evaluation; Curriculum Research; *Elementary School Science; Elementary Secondary Education; Grade 5; Grade 9; Grade 10; International Cooperation; *International Educational Exchange; *National Surveys; Science Education; *Science Instruction; *Secondary School Science; Testing Programs
IDENTIFIERS	*Science Education Research

ABSTRACT

This report concerns a descriptive study undertaken in 1982-1983 as part of the Second International Science Study (SISS) under the auspices of the International Association for the Evaluation of Educational Achievement (IEA) for the purpose of examining key elements of K-12 science instruction in the United States. Special attention was directed toward identifying the nature of curricula planned in science for grades 5, 9, and 12 in order to develop valid items for the international testing program employed in SISS. An empirical study was designed to measure the relative emphasis given in curricula to science content and relevant cognitive, affective, and psychomotor objectives for grades 5, 9, and 12. Curricula grids were examined in the traditional science domains, in applied/integrated science areas, and for science processes, skills, and attitudes. Information reported in this publication includes: (1) introductory statements (discussing science education in the United States); (2) study procedures (explaining study methodology and data analysis); (3) survey results (presenting and interpreting the data); and (4) science curriculum case study (discussing findings on aims, objectives, curriculum development and content, teacher education, science teaching and associated topics). A 50-item bibliography is appended. (ML)

An Analysis of Science Curricula in the United States

By

June K. Miller

A Monograph of

The International Association for the Evaluation of Educational Achievement [IEA]

Second IEA Science Study
[SISS]
UNITED STATES

Teachers College, Columbia University

An Analysis of Science Curricula in the United States

By

June K. Miller

Senior Research Associate
Second IEA Science Study
Teachers College, Columbia University

Assistant Professor
Queens College
City University of New York

A Monograph of
The International Association for the Evaluation
of Educational Achievement [IEA]

USA

Second IEA Science Study

[SISS]
UNITED STATES
Teachers College, Columbia University

IEA

Second IEA Science Study
Teachers College, Columbia University
New York, New York 10027

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

TABLE OF CONTENTS

TABLE OF CONTENTS

Chapter III, Cont.

Page

TABLE OF CONTENTS

7

LIST OF FIGURES

ACKNOWLEDGEMENTS

Suggestions in the editing of this monograph were provided by the National Coordinator of the Second IEA Science Study, Dr. Willard J. Jacobson, of Teachers College, Columbia University, whose early encouragement and continuing support were greatly appreciated, and the Associate National Coordinator of the Second IEA Science Study, Dr. Rodney L. Doran of the State University of New York at Buffalo. Their constructive comments were particularly helpful in organizing and revising Chapter IV, "The United States Science Curriculum Case Study."

Thanks are also due Janis W. Owen for her skills in helping to process the final draft of the manuscript.

Publication of this monograph was made possible through funding from the Spencer Foundation and the National Science Foundation.

J.K.M.

FOREWORD

This Study, An Analysis of Science Curricula in the United States, is one of a series of investigations undertaken under the auspices of the Second International Science Study in the United States. Similar studies of science curricula have been undertaken in about 25 other countries under the auspices of The International Association for the Evaluation of Educational Achievement (IEA). The Second International Science Study--United States has conducted a variety of studies in the United States ranging from science achievement studies to the examination of conditions in schools under which science is taught and learned. All of these studies have as their goal the improvement of the education of the children and young people in the countries that take part.

The studies that are sponsored by The International Association for the Evaluation of Educational Achievement (IEA) are all based on the assumption that educators in all countries can learn from each other. Certain practices and facilities may exist in some countries but not in others. For example, there are very few laboratory technicians or assistants in United States schools, but in some other countries there are lab technicians in many schools. United States science educators can study the contributions of lab technicians in other countries. In terms of science curricula, science programs in the United States are organized in a unique fashion with each science, such as chemistry and physics, characteristically offered for one year in the upper secondary school. Often, biology is offered in the 10th grade, chemistry in the 11th, and physics in the 12th. In other countries, the various sciences are offered for more than one year. Through international studies we may be able to study the relative effectiveness of various ways of organizing science experiences.

A similar study was carried out in 1970, and comparisons are possible between science education in 1983 and 1970. In this Study, some changes in the coverage of different topics and science processes have been identified.

Three stages of science curricula are identified in the Second International Science Study: The Intended Curriculum → The Translated Curriculum → The Achieved Curriculum. The Intended Curriculum refers to what we intend to teach and have students learn; it is often stated as goals, objectives, and science program plans or outlines. The Translated Curriculum describes how the Intended Curriculum is translated into educational activities; it is sometimes referred to as the opportunity to learn. The Achieved Curriculum refers to how and what students learn; in the SISS, the results on the achievement tests are indicators of the Achieved Curriculum. This Study, An Analysis of Science Curricula in the United States, deals primarily with the "Intended" Curriculum.

This Study is quite unique in that it is an analysis and empirical study of science curricula. It is "analytic" in that a wide range of science curricular materials, from local and state science programs to the most widely used science textbooks, were analyzed in terms of the international science curriculum grids that were provided. It is "empirical" in that knowledgeable science educators, including members of the U.S. Study's National Committee, rated areas of science content and process as to their coverage in the schools with which they were familiar. Through these analytic and empirical procedures, it was possible to get a quantified and perhaps more precise picture of the intended science curriculum in the United States.

Four populations were identified for the First Phase of the Second International Science Study in the United States:

Population 1.	All students in Grade 5 on 1 April 1983.
Population 2.	All Students in Grade 9 on 1 April 1983.
Population 3P.	All students enrolled in a secondary school physics course on 1 April 1983 and 1 April 1984.
Population 3N.	All students in the 12th grade on 1 April 1983 and 1 April 1984 who were not enrolled in any science course.

In this Study, the "intended" curricula for kindergarten through grade 12 (K-12) were analyzed, with the focus on the populations of students already described as well as those enrolled in Earth Science (3E), Biology (3B), and Chemistry (3C). In other dimensions of the SISS Study, the "translated" and "achieved" curricula were studied for the four populations that were identified.

<u>An Analysis of Science Curricula in the United States</u> includes a rather detailed description of the procedures used to analyze and rate science curricula, the results of the analyses and ratings, the science curriculum grids, and "The United States Science Curriculum Case Study." The ratings are for the traditional science content items and for such other science content ratings as History and Philosophy of Science, Environmental Science, and Health Science. Certain science curricular trends have been identified. One of the interesting findings was the growth in offerings of Environmental Science. Such science inquiry processes as Observing, Measuring, Interpreting Data, and Generalizing were also noted. Apparently there has been an increase in attention to selected processes of science.

This Study should be of value to everyone engaged in planning and developing science programs, preparing science textbooks and other science teaching materials, and to anyone who wishes to compare their curricula with science curricula in use in the United States. This may be one of the most extensive studies made of the science curricula in the United States within the context of a large international study. This Study can be considered to be a rich ore of science education information; it is waiting to be mined.

Many people have contributed to this Study. The members of the National Committee and other knowledgeable science educators made an essential contribution. The International Coordinator, Malcolm Rosier, and the Chairman of the International Project Council, John Keeves, helped provide the international framework for the Study. Other staff members and research associates have been free with their suggestions and helpful with their critical questions. We are deeply indebted to the Spencer Foundation and the National Science Foundation for the crucial support that made this Study possible.

Willard J. Jacobson
National Research Coordinator

Chapter I

INTRODUCTION

An Analysis of Science Curricula in the United States is a report of a descriptive study undertaken in 1982-1983 as part of the Second IEA Science Study. The purpose of the analysis was to examine key elements of K-12 science instruction in the United States. Special attention was directed toward identifying the nature of curricula planned in science for grades 5, 9, and 12 in order to develop content valid items for the international testing program undertaken in the Second International Science Study (SISS). Differentiated rosters of science content for elementary, junior, and senior high school, the practical and cognitive skills stressed in the learning of science, and analyses of the components of science curricula that make the science programs across the nation uniquely American, were researched in depth to reach the conclusions reported in this monograph.

An empirical study was designed to measure the relative emphases given in curricula to science content and relevant cognitive, affective and psychomotor objectives at the three target grade levels. The findings of the empirical study are reported in Chapter III.

This study had several specific aims. The first was to produce a case study of the elements that contributed to United States science education in the 1980s in a form that would be useful to science educators, curriculum specialists, textbook publishers, administrators, policy making agencies, and other interested parties. The data of large-scale national studies were incorporated into the final results of the present study in an attempt to present a balanced image of contemporary science education. Secondly, the study served to launch the participation of the United States in a global assessment of science achievement. The Second IEA Science Study (SISS), which is discussed in greater detail under the heading "Setting of the Study," is a comparative study of science education in approximately 25 countries across the world. In SISS, nations measure science "outputs" of their various educational systems by uniformly examining curricula, instructional practices and student learning. Final reports from the international evaluation will contain the results of the science achievement tests taken by the target populations in each nation.

One task of this study was to classify the contents and processes of United States science curricula in grades 5, 9, and 12. A broad-based survey was conducted to further identify the patterns of intended emphasis within the curricula areas. Thus, current indicators of "what" and "how much" were determined.

The International Center, which provided most of the guidelines for directing the national studies, designed three curricula "grids." Each contained descriptions of one of the following areas:

1. Traditional Science Domains--Earth Science, Biology, Chemistry, and Physics.
2. Applied/Integrated Science--History and Philosophy of Science, Environmental, Technical and Engineering, Rural, and Health Sciences.
3. Science Processes, Practical Skills and Attitudes.

These parameters of science curricula were scrutinized and evaluated through the use of a rating system devised for this purpose by the Second IEA Science Study (SISS) and used in the national surveys on curricula. The ratings of the Intended Curricula allow countries to identify sections of curricula that are heavily stressed, moderately or lightly stressed, or not covered. These may be compared to the curricula patterns of other nations at the "Intended" level or analyzed within the context of curricula implementation when the results of the translated and achieved curricula are completed. Specific linkages between curricula stages can be examined on a scale not done before. It will be possible to determine certain national characteristics by examining the ways in which national ratings differ from normative standards described in the international dimensions of the Study.

To effectively study the relationships between planned science experiences for students and the actual "yield" of these instructional agendas, SISS divided the curriculum sequence into distinct stages, which were termed the 1) "Intended," 2) "Translated," and 3) "Achieved" Curricula. The analysis reported in this study focuses on the first, or "Intended" stage.

The Intended Curriculum consists of detailed specifications of content and processes in centralized educational systems, or, more general guidelines in nations such as ours, where most educational decisions are made at the state or local level. It differs from syllabi or courses of study in that there are dimensions other than statements of time and subject contents that are included. Aims, objectives, teaching methodologies, suggested time allotments, texts, and reference materials are often suggested.

The Translated Curriculum is the curriculum that, in reality, is taught in the classroom. Depending upon the experiences of the teacher and other variables such as funding, the actual instruction may vary widely from published or avowed curricular intentions. It was possible to obtain indices of the Translated Curriculum through teacher responses indicating students' "opportunity to learn" specific concepts related to questions on the test instruments and keyed to areas of the Intended curricula.

Finally, the Achieved Curriculum is defined to be that which the students have internalized and learned from their science experiences. More specifically, it is the knowledge, understanding, and skills gained from instruction in science. Actual scores on achievement tests were the criteria by which the Achieved Curriculum was measured.

"An Analysis of Science Curricula in the United States" served a number of functions. As an intact study, it contributed to a fuller understanding of national characteristics in science education. As part of the National Project in SISS, the results (along with those of all participating nations) were used to develop an international core of common science curricula on which to base the international test questions. "The United States Science Curriculum Case Study," which describes the general conclusions of the curriculum analysis, was an integral part of the initial effort in the Project.

Basic Assumptions

In order for the countries participating in the international study to reap the benefits of these multi-level analyses (in which the collected data primarily enhances understanding in international education and secondarily addresses national issues), each nation relinquished a certain degree of autonomy and control in directing its own study. Where appropriate, observations regarding the design and execution of the present study are made relative to the experiences encountered while conducting the analysis. The suggestions are intended to help improve the design of future studies in which this Country takes part.

It is difficult to depict generalized curricular offerings in science when the educational system is de-centralized to the degree that it is in the U.S.A. However, it is possible to qualify and quantify significant features to convey the "meat and potatoes" of the diverse programs which exist. Given this premise, the findings from this study should yield some relevant insights into American science education that have not been addressed in recent years.

Practical considerations, including time constraints imposed for the completion of the case study and the availability of relevant sources of data, resulted in our having to reach certain conclusions that will not represent all facets of science curricula throughout the country. The focus of this study was on macro-features of our science education system rather than the characteristics of science content in individual school systems. Inevitably, some details were sacrificed in the collation and selection of the most representative data. Where necessary, these sections are prefaced within the text to offset any unintentional misrepresentation.

Additionally, in the depiction of curricula, consideration must be given to the components that are selected to best represent it. Generally, subject contents are central to this procedure, and are readily identifiable through instructional materials, such as texts and curriculum guidelines. In the SISS national study, the subject matter of science curriculum is classified under two main divisions: pure science and applied/integrated science. These are further divided into domains of science, and subtopics are listed within each domain.

In the process of examining the contents of United States science programs, a number of topics were identified through curricula which did not appear in the preliminary draft of international grid contents from SISS. By eliminating the "in-common" items, a "National Items" roster was developed. The procedures for evaluating this material are discussed in Chapter II. In tagging national science subject matter, we were able to study the effects of specific national components of curricula within the context of the larger study.

The skills and interests that are keyed to learning the subject contents are also integral to curriculum analysis. Doran refers to the convention of treating "process as content" in developing curricula blueprints and test items to elevate the instruction of science beyond factual recall alone.[1] The position taken in this study is that although there are substantive differences between science as a body of knowledge and the disparate affective, psychomotor and intellectual elements associated with internalizing that knowledge, the latter may be evaluated in much the same manner as ordinary subject contents. The Instructional Objectives Grid was employed to that end.

Furthermore, it is a main tenet of the Second IEA Science Study (SISS) that a correlation exists between the three defined stages of curricula (i.e. "Intended," "Translated," and the "Achieved"). The ratings obtained for the United States "Intended" science curricula in grades 5, 9, and 12 of this study may therefore be used in future comparisons within the SISS project and in the present national achievement evaluation.

United States Science Education in the 1980s

The catchword most often used to describe the condition of United States science, mathematics and engineering education of the early 1980s was "crisis." It captured the frustrated sentiments of a nation embroiled in economic and technological conflicts that many perceived to be deeply rooted to achievement in these academic areas.

In the realm of science education particularly, educators have witnessed the decline of 13- and 17-year-olds' achievement in the last four National Assessment of Educational Progress (NAEP) assessments which took place between 1969 and 1981-82. The declines have been attributed to many causes, such as inferior curriculum standards and inadequacies in teacher training programs. The data from this analysis and the subsequent testing should provide relevant insights into this national dilemma.

During the early 1980s, state administrators indicated shortfalls in the numbers of competent science teachers available in the elementary and the junior and senior high school. The problem of how to provide adequately prepared science teachers is common in United States elementary schools. Case studies published in 1978[2] revealed a number of teachers who were simply de-emphasizing science in the classroom or eliminating it entirely from the daily schedule of planned activities. In a separate study, elementary school teachers reported that they felt less adequately prepared to teach science than math, reading, or social studies.[3] This perception is shared by science supervisors and elementary school principals, who view the lack of teachers' pre and inservice science preparation a primary reason for low science emphasis in their schools.

This condition arises, in part, because state licensing guidelines for early childhood and elementary education vary in their science requirements. In a report from the National Science Teachers Association in 1982, it was found that only 19 of 46 responding states required science for early childhood certification; 36 states indicated science should be taken for elementary certification, although the number and type of course(s) were not specified.[4]

Deficiencies are greater at the secondary level. A survey conducted at the University of Iowa in 1982[5] revealed that of the states responding, 89% indicated a shortage of chemistry and physics instructors; 67% a shortage of earth science instructors; and 17% a shortage of biology instructors.[6]

Equally alarming is the fact that fewer graduates are planning to teach pre-college science. In part, this may be because of the entry level salary differentials which exist between private industry and public education institutions for science majors. According to a report in the New York Times, the average starting salary of a science teacher with a Bachelor's degree in 1984 was $14,000.[7] As of July 1981, starting salaries offered to Bachelor's degree candidates in non-teaching fields in the biological sciences averaged over $15,000, in the chemical sciences over $19,000, and in other physical and earth sciences nearly $22,000.[8] The number of student teachers in science decreased by two-thirds from 1971 to 1980, and of these, only half actually joined the teaching profession. Twenty-five percent anticipate leaving their professions in the near future.[9]

"Our scientific research and technological activity has been the finest in the world. We now see our technical preeminence eroding, and, if we fail to act, then 10 years from now our scientific capacity will suffer similar declines. But, I see a more serious threat to our nation...the indicators of deterioration of the quality and quantity of education in mathematics, science and technology...are the unmistakable harbingers of a growing chasm between a small scientific and technological elite and a citizenry uninformed, indeed ill-informed, on issues with a science component...."[10] The words were those of John Slaughter, former Director of the National Science Foundation, at a convocation held in May 1982 by the National Academies of Sciences and Engineering, but they expressed the thoughts of many concerning the level of science illiteracy which permeates the society at large. Paul Hurd, at the same meeting, stated unequivocally, "We are raising a new generation of Americans that is scientifically and technologically illiterate."[11]

A general decline in enrollments in science courses of high school students from 60% in 1960 to 48% in 1977,[12] as well as lower standardized college board scores (both verbal and math) during this same period of time,[13] are cited as corroborative evidence that a state of science ignorance is not confined to those who have left formal schooling behind.

Some of the data that has come from the testing of grades five and nine in the national SISS project seem to indicate that conditions have begun to improve. Of 26 items given to fifth grade students in 1970 and again in 1983, the students scored 3.5% higher in the 1983 evaluation. At the ninth grade level on 32 "bridge items," the scores were 2.4% higher.[14]

Comparisons with centralized systems of education, such as those of The Union of Soviet Socialist Republics, East Germany, the People's Republic of China, as well as a number of European countries, indicate the vast differences in ideology and outputs which exist between their systems and ours. In most cases, centralized systems appear to be more efficiently run, more effectively structured to address national priorities, and generally, to place much greater emphasis upon the sciences, technologies, and engineering subjects in pre-college training than does the United States. The majority of Eastern Bloc centralized systems encourage early specialization, and highly qualified technicians are recruited directly from specialized secondary schools. There is no equivalent "vocational" track of this quality in the United States.

In light of these international educational practices, the very structure of American science education is being viewed by critics as sadly inadequate. They perceive the economic and political prominence of this nation being threatened in part by more nationalistic education systems that are shaped by strong governmental support, involvement and consensus.

To address the salvos aimed at science education in the United States, we must begin by carefully examining the set of conditions that characterize science education in the United States. One important feature of this study was to attempt to collect empirical data to describe the science education in our schools. In doing so, "the crisis" may be viewed within a framework that challenges the myths and dispels popular misconceptions involving the purpose and functions of science instruction in this society. A discussion of implications is included in Chapter III.

Setting of the Study

"An Analysis of Science Curricula in the United States" is set within the context and purposes of a much broader and more comprehensive project entitled the "Second International Association for the Evaluation of Educational Achievement Science Study." This global endeavor, one of the largest international studies in education to date, had its headquarters at The Australian Council for Educational Research and was guided by the International Co-ordinator, Dr. Malcolm Rosier.

The IEA is an independent council of international educational research institutes. Since its inception in the 1950s, its prime function has been to study cross-national educational systems via strategies it has developed in cooperation with member nations. To date, it has published data on comparative education in such subjects as Science, Literature, Reading Comprehension, English and French as Foreign Languages, Civic Education, and Mathematics.

Begun in 1980, the Second IEA Science Study (SISS) is patterned after its predecessor, the First IEA Science Study (FISS). The First IEA Science Study took place between 1966-71 and has been described in a volume entitled Science Education in Nineteen Countries (Comber and Keeves, 1973).

The United States, England, Japan, Hungary and Australia along with a number of other countries participated in both the earlier and the present assessments. The opportunity to analyze shifts in science achievement from 1970 to 1986 is fruitful to the understanding of education practice in relationship to changing currents in the social, political, and economic arenas. In undertaking a follow-up study, some participating countries chose to develop separate dimensions within their national study for local analysis, in addition to examining the nature of different systems in light of internationally recognized norms.

Each participating nation in the study must provide its own funding for the national components. The first four years of United States involvement were funded by the Spencer Foundation while the Second Phase was underwritten by a grant from the National Science Foundation.

There are annual meetings of the IEA General Assembly in which representatives from all member nations meet to discuss mutual concerns and plan strategies for the upcoming year. In addition, periodic meetings are held by National Research Coordinators; national convocations are arranged when the time, resources and needs of participating countries permit.

A National Committee was appointed to help guide the United States Study. The eleven members of the panel represent a wide range of experience and expertise. Among the members are scientists, science educators, science supervisors, and experts in survey research.

Individual case studies of science curricula were produced by all SISS nations, to be used within the Project as a source of reference. It is the intention of the International Coordinator, Dr. Malcolm Rosier, to eventually publish the information compiled from the various case studies. The "United States Science Curriculum Case Study" is included in this monograph as Chapter IV.

FOOTNOTES

Chapter I

1. Rodney L. Doran, Basic Measurement and Evaluation, Washington, D.C.: National Science Teachers Association, 1980, p. 47.

2. Robert E. Stake and Jack Easley, Case Studies in Science Education, Volume I: and Volume II, Washington, D.C.: U.S. Government Printing Office, 1978.

3. Iris Weiss, Report of the 1977 National Survey of Science, Mathematics, and Social Studies Education, Washington, D.C.: U.S. Government Printing Office, 1978.

4. Kenneth Mechling, Carlton Stedman, and Kathleen Donnellan, "Preparing and Certifying Science Teachers." Science and Children 20 (October, 1982), p. 10.

5. Jack A. Gerlovich and Trevor G. Howe, "Where the Jobs Are." Science Teacher 50 (March 1983): pp. 56-59.

6. Ibid., pp. 58 and 59.

7. Jonathan Friendly, "After Lag, Teachers Start to Catch Up on Pay," New York Times, Vol. CXXXIV, (Aug. 31, 1985), pp. 1, 5.

8. National Science Foundation, Science and Engineering Education: Data and Information (NSF 82-30). Washington, D.C.: U.S. Government Printing Office, 1982, p. 196.

9. Robert E. Yager, Bill J. Aldridge, and John Penick, "Science Education in the United States," Science Teaching: a Profession Speaks, 1983, NSTA Yearbook, Washington, D.C.: 1983, p. 6.

10. John Slaughter reported in: Senta Raizen and Eugenia Grohman, eds., Science and Mathematics in the Schools: Report of a Convocation, (Washington, D.C.: National Academy Press, 1982), p. 4.

11. Paul Hurd reported in: Ibid., p. 3.

12. Ibid., p. 4.

13. Ibid., p. 3.

14. Willard J. Jacobson and Rodney L. Doran, "The Second International Science Study, U.S. Results," Phi Delta Kappan 66 (February 1985), p. 414.

Chapter II

PROCEDURES OF THE STUDY

The design of this curriculum analysis consisted of three stages. In the first stage, a review of studies conducted in science curricula since 1970 was undertaken to determine the pool of research in this field.[1]

The second stage entailed reviewing U.S. science curricula contents and processes in grades 5, 9, and 12 and integrating this material into the grid format proposed by the International Center. The "included" items were initially screened for representativeness, then added to the international core of traditional and non-traditional science curricula. This was a preliminary step to determining the nature of curricula emphasis, or coverage, in the United States.

The third stage involved an empirical study to determine patterns of curriculum coverage at the specified grade levels and comprised the third and final stage of this analysis.

A discussion of the results of the national study of science curricula is reported in Chapter III.

The process of review and selection of science curricula content was accomplished in one of several ways:

In this study an attempt was made to identify the most representative areas of subject matter planned for grade levels 5, 9, and 12 in the United States. Popular science textbooks were reviewed and a page number system was devised to catalogue their contents. The rationale for consulting textbooks as a source for the intended curricula was based on research findings from studies in national science education, including those of a large-scale survey of practices in science instruction. In the study, it was reported that the vast majority of teachers (90-95%) rely upon a science text as a major instructional resource 90% of the time.[2] Tables of the most widely used publications were listed in the Report of the 1977 National Survey of Science, Mathematics, and Social Studies Education by grade level;[3] it was this group of texts that provided the basic pool of information on science curricula contents.

The textbooks were evaluated in terms of topical coverage and relative importance of topics. The areas were separated into categories that corresponded to those used by SISS, and percentage ratings were calculated to estimate the relative emphasis the text placed upon a particular category. This value was determined by dividing the number of pages devoted to a particular topic by the number of pages of subject matter in the text.

Those topics that fell below 3% or were mentioned in fewer than 20% of the texts were dropped from the roster of intended science curricula.

The remainder were matched against a draft of contents proposed by SISS; where there was overlap, the item was retained as part of the international core. In the other instance, the contents were added to the grids as United States national content items. In those few cases in which the international roster contained topics which were omitted from most United States text-books, the items were retained so that further checks could be made through responses in the empirical study.

A second method of collecting content in science was to examine published material of specific, well-recognized programs of elementary, middle/junior high and high school science. These included projects such as SCIS, SAPA, MAPS, ISCS, BSCS, ESCP, and Project Physics. Research on NSF supported programs indicated that 20% to 27% of teachers in elementary and 33% to 52% of those in secondary public schools used them in instruction.[4] These programs provided teacher's manuals, textbooks, laboratory experiments, related literature and other publications, such as workbooks and individual modules. Most included general goals and process objectives. The method of analysis of these contents closely followed the procedure described above.

Additional reviews were undertaken of published state guidelines, national research studies on the status of science education, and curricula and position statements for science education published in journals in the field.

The first draft of "national curricula" in the United States was then submitted to experts in science curriculum at the university, district, and state levels, and the National Committee for additional refinement. Their suggestions were incorporated into the final version of science contents.

Science Content Rosters

The products of this investigation were two science content rosters, which represented the traditional and non-traditional (applied and/or integrated) subject matter of United States science curricula. Although three grades were singled out for further analysis, the content of science in the primary roster represents the range of *all* traditional science topics from K-12.

A second roster was created for content areas outside the traditional domains of Earth Science, Biology, Chemistry and Physics. This second roster, called "Other Science Content Areas" by SISS, consisted of science topics which had not been assessed in the First IEA Science Study (FISS). The five new categories are commonly considered applied and/or integrated science topics in this country.

Malcolm Rosier, International Coordinator of the current science evaluation, explained the difference between the two rosters thusly:

> This (traditional) content dimension classification system for traditional school science subjects is useful for the comparison of science curricula across countries and for the construction of the main international Science Tests for the study. However, it was not designed for the measurement of science content outside the traditional subject areas, and hence may not be sensitive to recent changes in the development of science curricula in some countries.
>
> One of these changes involves the extension of school science into areas beyond the traditional science disciplines, and especially into applied science areas. A second change involves the effort to integrate separate science areas into a single coherent science subject.
>
> In order to measure these new components of school science, an additional curriculum classification system has been prepared for the measurement of Other Science Content Areas[5]

The task of formulating a national roster for applied and integrated science curricula contents proved less straightforward than the task of matching up traditional science and determining national content items. A percentage of topics in the second roster are included in traditional science programs in the U.S., rather than presented separately as semester- or year-long science courses. The exception to this general pattern involved the integrated science topics under "Environmental Science." There was considerable evidence to indicate that this domain had grown as a new field in science curriculum programs across the nation.

Some difficulties arose in collating data for Populations 1 and 2 due to the nature of science curricula at these levels. It is common in the elementary grades to place major emphasis upon science-related process skills such as classification or observation. Content is often selected from a wide variety of topics in any of the traditional science domains, and less uniformity exists in what is prescribed at each grade.

At the junior/middle high school level, courses are often structured in modular units, with a heavier emphasis upon laboratory experiences than in the past, before curricula reform in the 1960s and 1970s. Again, content is selected to reflect the objective of a more investigative approach to science learning, and covers a wide range of different topical material in Life, Physical, Earth or Applied Science areas.

In response to the highly theoretical and analytical programs developed after 1957 (and the Soviet challenge of Sputnik), a counter curricular movement developed during the 1970s that stressed the interdisciplinary nature of scientific enterprise. This coincided with the society's growing awareness of environmental issues that were perceived, correctly or not, to have resulted from irresponsible, misdirected, or misapplied scientific research. These forces brought forth another kind of curriculum focus that sought to illustrate the relevance of science to daily experiences. Titles of programs, such as

Spaceship Earth, Using the Environment, Energy and Our Future, conveyed the relationship between man and nature, and the effects of technology upon limited natural resources.

A host of energy-related issues evolved into courses which dealt with ramifications of indiscriminate management of fossil fuels and alternate energy research, particularly in middle and junior high school. Topics that related to science content in interdisciplinary or applied branches became integrated into K-9 programs.

The pervasive influence of dataprocessing technology has likewise impinged upon instructional practices of science programs across the country. Although no widely used programs depended upon computers or computer-related software for science instruction, evidence was found to indicate that classroom time was being allotted for computer use. One emerging pattern involving science and computers was to apply the technology of keyboard, monitor and compatible laboratory equipment to complete lab experiments. The computer functioned as a measuring and recording instrument and replaced conventional laboratory set-ups in a wide range of science experiments.

The new directions described to this point have been reflected in the contents of some textbooks and programs reviewed for this analysis. Still, it was generally found that the most commonly used books adhered to a traditional view of science, particularly in the books published for high school biology, chemistry, and physics programs.

The process of identifying content for this roster was approached essentially in the same manner as that described for the main science roster. In reviewing the most commonly-used textbooks, topics in other science fields, such as environmental science, were gathered as well. This process limited the range of applied, integrated, and technological topics that were reviewed. However, since the purpose of this secondary content analysis was to identify the most representative "new" topical matter, rather than to describe the content of newer science programs per se, the decision to review the most commonly used science texts in science classrooms was adhered to. Suggestions from science curriculum specialists were included as well. Despite some problems, the formulation and utilization of this second roster served the desirable goal of identifying important new directions in science curricula since the early 1970s. This national science roster, including "new" national items, is shown in Chapter III, with rating scores for all the student populations.

Instructional Objectives Roster
Science Processes/Attitudes

The completion of this stage of the study entailed identifying the process skills and affective behaviors considered essential to science learning. These elements, as well as a listing of traditional science contents, were first proposed by L. Klopfer in "Evaluation of Learning in Science," in the Handbook on Formative and Summative Evaluation of Student Learning[6] and were adapted by SISS. A section entitled "Orientation" referred to the philosophical, social, and moral dimensions of science as well as the historical, economic, and technological ramifications of scientific research.

The bulk of data reviewed for this portion of the study came from published sources describing aims, objectives, and goals of science instruction. Some of the information was obtained from the textbooks that were used in the previously described section. Other sources included federal, state, and local guidelines, position papers from science education organizations, policy recommendations by national studies or review commissions, statements from popular science programs, and journal articles which discussed these issues of science curricula in depth.

While gathering information that was needed to complete this roster, it became evident that parts of the SISS classification system (particularly "Applications," and "Orientation") were unwieldy and therefore difficult to assess. However, the realities imposed by the time schedule from the International Center as well as the possible repercussions of developing a different classification system within the context of a cross-national study, discouraged us from pursuing other possibilities. With respect to identifying the most emphasized objectives in the cognitive, psychomotor (practical), and affective domains in this country, the SISS classification system generally proved satisfactory.

National items were not developed for the science process roster. Essentially, the subcategories under the process areas and affective behaviors were defined in broad enough terms to cover a wide variety of intended pedagogical objectives. Since most of the core process and affect categories of intended science curricula in the United States (as well as in other countries) were represented adequately, and since an examination of this nation's most typical science education resource material did not reveal overriding characteristics excluded by SISS, the classification was not amended for national items as the two content rosters were.

The roster used for evaluating science processes, attitudes, and "Orientation" is included in Chapter III.

In order to quantify areas of the intended national curricula for later comparisons with the "translated" and "achieved" curricula within the United States, and to determine the final core of science topics for developing the test items for the international science achievement instruments, it was necessary to conduct an empirical study to determine the relative emphasis given to science subject matter and processes within the intended curricula. To do this, rating forms were developed.

The Rating Forms

The instrument used to collect data was a basic, two-dimensional grid which divided the contents of science curricula into smaller topical categories, with horizontal comparisons across populations and vertical comparisons of content items (see Chapter III). Each instrument was amended from the SISS template to include national items as determined by the prior analysis of United States science contents. Three different grids were used to measure different aspects of the science curricula, based upon the curricula rosters described in this chapter. Overall, it was necessary to design seventeen instruments to measure all appropriate categories across all three grade levels. Separate analyses were carried out in each of the seventeen scored grids, and are described in Chapter III.

Figure 1 summarizes the actual breakdown of the separate instruments across science curricula domains and across Populations 1, 2, 3/3N, 3E, 3B, 3C, and 3P.

SISS POPULATION U.S. GRADE EQUIVALENT	1 5	2 9	3/3N 12	3E 12	3B 12	3C 12	3P 12
Traditional Science (Main Content Grid)	X	X	X	X	X	X	X
"Other" Science (New Content Grid)	X	X	X				
Science Processes/ Attitudes (Instructional Objectives Grid)	X	X	X	X	X	X	X

SCIENCE CURRICULA IN SISS STUDY
(FIGURE 1)

A clearer understanding of the functions of each of the grids may be provided through the comments of the SISS International Coordinator:

> The main grid deals with major content areas, organized within the traditional disciplines of school science: earth sciences, biology, chemistry and physics. The list of content areas attempts to provide a comprehensive classification system for these major disciplines. It is based on the grid used for the first (FISS) study...
>
> The types of topics covered within each content area will differ according to the age and developmental level of the students. In order to improve the definition of the content areas for the purposes of this (SISS) study, a list of topics

> has been suggested for each content area for each of the three population levels of the study...
>
> This curriculum grid for traditional school science provides a convenient classification system for the comparison of science curricula across countries and the construction of the main International Science Tests for the (SISS) study. However, it was not designed for the measurement of science content outside the traditional subjects, and hence is not sensitive to some recent changes in the development of science curricula.
>
> One of these changes involves the extension of school science into areas beyond the traditional science disciplines, and especially into applied science areas. A second change involves the effort to integrate separate science areas into a single coherent science subject.
>
> In order to measure these new components of school science, an additional curriculum grid has been prepared for the measurement of Other Science Content Areas...
>
> In addition to the specification of content areas, most modern science curricula also include aspects of the processes of scientific inquiry...
>
> There are many aspects to the processes of scientific inquiry... For the Second IEA Science Study it is proposed that the classification system to be adopted should be the one described by Klopfer... The Klopfer classification system is expressed in terms of behaviors that students should exhibit in carrying out the processes of scientific inquiry. The system does not provide a general description of student learning processes. Rather, it concentrates on processes involved in the learning of science, including practical and investigative skills, and attitudes.[7]

The Rating System

Assignment of a numerical "score" to each of the grid items was used to indicate the degree of emphasis and coverage. The range of possible values was 0-3, with 0 indicating that the specific content was not included or that it was planned for very few students. Ratings of 3 implied a high level of coverage, with the intention that 75% or more students should learn the content over a relatively long period. (See Figure 2.)

Thus, determination of the score was dependent upon two separate factors: the percentage of students intended to study the topic and the number of hours devoted in the classroom to its study. These were referred to as the "universality" and "emphasis" components in this study.

The numerical rating system was applied in toto to the measurement of United States curricula, despite some obvious shortcomings. The development of the rating system and the request to utilize it in the curricula analysis by all participating nations came from the International Headquarters.[8] The table that appears as Figure 2 summarizes the numerical rating system.

EMPHASIS OF CURRICULA TOPIC/CATEGORY (Per School Year)

	Major emphasis	Minor emphasis	Nil Emphasis
Pop. 1	more than 1 hr	less than 1 hr	nil
Pop. 2/3	more than 3 hrs	less than 3 hrs	nil
Universality			
All or most students (75%-100%)	3	2	0
Some students (25%-75%)	2	1	0
Very few or no students (0-25%)	0	0	0

DESIGNATION OF THE RATING SYSTEM BY NUMERICAL SCORE
(FIGURE 2)

It is apparent that of the nine possible combinations, five result in a "0" rating; one yields a possible "3" or a possible "1"; a rating of "2" is achievable in the remaining two instances. For example, assume that three hours of instruction are planned in a grade five science program in meteorology in Region Z, U.S.A. Since all or most students take science at this grade, the rater would score this item "3" in the traditional science grid.

Figure 3 is a sample page from the rating form designed to measure emphasis in traditional science content for Population 1. The complete form contained approximately 60 content items for this level, and included both SISS and national items. Each was scored for intended coverage and recorded in the column to the right. There were similar rating forms designed for all seven populations.

The Sample Survey

In those nations or states where there is no uniformity or consensus on the structure of science curricula, it is difficult to identify the areas intended for relative heavy or light emphasis in the classroom. One strategy, already described, is to review published materials related to science learning at particular grade levels. Another, suggested by SISS, is to evaluate samples of planned science curricula from different sections of the country by using a small scale survey.

The Sampling

Overall, 61 "packets," each containing 17 rating forms, were distributed. All members of the National Committee responded, as well as various administrators of schools, school districts, and practicing teachers from all four geographic sections of the country (West, North Central, South, Northeast). There was a response rate of over 90% (55 packets were returned). Scoring was limited to specific grade levels (grade 5, grade 9, and grade 12). The actual number of schools that were sampled was almost five times the number recommended in the SISS international guidelines.

Analysis of Data

The responses to each item on the three rosters--Traditional, Applied/Integrated, and Process/Attitude (Grids) were recorded and tallied across grades 5, 9, 12 (3/3N), and the four sub-populations of grades 12, 3E (students taking Earth Science in the final year of secondary school), 3B (students taking Biology in the final year), 3C (students taking Chemistry in the final year...), and 3P (students taking Physics in the final year...).

A mean and standard deviation were determined for each item, rounded to the first decimal. The coefficient of variation (the coefficient of variation equals the standard deviation divided by the mean of a group of scores), the mode, and the percentage at mode were also determined for each item. A discussion of the "patterns" in science curricula content that emerged from this investigation is found in Chapter III.

(Figure 3)

Rating Form for Science Content Areas

Population level 1 Year level GRADE 5

Curriculum name ELEMENTARY SCHOOL SCIENCE

(*) Items are U.S. Options

Content Area	Rating (3,2,1 or 0)
EARTH SCIENCE	
1 Solar System	
2 Stellar Systems	
*2aSpace Exploration & Recent Discoveries in Space	
3 Meteorology	
*3aThe Water Cycle	
4 Constitution of the Earth	
5 Physical Geography	
*5aOmit this item	
6 Soil Sciences	
*6aSoil Formation	
BIOLOGY	
Biology of the Cell	
7 Cell Structure and Function	
8 Transport of Cellular Material	
9 Cell Metabolism	
*9aThe Sun and Food Production	
10 Cell Responses	
11 Concept of the Gene	

FOOTNOTES

CHAPTER II

1. For the original review, see: June K. Miller, An Analysis of Science Curricula in the United States, (Ed.D. dissertation Columbia University, 1985), Chap. 3.

2. Robert E. Stake and Jack Easley, Case Studies in Science Education, Volume 1 and Volume 2, Washington, D.C.: U.S. Government Printing Office, 1978.

3. Iris Weiss, Report of the 1977 National Survey of Science, Mathematics, and Social Studies Education. Washington, D.C.: U.S. Government Printing Office, 1978, pp. B44-B46.

4. Ibid., p. 83.

5. Malcolm Rosier, The Analysis of Science Curricula, SISS, MSS 35, (ACER, November 1981), p. 20.

6. Leo Klopfer, "Evaluation of Learning in Science," in The Handbook on Formative and Summative Evaluation of Student Learning, eds. Benjamin S. Bloom, J. Thomas Hasting, and George F. Madaus, McGraw-Hill, 1975, pp. 559-641.

7. Malcolm Rosier, The Analysis of Science Curricula (draft version), SISS, MSS 13, (IEA, April 1981), pp. 5, 15, 17.

8. Rosier, MSS 35, p. 9.

9. Although references are made to the coefficient of variation and percentage at mode in this monograph, the figures are not included in the report of ratings beginning on page 60. The complete statistical report may be found in: June K. Miller, "An Analysis of Science Curricula in the United States," (Ed.D. dissertation Columbia University, 1985), pp. 231-252.

Chapter III

RESULTS OF THE SCIENCE CURRICULUM SURVEY

National Roster of Science Curricula Contents

The final draft of U.S. science curricula consisted of an international core and supplemental national contents identified in the early phases of the study. This section describes the nature of the national content items selected in traditional and applied/integrated science curricula.

Traditional Science Content - National Items

There were 24 content items added to the international core for Population 1, 14 content items for Population 2, and 9 content option items for each of the 4 populations in the final year of secondary schooling. The different numbers of items for each group were both a function of the contents of the original SISS template and national concerns reflected in the school curricula in this country.

In the domain of Earth Science, recent editions of American texts usually included some discussion of space exploration and recent discoveries made in the Solar System, as well as newer theories regarding the evolution of stars in outer space. While the ratings in these topics did not indicate a greatly elevated emphasis they were nonetheless higher than the Earth Science grand mean for each of the three general science populations. They fared less well in Population 3E, where the grand mean was higher than scores for national items.

The national items in the Biological Sciences differed less than those in Earth Science from international "core" scores across the populations. The national biology topics were emphasized at about the same level as those in the SISS roster. No national items were added to Population 3B.

Although there was a vast increase in biogenetic and biomedical information in the 1970s, progress in these fields was generally excluded from science curricula of the lower grades. The inclusion of regulator genes, enzyme induction, and current theories on repressor mechanisms were only observed in upper secondary biology textbooks.

Biological relationships that exist within the (changing) natural environment were identified as national items at Populations 1 and 2, but not at Population 3. The fact that Environmental Science was studied separately in the "Other Science Content" Grid may have had some effect on contents of traditional biological subject matter in general science curricula for Population 3.

The nine national items included at the Population 1 level in Chemistry involved simple chemical concepts such as the atom and manifestations of oxidation (rusting, burning), classification of materials into more basic chemical descriptions of matter (solids, liquids, gases) and environmental issues such as pollution, examined from a chemical point of view.

Of the four major science domains, chemistry was the only subject for which no national options were added at the lower and upper secondary levels. Two factors may help account for this. The first, mentioned briefly at the beginning of this section, related to the core components of the original SISS template. In the case of chemistry, the topics selected to represent traditional subject matter cross-nationally closely approximated the intended curricula contents for grades 9 and 12 in this country. The second factor was dependent upon the relative changes that have taken place in this nation since 1970 in this particular field of instruction. Since the core items of the SISS grid were essentially the same as those used from the First International Science Study, the fact that no real differences in national curricula were apparent 10 years later attested to the stability of the curricula in this domain over the same period of time. Put differently, chemistry as a discipline had changed least of all four traditional sciences in the schools' perception in grades 9 through 12 in this country. A report by the Chemistry Education Task Force worded their findings more bluntly:

> Curriculum materials of high quality and demonstrable effectiveness do not exist in profusion; the lower the grade level the greater the need. Marketing forces push instructional materials toward conformity and uniformity, with the predictable result that neither diversity nor excellence is found or served.[1]

Twenty-seven national items were added to traditional Physics content for all general populations and Population 3P, although some of the items in both the international core and the national additions might also have been classified (as curricula) under other domains. For example, some aspects of molecular and atomic physics are also taught in first year Chemistry courses as well as in Physics. Similarly, kinetic theory, changes of state and latent heat are often taught from a chemical viewpoint. On the other hand, "chemistry of life processes" would have been more appropriately listed as biological science, rather than Physics. Since the distribution of subject matter had already been established by SISS, the integration of optional content followed the structure of the international grid.

There were 10 national items added to the grid for Population 1 which consisted of topics in: measurement (the Metric System), time, gravity, the nature of waves, light, static electricity and nuclear energy. A review of textbooks used for grades four through six did not uniformly cover all these topics per se, but there was evidence to indicate that most were included in planned science curricula at or before the fifth grade level. For example, measuring in metric units was covered in United States curricula as early as grades 1-3 of primary schooling, in science as well as areas outside of science, such as mathematics. Reference to concepts of gravity, (sound) waves and static electricity were noted for grade three science in the teaching guidelines of New York City's Minimum Teaching Essentials (K-9). Most texts reviewed in this study contained conversion tables of the English to metric system. All mentioned waves as a form of energy, with sound or light used as typical examples. Magnetism and static electricity were included with regularity. Time and its measurement was discussed in relation to the movement of planets and the sun in the solar system; occasionally, it was mentioned in conjunction with weather, the seasons, and day/night. Topics in nuclear energy with its peaceful and defense applications were added as national items at the suggestion of some members of the National Committee. A large percentage of textbooks for Population 1 mentioned nuclear energy as a potential source of energy but excluded reference to its potential destructive powers.

The national items in Physics for Population 2 generally consisted of similar topical areas. Pulley systems under the general heading of mechanical energy, wave properties, heat, generation of electricity (chemical and magnetic), and nuclear energy were among those selected; altogether, there were 10 items.

There were seven topics in physics added to the SISS template as national items in the terminal year of general science curriculum. All of these topics dealt with different forms of energy, particularly light, electricity (generation and transmission), magnetism and nuclear.

One finding of the curriculum analysis was that greater emphasis was placed upon energy as a general, unifying concept in the United States than in other countries (for the last age-group) . Of the 34 national option items added to the physical science roster, 59% dealt with energy-related subjects. A detailed analysis of the rating outcomes of these additional national items, as well as those of the "core" items in the main science content grid, are discussed in the "Results" section of this chapter.

Applied/Integrated Science - National Items

There were five major "headings" under this secondary science content grid. Each of these represented science-related subject matter perceived by SISS to be relatively new additions in science curricula across the globe. Because of this, these areas had no true antecedents in the first curricula analyses, nor were test items extant from the previous international science study.

The specific purpose of evaluating this roster was to determine the degree to which the contents of integrated or applied science permeated science programs, and to measure their effect in the school through the curricula ratings, OTL responses, and testing program.

The selection of national items for the "Other Science Contents" was based upon a review of most commonly used science texts below the upper secondary level. These texts generally enphasized the contents of traditional science domains and seldom included applied or integrated topics. In the chapters that included discussion of non-traditional topics, the topics were presented in context to the basic science rather than featured separately. (This characteristic did not apply in science programs developed as alternatives to the traditional secondary science sequence.)

The contents of the applied/integrated roster were less precisely described than those of traditional science. For example, categories were not separately delineated for each population level as they were for the main science content grid. One reason for this open ended format is due to the nature of the subject matter, which does not lend itself to categorization in the manner of traditional science contents. Altogether, there were eight national items added to the international core proposed by SISS evaluated in general science curricula.

Under the category "History and Philosophy of Science," national additions in content were labelled "Sociology of Science," and "Controversies Associated with Science and Technology." These areas reflected material found in curricula that sought to examine the relationship between science and different facets of society; its alliances with industry, economics, and politics, for example. There was some evidence (particularly at the junior high school level) that the traditional image of science as a remote, elitist institution is being replaced by more objective views of it as a research conduit to developing technologies, central to progress in the fields of nutrition and health, and ambivalently, both the source of and solution to various societal problems. Pollution of streams by chemical wastes, deleterious effects of acid rain, X-ray radiation, and toxic pesticides were some examples of societal problems related to science. Moral implications of research and development also fell into this category, although this topic was infrequently mentioned.

Under "Environmental Science," the second heading, the national topic was entitled "Population and the Environment." Ecological concerns were reflected in science curricula at the primary and early secondary levels. Changes in the environment from natural and man-made causes were shown to affect communities in various ways. Issues of population size were raised in terms of available food supplies and diminishing resources, as well as natural causes of population control.

"Technical and Engineering Science," the third content area of this grid, generally described aspects of applied science that are covered in American curricula under the traditional sciences, particularly physics. The exception was a sub-heading entitled "Microprocessors and Computers." A national topic, "Relationships Between Science and Technology," was added. Since we did not specify the particular nature of these relationships, the topics that might be included in science curricula under this heading covered a wide spectrum. In primary and middle school texts, there were occasional references to the uses of earth satellites and how they are used to gather and relay both scientific and commercial information throughout the world.

The final two categories, those of "Rural Science" and "Health," did not generally reflect applied content included in science curricula in this country, or content perceived as representative of science in grades 5, 9, and 12. "Rural Science" topics are covered more often within agricultural courses in vocational schools, while the subject matter of "Health Science" is frequently taught by science teachers in Biology, Health, First Aid, or Drugs and Alcohol Abuse programs. One item was added to the core in each of these categories. The first, under "Rural," was "Mechanization of Agriculture"; the other, under "Health," was "Death and Dying."

Rating Results of Intended Science Curricula in the United States

A report on the ratings given by professional science educators to the three intended science curricula grids at the target populations (1, 2, 3/3N, 3E, 3B, 3C, 3P) follows. The national items discussed in the previous section were assessed along with those included in the original template. Seventy-nine separate rating scores were obtained for the items in traditional science, 23 for non-traditional science, and 48 for the process grid.

It should be noted that the number of content items listed under each of the traditional science domains or applied/integrated science categories differed. The items were chosen to reflect the range of topics within the discipline by the international rosters; apportionment was thus pre-determined except for the addition of our national items. Some experts in science education raised objections regarding both the unequal distribution of items and their selection (content validity) for United States curricula evaluation. Specific examples regarding the latter point are contained in this chapter.

Data Analysis and Presentation

The results for each item were analyzed by tallying all responses, then determining the mode, percentage at mode, mean, standard deviation, and coefficient of variation.

The results were then grouped by population and by science subject. Grand means are thus reported for each population in each of the traditional science domains (Earth Science, Biology, Chemistry, and Physics), non-traditional science domains (History and Philosophy of Science, Environmental Science, Technical and Engineering Science, Rural Science, and Health Science), and instructional objectives (A - Knowledge and Comprehension, B - Science Inquiry I, Observing and Measuring, C - Science Inquiry II, Defining and Solving Problems, D - Science Inquiry III, Interpreting and Generalizing Data, E - Science Inquiry IV, Building... A Theoretical Model, F - Application of Scientific Knowledge..., G - Manual Skills, H - Attitudes and Interests, and I - Orientation).

These major headings reflect the arrangement of the contents and processes by SISS in all three main curricula grids.

Rating Results of United States Intended Science Curricula

The complete report of scores obtained in the science curricula survey is presented at the end of this chapter, beginning on page 60. The results are recorded on three sets of grids: the first lists all the topics evaluated in the traditional science domains; the second lists the topics evaluated in the applied or integrated sciences; the third lists science instructional objectives (cognitive and practical) as well as attitudes and orientation evaluated in the study.

The horizontal axis of each grid shows the populations of students involved in the curricular survey and the vertical axis lists the specific item, or feature in curricula that is being rated. Numerical scores thus represent the mean rating of the curricula item for a specific grade level or specialized group of students.

Ratings were based on a four (4) point scale, which ranged between zero (0 = nil coverage in science curricula) to three (3 = high coverage). See Figure 2, Page 18 for score guidelines.

Population 1 - Traditional Science Ratings

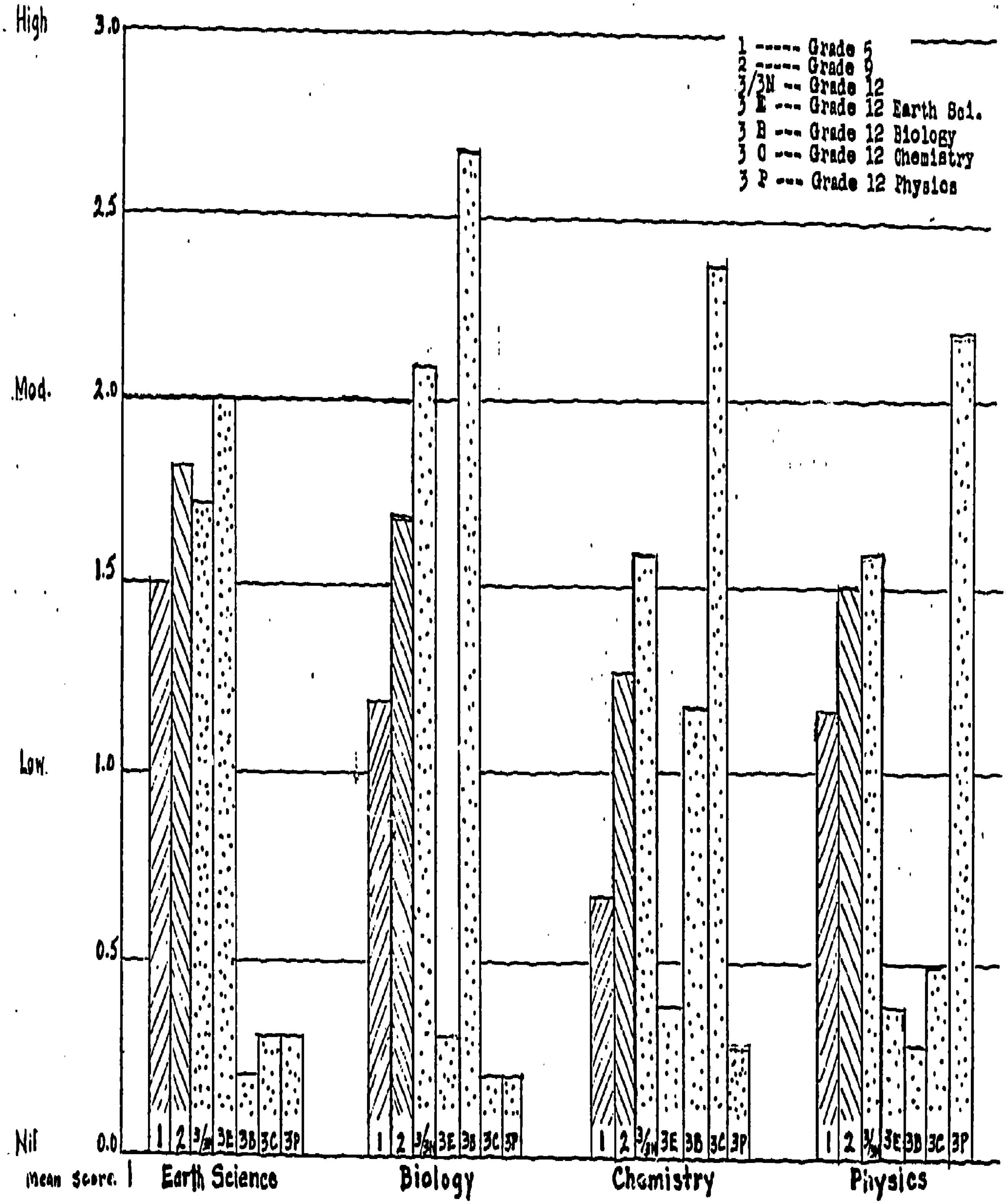
Of the four science domains, Earth Science received the highest mean rating (1.5) for coverage at the fifth grade level, followed by mean scores of 1.2 for both Biology and Physics. Chemistry received the lowest overall rating with a mean of 0.7. (See Figure 4 on page 29.)

There were nine topics (core topics and national additions) listed separately under Earth Science. Those receiving a modal score of 2 (indicating moderate coverage in the intended curriculum) were clustered about content related to the Solar System, meteorology, physical geography, and the Earth. A modal rating of "3" was obtained for only one topic listed under this science - the Solar System.

The lowest ratings in this block of scores were in the Soil Science domain. These received ratings in which the modal score was "0" and the percentage at mode averaged 60; means were between 0.5-0.7, far below the overall mean of 1.5.

Two out of three of the national items added to this science domain had mean scores equal to or above the grand mean for Earth Science at Population 1. This parity in ratings indicated that Grade 5 national topics reflected content validity in nation-wide programs at about the same level as international core topics in this branch science.

Although Earth Science received the highest grand mean of the



(FIGURE 4)

U.S. Mean Ratings — Traditional Science Content traditional sciences in Population 1, it was lower than grand means in Earth Science at the other main population levels. One might have anticipated this result in light of the relatively little time devoted to science in the elementary grades compared to the lower and upper secondary levels.

In Population 1, both Biology and Physics had grand means of 1.2. Of the 19 topics in Biology and 30 in Physics, modal scores of "3" were given to 5 topics in Biology and 3 topics in Physics. Proportionally, there were more topics in Biology covered at "high" ratings in the science curricula. These areas (9a, 12, 17, 18, 19) concerned life forms, photosynthesis, animal reproduction, human biology (systems), and natural habitats. In Physics, the areas of curriculum rated at modal scores of "3" (39, 39a, 49) were in measurement, the Metric System, and vibrations and sound.

Areas where coverage was lowest in Biology (those below means of 1.0) dealt with genetics, cell functions, regulatory systems, evolution, and Darwinian Theory (8, 9, 10, 11, 14, 21, 22, 23). In Physics, comparable low ratings were found in topics dealing with the dynamics of motion, buoyancy, kinetics, wave properties, spectra, principles of simple electronics, and elementary atomic theory (42, 44, 47, 50, 50a, 55, 56, 58a, 59a).

The two national content items included in Population 1 Biology (9a, 23a) received higher mean scores than that of the grand mean for all topics under Biology. Together, their mean was 1.6 as compared to the grand mean of 1.2.

There were ten national items added to the basic SISS grid for Population 1 Physics. Eight received mean scores at or above the grand mean. The national items that received exceedingly low scores, in fact the lowest of the entire 30 items rated in the Physics block at Population 1, dealt with nuclear energy, and its varied applications. Altogether, the mean for all national option items in Physics was 1.3.

When the coefficients of variation were compared, it was found that generally greater agreement existed in the ratings given in Physics than in Biology. This may indicate that certain "blocks" or categories are more uniformly included in elementary physical science curricula than in biological science curricula. However, one should use caution in generalizing this tendency to <u>all</u> of elementary Physics and elementary Biology.

Of all four science domains, Chemistry received the lowest ratings for content coverage at the fifth grade level. Over 70% of the topics included in the SISS grid under Population 1 had mean scores that fell below 1.0. Of these, almost 60% had means for coverage between 0.0 to 0.5.

The grand mean for all Chemistry topics was 0.7. Out of 24 topics describing the contents of Chemistry at the Population 1 level, 19, (or

79.2%) received modal ratings of "0." The categories which generally received highest ratings in coverage achieved means that ranged between 1.0 to 1.7. There were seven content items in this class, six of which were national items; specifically, these (24, 24a, 25a, 27a, 29a, 35a, 36a) dealt with the physical and chemical nature of matter, simple chemical reactions, the Celsius Scale and measurement of heat of reactions, fuels and oxidation.

Taken together, the national items were rated 1.1 in coverage compared with a grand mean of 0.7 for Chemistry at Population 1. Standard deviations were 0.3 and 0.5 respectively.

The low level of coverage for this particular science domain at Population 1 may be due in part to the generally abstract nature of Chemistry. For example, in many instances, it is difficult to describe why certain elements "behave" differently under similar circumstances without introducing some elementary concepts of atomic structure and theory to the students. While arguments could be presented for making Chemistry a more integral part of science programs at the elementary school level, research suggests that most teachers have neither the equipment or the experience to do so.

In addition to Chemistry topics receiving the lowest overall mean for coverage, it also reflected the least uniform pattern of rating assignment, as revealed by an examination of coefficients of variation for all traditional contents. Earth Science curricula showed the greatest uniformity, followed by Physics and Biology.

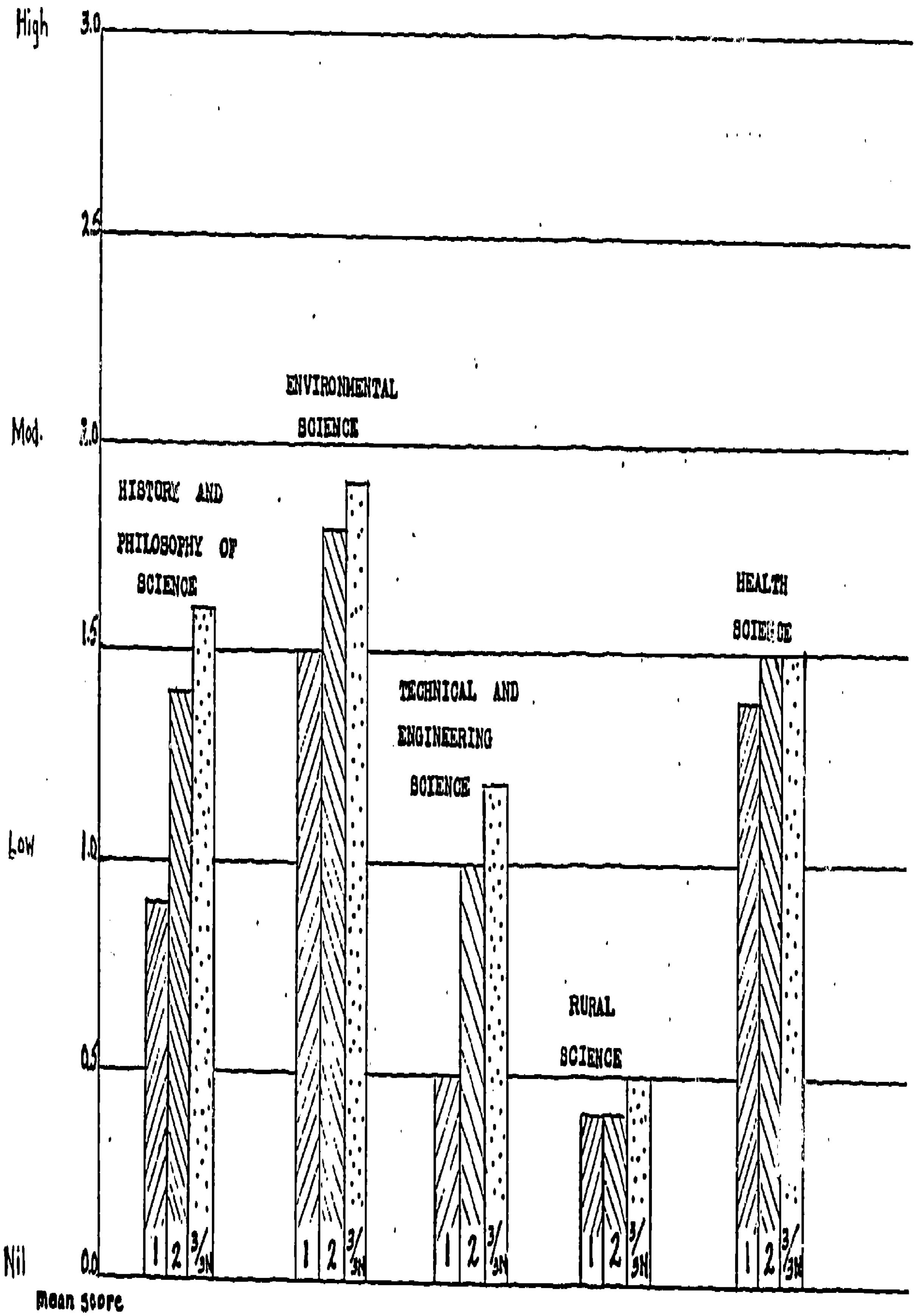
Thus, of the four traditional sciences, Chemistry appears to hold the least stable position in the traditional curriculum for Population 1. In some areas of the country, it may occupy a relatively stronger position in elementary science (although less than the other traditional sciences), while in other regions, the opposite may be true.

Population 1 - Other (Applied/Integrated) Science Content

Applied/integrated science subjects are generally taught apart from conventional subject domains in traditional science at the secondary level in the U.S., but are incorporated into science instruction at the lower grade levels. This curricula material, collectively labelled "Other Science Content" by SISS, was grouped into five broad "categories." The ratings were analyzed in the same manner as the Traditional Science Grid ratings; tabulated data include the mean, standard deviation, coefficient of variation, mode, and % mode for all individual sets of content items. (See Figure 5 on Page 32.)

Of the five categories, "Environmental Science" achieved the highest grand mean (1.5), while "Technical and Engineering Science", along with "Rural Science," were the lowest (0.5 and 0.4, respectively). "Health Science" followed "Environmental Science," with a mean of 1.4. Finally, "History and Philosophy of Science" was midway between the two extremes,

(FIGURE 5)



U.S. Mean Ratings—Other (Applied, Integrated) Science Content at 0.9.

As we mentioned, the areas in this grid represent relatively "new" content (added to most science programs after 1970) in science curricula. The "Other Science Grid" was not included in the assessment of curricula in the First International Science Study. The fact that some achieved mean scores larger than those in the traditional domains indicates that perceptions regarding science curricula have broadened considerably in the last decade and a half. However, the phenomena appear to be largely confined to specific areas, vis a vis the study of the environment, health, and history and philosophy of science at Population 1.

A note of caution is directed toward the interpretation of results for some parts of this grid. It is sometimes difficult to distinguish between traditional and applied/integrated science in United States curricula because much of what is considered "science" before high school contains elements of both. For example, there are some topics that were rated under "Environmental" and "Health Science" that might also be considered differentiated Earth Science and Biology curricula. Therefore, when examining the means of various sections of this grid, it is suggested that readers refer to the rosters at the end of this chapter and that open minds be maintained regarding curricula placement under traditional or non-traditional science content.

In view of the changes experienced throughout the country in the late 1960s and 1970s (during which time political and social forces became increasingly concerned with ecological issues), it is not surprising that Environmental Science scored as high in coverage as Earth Science at the 5th grade level. The field ranked higher than the remaining three domains of traditional science at Population 1. Its grand mean was 1.5, with a smaller standard deviation (0.4) and coefficient of variation (0.3) than Earth Science. The modal score for three of five subtopics was "2," which indicated a moderate level of content coverage. These subtopics were in the area of energy resources and their utility, and current topics of conservation ("Preservation of Habitats"). A national item, "Population and the Environment," had a relatively low mean of 0.9 (SD 0.9).

It is quite apparent from our rating outcomes that Environmental Science made the greatest inroads of all the "new" fields introduced to the curriculum. Most often however, its contents are integrated into the science curricula of general science, life science, and physical science, as are most science categories at this grade level.

"Health Science" is somewhat different from most science because it is often scheduled separately from the formal science program in schools in the United States. Because it was included as "Other Science Contents" by SISS, all participating nations evaluated it along with the more representative, applied or integrated science areas. An unexpected finding from the rating analysis was that topics in this field were ranked ahead of most other science-related categories for fifth grade. This may result from the convention that "Health" is often a "required" course (part of the core program for all students) in many elementary and intermediate schools in this country. The grand mean was 1.4 (SD 0.7). The area with the highest scores was in Personal Health, which involved aspects of food, diet, nutrition, exercise, illness, disease, injury, and first aid. Drugs, alcohol and narcotics were also included. The latter topic received a mean of 2.2 (SD 1.0), with a modal score of 3. "Interpersonal Relationships" and "Community Health" had means between "low" and "moderate" emphasis. In both instances, the modal score was "1." The lowest score was obtained by a national option item dealing with causes of death. It was rated 0.4 (M) with a SD of 0.6.

Topics listed under the "History and Philosophy of Science" had a grand mean of 0.9 (SD 0.5). Those which dealt with the nature of science (the stages of scientific methodology) and its historical development ranked relatively higher in coverage than the national item regarding the sociology of science, including controversies in scientific research.

One topic listed under the broad domain of "Technical and Engineering Science" focused upon a technology that had considerable impact upon all strata of society during the decade of the 1980s. Its applications in curricula are described under item #11, "Microprocessors and Computers." (See discussion in Population 2 results of microprocessors and computers on page 42.) The range of scores at the elementary level suggests that little consensus existed about computers and their role in the science classroom. It averaged the lowest of all topical areas in "Other Science Content" for Population 1, with a mean of 0.2 (SD 0.6). The modal score was "0", assigned by 82% of the raters. These results suggest that computer-assisted-instruction in elementary science did not make significant headway in the first half of the 1980s.

There was also little evidence to indicate that "Rural Science," commonly called Agriculture, played a significant role in the elementary science curriculum. The contents listed under this category (animal and plant husbandry, for example) are more likely planned for vocational students at the secondary level who attend specialized schools or programs within schools. All six topical areas received means below the 1.0. level. Modal scores for all areas were "0," and the percentage at mode reflected a higher than average level of consensus in this part of the assessment; between 52.9% and 76.5% of the ratings per topic were evaluated at "nil" for coverage. The grand mean for content in this field was 0.4 (SD 0.3).

Population 1 - Instructional Objectives

Before discussing the rating results of the objectives grid, several preliminary comments must be made with regard to the nature of the matrix used. The format was based upon one proposed by Leo Klopfer in the Handbook on Formative and Summative Evaluation of Student Learning[2], and contains a hierarchy of intellectual skills patterned on Bloom's taxonomy as they relate to science inquiry skills. In addition, the matrix contains categories that describe practical science skills stressed in common laboratory experiments, desirable attitudes and interests developed by learning science, and a section termed "Orientation" which, in curricula, enhances and broadens students' perceptions of science. (See Figure 6 on Page 36.)

The results of the ratings of this grid at Population 1 were fairly representative of the results at the other populations, although the coverage was, as anticipated, at a lower mean level for the fifth grade. This repetitive pattern, observed consistently in this analysis, was dubbed "the ripple effect." That is, the pattern or "profile" formed within each curricula grid by the means of its constituent domains for one population was reproduced, with minor variations, in the remaining populations. It has been suggested by some science educators that curricula influences are likely exerted downward over time. Thus, a "ripple effect" set off by curricula decisions made at the high school or college level, filters down to the middle or junior high school, and finally is absorbed by the elementary school.

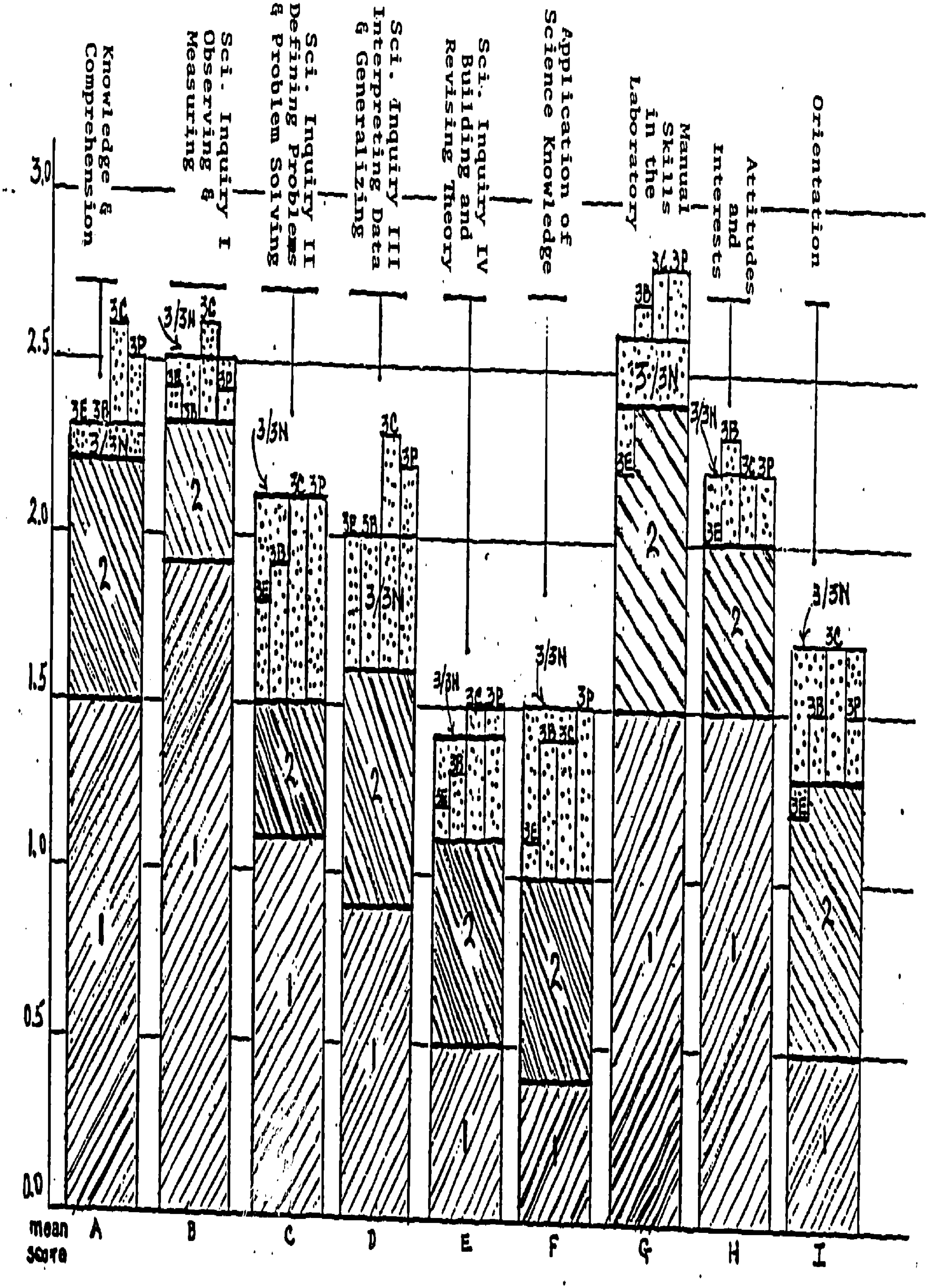
The analysis of this grid indicated that practical science skills and fundamental inquiry skills have, as a whole, become the most highly emphasized process areas in science curricula, rivaling the classical objectives of knowledge and comprehension in terms of relative emphasis. The NSF-sponsored programs of the 1960s, with their "hands-on," inquiry-based approach to science learning, have influenced the succeeding generations of science programs following in their wake. Although the paradigm of "discovery" in science is not applied as literally in programs of the 1980s, obvious elements remain from the activity-oriented approach to learning that pervaded the science curricula at all population levels. At the same time, results from this analysis indicated that there was less attention paid to the higher level, critical thinking skills such as analysis, evaluation, and synthesis in the curricula of the 1980s than in the earlier prototypes.

At the fifth grade level, the instructional objective that received the highest overall mean was "Science Inquiry I--Observing and Measuring"; it averaged 1.9, (SD 0.4). Of the five areas listed under Inquiry I, those which dealt with direct observation, measurement, and record keeping received means at or above a moderate level: 2.3, 2.0, 2.1, respectively. Those which required judgemental decisions, estimations and appropriate instrument selection fell below this level.

"Science Inquiry I" was followed by "Knowledge and Comprehension," "Manual Laboratory Skills," and "Attitudes" which received uniform means of 1.5, (SD 0.2, 0.6, and 0.4 respectively).

The cognitive domains of "Knowledge and Comprehension" have consistently ranked first in terms of science program objectives in the past. (While most NSF programs had modified the emphasis placed upon knowledge acquisition and placed greater stress on conceptual understanding and critical evaluation skills, the process of science learning was, in fact, heavily dependent upon these components.) Essentially, the high premium placed upon recognition and understanding is retained in curricula in the

(FIGURE 6)



U.S. Mean Ratings–Instructional Objectives, Attitudes in Science

1980s, although other objectives are perceived to be important as well. Categories under the knowledge and comprehension heading most often received the highest individual scores in the Process Grid across all populations. At Population 1, "Knowledge of Specific Facts" (Item A.1) received the highest mean of all 48 items. It was rated 2.6 (SD 0.6). The picture shifted slightly when all subcategories in the domain were averaged together. The ranking of the process domain dropped to second place (after Scientific Inquiry I: Observing and Measuring). Again, it is important to note that this occurred only when process areas were compared by their grand means.

There was a pronounced decline of emphasis in the remaining complement of inquiry skills on this grid. The drop was first perceived with the group of items in "Scientific Inquiry II" (Defining Problems and Problem Solving) and continued through "Scientific Inquiry III" (Interpreting Data), "Inquiry IV" (Building and Revising Theory) and "Application" skills (relating science theory to other situations). The mean scores for these categories were 1.1 (SD 0.3), 0.9 (SD 0.1), 0.5 (SD 0.1), 0.4 (SD 0.1).

Finally, the topics included under "Orientation" received an overall mean of 0.5 (SD 0.1). There seemed to be little attempt made in the lower grades at putting science into a wider perspective, or for examining it in terms of its inherent value to society. (See page 74.)

The "picture" of elementary school science that emerged from this analysis suggests that attempts are being made to encourage youngsters in primary grades to perform simple experiments, which require a limited familiarity with scientific methodology. One suspects however, that despite these efforts, a great many teachers in grade school do not have the proper facilities, materials, and training to carry out "doing science" in the manner described. According to one national survey, only 20% of schools containing grades K-6 have a specific budget for science supplies. Of these, the average amount allotted per pupil was $1.56.[3] In the same study, the time spent on science in grades 4-6 was reported as 28 minutes per day, lower than all other major subject areas.[4]

There appear to be more "hands-on" activities today for Population 1 students than there were prior to the infusion of NSF inquiry-approach programs of the late '60s and '70s. The net effect on elementary classroom science has been a purported change of focus from teacher-centered to student-centered instruction. This shift of emphasis places greater priority on the students' learning and using basic science skills in addition to learning and reciting general science information. A strongly developed process orientation to science curricula became evident after scores of the different grids were compared. Higher means were obtained on laboratory skills and fundamental inquiry skills than on specific subject matter at this grade level. However, the concession towards "learning through doing" appears to be limited to only the most perfunctory experiences of "discovery" for students. Routine practice in techniques of science, such as weighing or measuring objects, observing artifacts via instruments--magnifying lens, magnets, etc, were stressed above the more thoughtful, structured inquiry investigations that were at the heart of projects like SCIS or SAPA. Further, it was noted that the single most highly rated item on the process grid was "Knowledge of specific facts," out of a roster of 36 other possible process-related or practical skills. While attempts have been made to include some of the flavor of inquiry programs in science curricula for the elementary grade levels, it appears that entrenched, time honored practices of learning such as textbook reading, recitation and memorization leading to basic knowledge and comprehension of science are emphasized over training students to "think critically" in science.

Population 2 (Grade 9) - Traditional Science Content

Components of the curricula grids were basically the same as those of Population 1, except for national items in science content areas, which were selected for ninth grade only.

It may be recalled from the introductory discussion of this chapter that 14 items were included in the final set of national topics covering traditional science and eight in the non-traditional content grid.

Results from the rating analysis showed similar levels of emphasis for Earth Science and Biology. As anticipated, the means of each domain increased over those obtained for Population 1. As in the case of grade five science curricula, Chemistry content again was rated lowest overall. Physics was slightly higher, although the difference in coverage between these two domains was not as great as it was for Population 1. The grand means per domain in traditional science were: Earth Science, 1.8 (SD 0.5); Biology, 1.7 (SD 0.4); Physics, 1.5 (SD 0.5), Chemistry, 1.3 (SD 0.5).

An initial review of the most commonly used science textbooks in grades seven through nine supported these results. Of the 13 texts listed by title in the Weiss study[5], 9 deal primarily with the domains of Earth and Biological Science. Of those remaining, none mentioned Chemistry in their title, and further perusal of these indicated that most "Physical Science" consisted of the following topics: magnetism, mechanics, atoms, molecules, and elementary atomic theory.

Of the nine topics listed under Earth Science, five received a mean rating of 2.0 or above, indicating a moderate to moderately high level of coverage. These were concentrated in the area of astronomy ("Solar System" and "Space Exploration"), "Meteorology," "The Earth," and "Physical Geography." Just two topics, the "Solar System" and "Meteorology," had modal scores of "3," which indicated a high level of content coverage and emphasis. Percentage at mode was 52.4 and 47.6 respectively, slightly higher than the percentage at mode figures for the Population 2 average. The lowest mean scores were again related to the study of soil. These averaged ratings near 1.0, with standard deviations around 0.9.

One of the three national items added to this domain at the Population 2 level received a mean of 2.2, a score that was high relative to the Earth Science mean of 1.8. The topical content was "Space Exploration and Recent Discoveries in Space." The other two items, "Glaciation" and "Soil ph," received average scores of 1.7 (SD 0.9) and 1.0 (SD 0.8).

The contents under Biology received a grand mean just below that of Earth Science at the Population 2 level. Those areas which had relatively high ratings (above 2.0 for this population and domain) fell into the following categories: Cell Structure - 2.2 (SD 0.9), Lifeforms - 2.1 (SD 1.0), Metabolism - 2.0 (SD 0.9), Plant Growth and Reproduction - 2.0 (SD 0.9), Natural Environment - 2.1 (SD 0.9) and Cycles in Nature - 2.1 (SD 0.9). Only one topic, the "Gene," received a modal score of 3 (43.9%), although there were two with bimodal score distributions of 3 and 2; these were related to the structure of the cell, and cellular responses (42.9%, 33.3%). On the other hand, the contents which seemed to yield the lowest scores (1.0 or below) dealt with zoology and population genetics, with means at 1.0 (SD 1.0) and 0.8 (SD 0.8). There were two topics with modal scores of "0"; Zoology (i.e. "Natural Groups and Their Segregation"), and "Evolution." Percent at mode was 40.0 and 35.0 respectively. These latter categories were rated similarly in their modal score at Population 1 as well.

The mean for the domain of Physics was 1.5 (SD 0.5). Of 30 topics, only four received "3" ratings as modal scores. These dealt with content in measurement, energy, and changes of state (including freezing). It should be apparent to curriculum specialists that these topics are often included under Chemistry content in the United States. Such occasional anomalies occurred because content under science domains were assigned at the international level, and to preserve the uniformity of rating comparisons, it was necessary to use the prescribed format. It is therefore important to consult the full roster of descriptive contents in traditional science at the end of the chapter for rating results, and to realize that the international grids do not always describe science domains from our national perspective.

Content related to dynamics and current electricity, as well as measurement and change of state all received mean ratings at 2.0 or above. While considered "moderate" on an absolute scale, they represent a high level of coverage in the science curricula planned for all students. By comparison, grand means above 2.1 were not achieved in any content domain in the three main populations.

Four content items in the domain of Physics received rating means of 1.0 or lower. They dealt with aspects of electronics, theoretical physics and nuclear weaponry.

A total of 10 option items were included in Physics for this population. Their overall grouped mean was 1.3, slightly under the grand mean of 1.5. However, the majority of items in the sub-group (6 out of 10) obtained individual means at or above 1.5, which indicated that national curricula components were identified successfully in this section of the survey. (Refer to pages 64-66 for specific items.)

There were fifteen topical listings under the domain of Chemistry. No national items were added to the international core. The overall mean rating, 1.3 (SD 0.5), although still the lowest of the traditional sciences at this grade, represented the greatest percentage gain in content coverage and emphasis of all science branches when compared with Population 1 ratings.

Only one item listed as Introductory Chemistry, received a mean rating above moderate (2.1, SD 0.9) with a modal score of 3. The majority of mean scores, eleven of the total fifteen, fell into the low to moderate range. "Electro-chemistry," "Chemical Equilibrium," and "Organic Chemistry" all fell into the low range, with means and standard deviations at 0.9 (SD 1.0), 0.4 (SD 0.7), and 0.5 (SD 0.5).

The size of the standard deviations in this last set of scores indicates that only a handful of science programs regularly include these topics in the ninth grade.

The coefficients of variation were smallest for items in Earth Science and Biology, and largest for items in Chemistry and Physics. Based upon the ratings for this content grid at Population 2, science curricula in the United States has "more uniformity" in the domains of Biology and Earth Science than in the two physical sciences at Grade 9. This represented a somewhat parallel situation to that found for traditional science curricula for Population 1.

Population 2 (Grade 9) - Applied/Integrated Science

During the 1970s, there had been some attention focused on revamping science programs at the middle and junior high school levels in this nation. Efforts were directed towards turning general science curricula into broader-based, modular sequences. Science courses with global concerns--energy and energy depletion, nutrition, health and population growth, ecology, and pollution started to proliferate. In place of year-long sequences which covered Life, Physical, and Earth Science separately, experimental programs began to appear in the areas described, or in specialized science domains such as Physical Geography, Marine Biology, and Oceanography, Astronomy, Meteorology, or Environmental Studies. Science-related subject matter, such as technology, drugs, computers, and career education were also incorporated into the curricula. At the same time, the planned coursework tended to focus more on student-centered learning. Laboratory investigations became an integral part of this approach, even in those instances where more traditional sequences prevailed.

In a review of the most commonly used textbooks in grades seven through nine, there was evidence of this encroachment into the science programs. Life in the Environment and Interaction of Man and the Biosphere were the titles of 2 of the 13 most commonly used texts.[6]

The measure and extent of these changes were revealed through the assessment ratings of the "Other Science Content Grid" of applied/ integrated science. Here again, the major drawback was that the contents of this grid did not consistently reflect the way American science curricula is planned in most schools. National content topics were added to offset this, but the five main categories were pre-determined and could not be changed.

As noted previously, the applied/integrated science roster consisted of topical areas newly introduced to science curricula. As categories, none accurately represented intact United States science programs. Raters were thus required to isolate some items from Group X, some from Group Y, and combine these to represent, in their own estimation, the contents of United States science program Z. Under these circumstances, it was not possible to readily identify "new curricula" in this nation by course titles or program via the analysis. What was accomplished in place of this was a determination of "fresh" subject matter that was included in the planned science experiences of students. These curricula components were not evaluated in the first international science study.

When the ratings were tallied, we were somewhat surprised at the levels of coverage given this group of new science content. Three of the five major categories yielded means that were comparable to those achieved by the traditional sciences in Population 2. "Environmental Science," "Health Science," and "History and Philosophy of Science" had overall means of 1.8 (SD 0.2), 1.5 (SD 0.6), and 1.4 (SD 0.5).

Within topics under "Environmental Science," the item receiving the highest mean score of 2.2 (SD 0.9) referred to energy (fossil fuels, and alternate energy forms, including non-finite resources). Its modal score, 3, was flagged by over 50% of the raters. This was followed by two related areas which had means of 1.9 (SD 0.8), and 1.8 (SD 1.1). "Environmental Impact," the first of the two, described different types of pollution (atmospheric, aquatic, terrestrial) and its causes: population growth, industry and mining, for example. "Habitats" mainly dealt with issues of planned conservation.

Topics under "Health Science" covered an array of subject matter. The highest mean rating in this category was for "Personal Health," and included nutrition, illness and disease, and drugs. It received a mean of 2.2 (SD 1.0). "Personal Growth and Sexuality" received the next highest mean of 1.8 (SD 1.2). These two topics had modal scores of 3, given by more than 50% and 37.5% respectively, of the raters.

The areas described under the heading "History and Philosophy of Science" dealt with a number of separate issues. For example, the topic receiving the highest mean, "Nature of Science--Stages of Scientific Method," might have been more appropriately evaluated under the cognitive process grid, in the context of practices of scientific inquiry, or possibly related to different levels of critical thinking. Its mean was 2.1 (SD 0.9). The second highest item referred to the historical setting of science and particularly to biographical sketches of famous scientists. Its mean was 1.4 (SD 0.8). There was less emphasis placed on ethical issues or controversies associated with science and technology. This area received the lowest average score, although it was still above the low level; 1.2 (SD 1.0). Modal scores of "2" were typical of the contents of this category, with percentage at mode between 37.5-50.0.

"Technical and Engineering Science" was difficult to evaluate at this grade level since its contents were not representative of lower secondary science programs per se in the United States. Topical categories under this heading reflected a vocational orientation common to systems that differentiate students after elementary school. or before the 10th grade. The three main areas, "Vehicles," "Manufacturing Processes," and "Microprocessors and Computers" are taught in this country in vocational trade schools, high school physics, or computer science courses. In reviewing the ratings, from this section particularly, care should be taken to avoid misinterpretations. Content covered by "Vehicles" included engines (internal combustion, steam, electric motors, gears, and mechanics in general), the study of aerodymanics, and other mechanical modes of transportation. It had a mean of 1.4 (SD 0.7), which reflected the scores attained in Physics for this population. "Manufacturing Processes" included the industrial procedures for making or processing food, plastics, paper, clothing, and steel, etc. The mean for this topical listing was 1.0 (SD 0.7) and more likely reflected what would be taught in Home Economics, or to a lesser degree, Chemistry, in this country. It might be recalled that for this population, Chemistry had an overall mean of 1.3.

"Microprocessors and Computers" was a subcategory of Technical and Engineering Science that described the range of activities usually covered in computer science programs. When this survey was taken, programmatic designs varied widely from school to school in both content and contact hours. The mean score of the core item was 0.9 (SD 0.9). It was not possible to differentiate between computer software planned for use in science curricula and software for use in other types of instruction related to computer use. Neither was it possible to identify the prime use of software (i.e.) drill, enrichment, evaluation, recording data, word processing, etc.). The ratings for Population 2, as well as those for Population 1 and Population 3/3N should therefore be regarded as conservative estimates of a broadly described area of curricula.

In the period of time that has passed since the survey was made, states have written computer literacy guidelines into their requirements for high school graduation. The rapid changes in this field are apparent from the increase in the number of schools using computers in the early part of the 1980s...in the school year 1982-1983, 42% of elementary schools and 77% of all secondary schools had microprocessors available for students. Their numbers had tripled since the fall of 1980.[7] The need to develop well-articulated computer programs in both elementary and secondary schools has become a necessity.

The national item added to this category (Technical and Engineering Science) represented topical matter in science curricula that conveyed the relation between science and technology. The rating of 0.8 (SD 0.8) indicated that curricula describing affinities between science and technology were sporadically "covered" at low levels, although specific information regarding the subject matter per se was not determined.

"Rural Science" received the lowest coverage of all new, or "Other Science" categories. The probable causes for this have been discussed in the section of results for Population 1. Additionally, the schools that include curricula of this nature (vocational and those in rural communities), comprised a relatively small portion of this sampling. The mean for the category was unique in this analysis because it remained virtually unchanged for all populations. The average score for six topical items was 0.4 (SD 0.1).

When the ranges of the coefficients of variation were compared in this grid, the content which exhibited the smallest variation was "Environmental Science." Coefficients of variation were between 0.4-0.6. "History and Philosophy" followed with coefficients of variation that were between 0.4-0.9. "Technology and Engineering Science," and "Health Science" were somewhat similar, with spreads of 0.5-1.0 and 0.5-1.2. The only category with relatively large CVs throughout all topics (1.3-2.0) was "Rural Science." With the exception of this last grouping, coefficients of variation were generally smaller than those obtained for Population 2 in traditional science.

Population 2 (Grade 9)- Instructional Objectives

The pattern of emphasis within the Process Grid closely resembled that for Population 1. The most highly rated areas were in practical skills, basic science skills of measurement and observation and the cognitive domain of knowledge and comprehension. The overall means of these three categories were above the moderate level; 2.4 (SD 0.1), 2.3 (SD 0.3), and 2.2 (SD 0.5). The means may be somewhat misleading however, in that they mask the nature of the individual scores obtained within these process categories. Additionally, because the mean scores of the three separate objectives were substantially so close, it seems more appropriate to examine the results in terms of the pattern of individual items within each section.

Although the mean rating was highest for laboratory-related manual skills, the highest mean scores for individual items of the grid were in the knowledge and comprehension block, a situation common to most curricula propulations. Specifically, rating averages of 2.9 and 2.8 were achieved for "knowledge of specific facts" and "knowledge of scientific terminology" at the ninth grade level. One conclusion to be drawn from these data is that, although there is a slight bias in favor of designing science curricula to emphasize practical science skills over the acquisition of science knowledge, learning science is still heavily dependent upon the ability to recall specific pieces of information. The modal score of "3" for knowledge of facts was almost unanimously agreed upon by 89.5% of the raters; the percent at mode for scientific terminology was also unusually high--78.9%.

The third and fourth most highly rated single items were for "observation of objects and phenomena" and "measurement of objects and changes," which were located in the block for Scientific Inquiry I: Observation and Measuring. These received averages of 2.7 (SD 0.6) and 2.5 (SD 0.6). Modal scores were both "3" and percent at mode was considerably above the norm, 78.9% and 57.9%. Again, the predicament of making general statements about the whole versus its parts presented itself. As a category, Science Inquiry I ranked second to Manual Skills; the items in the latter domain, however, elicited lower individual means than the four items mentioned above. Perhaps the most appropriate comment regarding the relative importance of knowledge versus practical skills at the lower secondary level is that they seem to be of almost equal value in planned science curricula.

Although the nature of the next objective was somewhat different, the emphasis of positive attitudes and interests in science curricula was ranked fourth highest overall in this grid. Individual item means in the domain were distributed within 0.3 points of each other. The grand mean was 2.0 (SD 0.1).

The investigative skills which are most commonly associated with science inquiry are discussed together in this section since their ratings reflected a pattern similar to that for Population 1. Sections C-F of this grid classified increasingly higher level intellectual skills required in conducting research (structured, planned, controlled) experiments. Science Inquiry II (defining problems and problem solving) and Science Inquiry III (interpreting data and generalizing) had overall means which only differed by 0.1. Science Inquiry III was higher, with a mean of 1.6 (SD 0.1); Science Inquiry II was emphasized at 1.5 (SD 0.3). These signified coverage midway between low and moderate. Cognitive processes involved in Science Inquiry IV (building and revising theory) and Applications (applying science knowledge) received the lowest overall ratings within the grid for this population. S.I. IV had an overall rating of 1.1 (SD 0.2) and Applications averaged 1.0 (SD 0.2). Again, the pattern of emphasis indicated that United States science programs did not place great stress on higher inquiry skills at the lower secondary level.

The section labelled "Orientation" received an average score of 1.3, SD 0.1. It may be recalled that this section described relationships or characteristics of science in a social, historical, and philosophical perspective. One drawback of this section is that its contents reflected diverse aspects of science curricula that were more appropriate to evaluate within the applied integrated curricula grid. This factor may have had some bearing on the generally depressed scores it displayed.

When the mean scores of all grids were compared for Population 2, the Instructional Objectives ranked highest; its domain averages also had the lowest coefficients of variation indicating greatest rater agreement in scores for this grid. One interpretation of these results might be phrased as a hypothesis: "At Grade 9, the learning and using of specific science processes are perceived in this Nation to be more important than the learning of specific science contents." It is possible that more emphasis is now being placed on learning specific science processes.

Population 3/3N (Grade 12) - Traditional Science Content

In order to provide some insight into the rating results at this level, it is important to reiterate the differences between the five groups which were evaluated at the final year of secondary school. Therefore, a brief explanation of the main population and sub-populations is provided below. A fuller description, with the background factors that explain the rationale for selection of these clusters, was discussed in Chapter II.

Population 3 is composed of all final-year secondary school students. In the United States, the[8] majority of seniors, about 66%, are not taking any science coursework. This group was designated 3N. Of the minority of seniors who are taking science, four different groups were identified: 3E (Earth Science), 3B (Biology), 3C (Chemistry), and 3P (Physics).

The science curricula ratings for each of these were determined by the following criteria. For Population 3/3N, (all seniors, including those currently studying science and those who are not), the raters were asked to base ratings on the last general or integrated science curricula taken by the majority of students. Most typically in the United States, this was 9th grade science. Less commonly, it might have been an 8th or 10th grade science program. Most raters identified the science program as 9th grade general or physical science and 10th grade biology or general science for both academic and non-academic students. The mean scores, therefore, most heavily reflect the content coverage of these courses.

The ratings from these terminal science courses were used to help determine the level of science literacy that is achieved within each country. Based upon the ratings received from the member nations, test items for Population 3/3N were designed to reflect the "residual" science outputs of the global system of secondary education. The general, non-specialized population was evaluated on this last level of general applied/integrated science.

For the remaining four groups, ratings were based upon the curricula contents of the specialized science being taught students in the 12th grade. Most often, in the United States, scores were based upon the first year curricula of that science.

Because of the partial overlap of content assessed at the Population 2 and Population 3/3N levels, the increased coverage from grade 9 to grade 12 was not as great as one might first anticipate. The domain which achieved the highest ratings was Biology, which had a mean of 2.1 (SD 0.2) for all items; Earth Science, Chemistry and Physics had grand means that were within 0.1 points of each other. They were 1.7 (SD 0.3) for Earth Science; 1.6 (SD 0.2) for Chemistry; and 1.6 (SD 0.4) for Physics.

It may be recalled that the highest ratings for the previous populations had been in Earth Science. The fact that Biology ranked highest in Population 3/3N was likely due to the content of science in the "last year of science taken by the majority of students." One strong possibility is that the general science taught at this point contains a high concentration of Biology topics or _is_, in fact, a biology course for general students. Of the 17 items listed in this domain for this population, 14, or 83.4% achieved means at the moderate level or higher. This percentage distribution of moderately high scores within one branch science was atypical for the main target populations. Ten items of a total of seventeen had modal scores of "3" with modal percentages that ranged between 42.9% and 64.3%. The majority of ratings were dispersed above moderate in coverage. The few which fell below this level for this population appeared in a block and had identical means of 1.7. The specific items were related to natural groups and their segregation, population genetics and evolution. Based upon our analysis, it appeared that relative to other contents normally included in biology, these topics were emphasized less other areas in final science programs for Population 3/3N. It is also probable that some raters based their evaluations on the first year of general biology curricula since, at the time of this survey, most states required one science for high school graduation. The majority of students would be expected to have studied this subject although it is not, in theory, considered an integrated or general science course in this nation.

Earth Science topics for the most part received individual mean scores that were distributed between 1[illegible] and 1.9. Only two of eight items received mean scores above this level. These dealt with the Solar System and physical geography; their means and standard deviations were 2.2 (SD 1.1) and 2.0 (SD 1.1). Two national option items were added to the grid for this population and their means were comparable to the ones received for core items.

The domains of Chemistry and Physics both received overall averages of 1.6 (SD 0.2) and 1.6 (SD 0.4). Only one item in Chemistry was rated above moderate in coverage. When compared with coverage of topics at Population 2 and Population 1, there was a greater pattern of uniformity in Chemistry curricula and less discrepancy between the most heavily emphasized and the least emphasized items. The most common modal score was "2" which was representative of 40% of the items. Modal percentages varied between 35.7% through 50.0%. No national options were added for this main group in this domain. The contents under Physics had a wider spread of individual mean scores than Chemistry, although the grand means were both the same. The range was 0.9-2.4, or from low through moderately high. Three topics received ratings at or above the moderate level: Measurement, 2.4 (SD 1.0); Energy, 2.2 (SD 1.1); and Vibrations and Sound, 2.0 (SD 1.0). The lowest ratings were reserved for topics dealing with Electronics (i.e. television, etc.) and Theoretical Physics. One unexpected result regarding this population emerged when cross-population scores were examined in Physics for each content item. The national item dealing with nuclear weapons and their control was covered at the highest level by the 3/3N population. Although the absolute value of the mean score was low, (1.1, SD 0.9), compared with the other groups at the upper secondary level, it was notable. The population which most closely approximated this score was 3P, with a mean rating of 0.9 (SD 0.9) given to the item. All other sub-groups had averages at or below 0.6. An item that might be somewhat related to this topic appeared in the roster for applied/integrated science content as national item 3b - "Controversies Associated with Science and Technology." Its mean rating in 3/3N was 1.4 (SD 1.1).

When one examines the relative dispersion of scores about the means in the items within the traditional content domains for 3/3N, the science which had the lowest set of coefficients of variation was Biology, followed by Chemistry, Earth Science, and Physics. The ranges for each set were as follows: Biology (CV 0.3-0.6); Chemistry (CV 0.4-0.9); Earth Science (CV 0.5-1.0); Physics (CV 0.4-1.3). The implication of these scores is that the greatest uniformity for coverage of topics in science curricula exists in the domain of Biology for this population; topics under Physics, on the other hand, seem to display more variation in the degree to which separate contents are emphasized, or covered, in the intended curricula. The contents of Chemistry and Earth Science are planned with degrees of uniformity that lie between the two extremes.

Population 3/3N (Grade 12) - Applied/Integrated Science

Population 3/3N was the last population group for which coverage of applied/integrated science curricula was measured. As we had noted previously, the four other 12th grade populations were groups that specialized in a given science curricula. Content in traditional science is almost completely reflective of the discipline. The decision was therefore made to confine this secondary content grid analysis to the main populations.

When compared to the results of Population 1 and Population 2, there was a levelling off in the trend toward increased coverage of topics in this population. One of the main reasons for this is likely due to the similarities in curricula rated for Populations 2 and 3/3N. In some cases, ratings of curricula contents were identical, since, at the time of this evaluation, the ninth grade was the last year cited by some raters that the bulk of graduating seniors in the district were required to take science.

The pattern of coverage established by grades 5 and 9 for this grid was repeated by 3/3N with one minor exception. As was the case with the younger groups, "Environmental Science" received the highest overall average 1.9 (SD 0.2). This represented a slight increase over the rating average obtained for Population 2. The increase in mean score between the youngest and middle populations was 0.3; between the middle and oldest populations was 0.1. The topics which received highest individual mean scores (above 2.0) were in energy resources, conservation, and natural and man-made causes of pollution. The means for these areas were: Energy Issues, 2.1 (SD 0.7); Conservation, 2.1 (SD 0.9); and Pollution, 2.0 (SD 0.7). "Conservation" received a modal score of "3," while all other items in this section received modal scores of "2."

The second highest domain mean was 1.6 (SD 0.5), in the field of "History and Philosophy of Science." This ranking was a departure set by the patterns of coverage at the lower populations where "Health Science" ranked second highest in overall means. For 3/3N "Health" ranked third, with an overall mean of 1.5. However, the difference between these domains at 3/3N was so slight that no clear pattern emerged regarding relative position strength. It is more likely that the two fields have approximately the same level of emphasis in this population. The single item under "History and Philosophy" that received a modal score of "3" pertained to the "Nature of Science" (i.e. stages of the scientific method). Modal percent was 50.0. The placement of this particular item in applied/integrated science, rather than with process/attitudes may have influenced the score given by raters. The placement of the item was determined by SISS prior to the assessment however, and the option to change item locus was decided against at the national level for reasons related to the nature of cross-national studies.

."Technical and Engineering Science" received an overall rating mean of 1.2 (SD 0.1), which showed a slight increase (0.2) from the lower secondary population (grade 9). The topics rated most highly were related to 1) engines, motors, vehicles and 2) relationships between technology and science; means for both items was 1.3; modal scores were similar, at "2."

Topics related to computers and software received a mean of 1.2 (SD 0.9). Compared to the same content at the Population 2 level, this represented an increase in coverage of 0.3. This relatively small increase between groups again likely reflected the similarity in content assessed at both populations.

"Rural Science" received the lowest coverage ratings across all domains. This was similar to the results of the other groups as well. The mean for Population 3/3N was 0.5 (SD 0.1) as opposed to 0.4 mean for the 5th and 9th grade level; the elevation of coverage was so slight that no conclusions were drawn about increases from the data.

The values and range of the coefficients of variation were smallest for "Environmental Science" (0.3-0.5) and grew increasingly greater and/or wider for "History and Philosophy" (0.4-0.9), "Technical and Engineering" (0.7-0.9), "Health" (0.4-1.6), and "Rural Science" (1.3-1.8). These results indicate that the curricula for "Environmental Science" are more uniform in coverage of topics than the other applied science domains. "Rural Science" topics showed the largest variation. The remaining three held positions between these extremes. In this context, a somewhat similar result was observed for Population 2 in this grid.

Population 3/3N (Grade 12) - Instructional Objectives

The ratings for instructional objectives in Population 3/3N showed the greatest gain of the three grids when compared to Population 2 ratings. The average gain was 0.3 points for nine different domains.

The pattern of relative highs and lows formed by the means at the lower grade levels was repeated at 3/3N. The four most emphasized objectives were, in order of descending means, "Manual Laboratory Skills" (2.6, SD 0.1), "Science Inquiry I" (2.5, SD 0.3), "Knowledge and Comprehension" (2.3, SD 0.4), and "Attitudes" (2.2, SD 0.2). It should be noted that these means [illegible] levels of absolute coverage that are in the moderately high range. This was exceptional since ratings of this magnitude did not appear across any other main population in any domain. Higher ratings were generally restricted to the specialized science sub-groups.

There were relatively large gains observed between Population 2 and 3/3N on intermediate level inquiry skills, such as problem seeking, experiment designing, data interpreting, interpolating, extrapolating, and generalizing conclusions (Science Inquiry II and III). These two domains obtained means of 2.1 (SD 0.2) and 2.0 (SD 0.1). The remainder of the process skills, those involved in retesting theoretical constructs and applying learned information to different situations, received the lowest average ratings on the grid for Population 3/3N. These were 1.4 (SD 0.2) and 1.5 (SD 0.3). Topics under "Orientation had an overall mean of 1.7 (SD 0.1). Again, the same "valleys" were also observed in all seven population groups, lending credence to the theory that with relatively few exceptions, the intended agenda in laboratory experiences does not encourage American students to think divergently about science phenomena. "Doing science" has the same connotation as "hands-on" activities. There appears to be some evidence of student-centered projects, but the emphasis is more upon "rebuilding Hoover Dam" than revising, refining, or designing a different model.

The elevations in coverage of the process/attitude grid was an unanticipated outcome of this survey. Reasons for this occurrence can only be speculated upon, since raters did not uniformly identify the actual last grade or course title they had assessed for 3/3N.

One possible scenario is that some schools evaluated in this last main population group retain facsimiles of general or integrated science programs in senior high school, most likely at the 10th or 11th grade levels. In such cases, one would reasonably expect a heavier emphasis placed on elements of process skills due to maturation of the age cohorts.

A second possibility was raised earlier in context with the ratings from the traditional science grid. It may be recalled that the rating mean increase for Biology was notably greater than for the other three traditional domains when compared to Population 2. The effect of this infusion of biological content into the curricula may be linked with attendant process skills being emphasized as well.

Finally, in a de-centralized system such as in the United States, characteristics of science programs vary, even at the same grade level. By selecting a broad enough sampling, these differences hopefully balance out to give a fairly representative picture of overall conditions. However, the chance that a distribution may be unintentionally skewed in a given direction does exist. The raters who evaluated Population 3/3N were asked to judge the coverage of topics; they were not asked to rate a given grade, or a given course of studies, but the curricula of the last grade that the majority of upper secondary students had taken science. It is reasonable to assume that there was variation in the courses assessed as well as the grade, even though the modal grade was grade nine. The unexpected findings in the process areas may be attributed to the singular nature and set of circumstances upon which the 3/3N national ratings were made.

Specialized Populations Studying Traditional Science
(3E, 3B, 3C, 3P)

To evaluate science curricula in the traditional sciences planned for the last year of secondary school, four sub-population groups were targeted in the international analysis. For some nations in the study, students who specialize in science in secondary school are specifically "tracked" to learn content related to professional fields of endeavor, such as engineering, technology, and allied areas in science. In the United States, the students most likely to study a traditional science in the last year of high school are those who intend to continue their education in a two or four year college. For this reason, as well as those that deal with the specific characteristics of national systems of education, students at this level are not truly comparable across nations.

Enrollment figures for 1981-82 indicated that Chemistry and Physics account for only 7% and 12% of the total 12th grade enrollment; Biology and Earth Science together accounted for 4% at this final year.[9] Most of the students who take science elect Physics in the senior year.

Because of the small percentages of students studying science at the end of secondary school in this country, it was necessary to revise the criteria set for awarding points denoting high, moderate, and low coverage to curricula topics. In place of considering both the "universality" and "emphasis" dimensions for coverage, where universality indicated the percentage of students involved in the study of intended curricula (75%-100%=high, 25%-75%=low-to-moderate, 0%-25%=nil-to-low), it was necessary to base ratings directly on the "emphasis" component, which was determined by the numbers of classroom hours planned for the teaching of the separate items listed under content and processes. More than three hours per year indicated "high"; between two and three hours, "moderate"; less than two hours, "low." A rating of 0 indicated that the material was not included in the curricula. Although ratings were obtained for these sub-groups that convey the relative degree of content emphasis in the "spirit" for which they were intended, it should be noted that the ratings obtained for Populations 3E, 3B, 3C, and 3P are not absolutely equivalent to the ratings for the main populations. However, it may be stated with a fair degree of certainty that the ratings are comparable, since the prior scores were based upon populations of students that were close to 100% of school enrollment. The determination of ratings was thus heavily dependent upon the emphasis component of the curricula in both situations.

The ratings given to each of the four sub-groups in the traditional sciences were mostly confined to the domain of specialization; therefore, the ratings in the remaining three science branches often were "0." Exceptions were limited to those instances in which content in the international grid reflected a different organization from that of traditional science curricula in the United States. For example, item #37 under the domain of Chemistry, referred to "Biochemical Reactions--respiration, fermentation, photosynthesis, transport of O_2/CO_2 by hemoglobin. Enzymes--structure and properties." These contents rarely are planned for significant inclusion in traditional United States Chemistry programs, but are, most often, a part of Biology curricula. The ratings for Population 3B might thus be higher in the domain of Chemistry than one would anticipate due to the presence of items such as these.

Population 3E, the sub-population studying Earth Science in the last year of secondary school, received an overall mean of 2.0 (SD 0.3) for topics under Earth Science. Of a total of 8 items, 5 achieved means at or above 2.0. The highest ratings were given to 3 separate content areas. These were, in descending order of means, meteorology (2.4, SD 1.1), the constitution of the Earth (2.3, SD 1.1), and physical geography (2.3, SD 1.1). Following these were the Solar System (2.1, SD 1.3) and stellar systems (2.0, SD 1.3). Although no topic was rated at a "low" level for coverage, the lowest scores of the domain were accorded to Soil Science (1.5, SD 1.0).

When compared to other domain sciences, the mean rating of Earth Science curricula was the lowest for overall topics. There are at least two possibilities that may account for this. One is that Earth Science is the "newest" of the traditional sciences to be taught in upper secondary school. In prior decades, its contents had been commonly taught in elementary and middle-junior high science programs in this country or not at all. Although this situation changed somewhat in the 1980s, it is still considered a "first science" to be learned at the upper grade levels. As such, the contents within the domain in school programs may be less uniform than the contents of other traditional branches. For example, some of the contents of the applied science grid under "Environmental" and "Rural" sciences may be included as Earth Science in some parts of the country. If this is indeed the case, overall ratings might have been higher had the "Other Science Grid" been included for evaluation in this domain. A second contributing factor might relate to the actual roster of contents under Earth Science developed and used by SISS. There were, in hindsight, some areas entirely omitted from the international grid which presented a less-than-complete picture of Earth Science according to some state guidelines. Some of these areas included map reading, oceans and shorelines, and geologic events (descriptions of relative developmental changes in the Earth's lifetime). Although it can be argued that these topics were contained under given roster headings, it is now quite clear that such broadly defined headings yielded less information than a more complete listing of subject content.

As anticipated, the mean ratings of Population 3E were close to zero for topical coverage in the other traditional domains. The grand means were: Biology (0.3, SD 0.2), Chemistry (0.4, SD 0.1), Physics (0.4, SD 0.2). One single item listed under Physics content received a mean score of 1.0. This item dealt with measurement and errors of measurement, significant figures, and estimations.

Comparison of coefficients of variation for 3E, 3B, 3C, and 3P ratings revealed the largest CVs for Earth Science, indicating that there is more variation in the planned curricula contents of Earth Science than in any other traditional science at the upper secondary level in the United States. Content items in Biology had the smallest CVs. Based upon this data, it is likely that the most uniform content is found in the Biology curricula of the year-long, traditional science programs at the upper secondary level.

The mean score for Population 3B in Biology was 2.7 (SD 0.2). This was the highest grand mean in traditional science curricula across all populations. All 17 items listed under this domain had modal scores of "3"; percentage at mode varied between 47.1 to 93.7. These percent figures represented unusually high levels of rater agreement when compared to other sets of ratings.

Overall means obtained by 3B in the other traditional domains were: Earth Science (0.2, SD 0.1), Chemistry (0.7, SD 0.3), Physics (0.3, SD 0.2). To some degree, aspects of chemistry are covered in the biology curriculum at the upper secondary level. The ratings in Chemistry, although still low, were higher for this population than for any other outside-the-subject domain mean. Three topics received mean scores between 1.1-1.5. They dealt with concepts of introductory chemistry, chemical processes' and chemistry of life processes. In biological science, these contents focus on respiration, digestion, photosynthesis, enzyme activity, and the organic constituents in DNA, RNA, cells, nerve or muscle activity, among other topics.

Rating means for Population 3C resulted in the following breakdown per science domain: Chemistry - 2.4 (SD 0.5), Physics - 0.5 (SD 0.4), Earth Science 0.3 (SD 0.1), Biology 0.2 (SD 0.1). All but one item in Chemistry received modal scores of "3", with modal percentages varying between 56.3 and 93.8. Three topical means in Chemistry were below moderate in coverage. These areas are more often found in applied or integrated science programs or in a different branch of traditional science. These referred to industrial and environmental chemistry and biochemical processes of life.

Examination of the other science domains revealed that four items categorized under Physics achieved averages above 1.0: Measurement, M = 1.1 (SD 1.4); States of Energy, M = 1.1 (SD 1.3); Changes of State, M=1.4 (SD 1.4); Kinetic Theory M = 1.3 (SD 1.4). The large standard deviations for this group indicated the variation in ratings within each of these separate contents. It was hypothesized that the variation in scores partially resulted from raters who misinterpreted the instructions to score other science domains in addition to the contents of the specialized science. In some instances, all branches but that which the population was to study were rated "nil" for coverage. When these were averaged in with just a small proportion of numerical scores, a larger than "typical" standard deviation was obtained.

The last specialized population evaluated for coverage in traditional science was 3P. This group attained an overall mean of 2.2 (SD 0.5). Topics which fell below a moderate level were: hydrodynamics, polarization of waves, electrostatic generators, electronics, and atomic, molecular and theoretical physics.

Of the 28 items listed under Physics, 21 received modal scores of "3"; modal percentages varied between 38.9 and 88.9. No topics in the other traditional domains were covered at any notable level. The means of the other science domains for 3P were: Earth Science 0.3 (SD 0.2); Biology 0.2 (SD 0.1); Chemistry 0.3 (SD 0.3). These ratings were typical of the values obtained by other specialized populations outside their own subject science.

Specialized Populations in Science - Instructional Objectives

Seven of nine categories on the Process/Attitude Grid referred to the practical and cognitive skills used to learn science. The remaining two areas described attitudes and perceptions towards science that are desirable in science curricula.

Since the four sub-populations achieved like means in the process areas of this grid, this summary of results will not focus on individual population groups, as in the preceding discussions. Instead, we will concentrate on the general patterns of coverage set within each process area by all four groups. The order in which the process areas are discussed generally reflect their rank order, by mean coverage, achieved by the special science populations.

The categories which depicted practical skills used in science (Manual Skills), the cognitive processes termed "Knowledge" and "Comprehension" by Benjamin Bloom and the inquiry-related skills of observation and measurement (Science Inquiry I) obtained the highest scores on the grid.

The sciences that, by convention, stress laboratory experiences in the curricula ranked "Manual Skills" higher than any other grid component. These were 3B (M 2.7, SD 0.1), 3C (M 2.8, SD 0.1), and 3P (M 2.8, SD 0.1). It should also be noted that the physical science groups placed greater emphasis upon Sections G, A, and B of the process objectives than on the subject contents of curricula. Thus, for 3E, 3C, and 3P, the means of these areas of the process grids are higher than the means achieved on the traditional science content grid.

From the results of this study, it appears that there is currently great emphasis placed upon the acquisition of scientific facts, terminology, and concepts in the intended curricula. These areas of Section A received uniformly high scores across _all_ populations and were among the most highly rated individual items of the analysis. The emphasis diminished, however, as the level of knowledge grew more abstract. Thus, the items related to "identification (recognition)...in a new context," or "translating...symbolic forms of knowledge to other symbolic forms" had means that were almost one integer less than the memory-dependent items associated with knowledge gain. 3E, 3B, 3C, and 3P had mean ratings for Knowledge and Comprehension (11 items) of 2.3 (SD 0.4), 2.3 (SD 0.4), 2.6 (SD 0.3), and 2.5 (SD 0.3).

The practice of empiricism in science involves utilizing replicable procedures in the laboratory. The basic inquiry skills of observing and measuring are closely tied to the practice of manual dexterity and laboratory technique required in most scientific investigations. The process domain describing the former science objectives in curricula (Science Inquiry I) was ranked highest by Population 3C--2.6 (SD 0.2), followed by 3P--2.4 (SD 0.3), and 3E--2.4 (SD 0.2); 3B averaged 2.3 (SD 0.5).

True "inquiry" investigations require one to recognize and identify problems, design and conduct appropriate experiments (Science Inquiry II), and finally, process and interpret the experimental data in a meaningful, scientific manner (Science Inquiry III). These science processes primarily engage four operational stages of Bloom's taxonomy: Application and Analysis, Synthesis, Evaluation. Here, the mean scores for the specialized sciences began to taper off towards the moderate end. 3E and 3B had lower scores than 3C and 3P. In all groups, the lowest item average in Science Inquiry II was for "Design of appropriate procedures for performing experiments"; in Science Inquiry III, it was, "Evaluation of a hypothesis under test in the light of data obtained." Compared to other items in the two process domains, these described the more thought-challenging aspects of scientific investigations. The means for Science Inquiry II were: 3E, 1.8 (SD 0.3); 3B, 1.9 (SD 0.2); 3C, 2.1 (SD 0.3); 3P, 2.1 (SD 0.2). In Science Inquiry III, they were: 3E, 2.0 (SD 0.2), 3B, 2.0 (SD 0.2); 3C, 2.3 (SD 0.3); 3P 2.2 (SD 0.3).

The highest level of intellectual activity in inquiry deals with the creation, testing, and revision of original constructs or hypotheses in science (Science Inquiry IV), and the application of science (knowledge and process) to other circumstances (Bloom's application, evaluation and synthesis). In these realms of creative thinking the specialized science groups exhibited the lowest averages of the grid. Mean scores for 3E and 3B dropped to levels that were not appreciably different from those of 3/3N. The remaining two groups of physical science had slightly higher ratings overall in these process domains; their scores however, were only slightly above those for 3/3N. The mean ratings for Science Inquiry IV (Building and Revising Theory) were as follows: 3E, 1.2 (SD 0.3); 3B, 1.3 (SD 0.3); 3C, 1.5 (SD 0.3); 3P, 1.5 (SD 0.3). "Application" had the following mean scores: 3E 1.1 (SD 0.2); 3B 1.4 (SD 0.3); 3C 1.4 (0.2); 3P 1.5 (SD 0.5).

Ratings in the Process Grid also included indices of desirable science attitudes and interests promoted in curricula and indices of the degree curricula nurture awareness of implications of science in society, history, philosophy, and other realms. The average ratings of "Attitudes/Interests" across the four specialized science groups fell into the moderate range. The fact that this overall level was achieved attests to some conscious attempts of curriculum developers to make traditional science a positive, constructive, reflective experience and a desirable career choice for some with special talents. The means of the specialized science populations were as follows: 3E, 2.0 (SD 0.1); 3B, 2.3 (SD 0.2); 3C, 2.2 (SD 0.2); 3P, 2.2 (SD 0.1).

The areas related to Section I, "Orientation," fell considerably below moderate in coverage. Population 3E exhibited the lowest average 1.2 (SD 0.1), while 3B and 3P both had means of 1.5 (SD (B) 0.3, SD (P) 0.2) and 3C achieved the highest overall score of the group, 1.7 (SD 0.3). It was interesting to note that the special population ratings were lower than the 3/3N ratings in this section. One possible explanation for this is that the contents described curricular issues outside the realm of "pure" science.

As cited earlier in this report, items in the "Orientation" category did not typify the nature of this third roster, which dealt with cognitive and practical science processes and attitudes. Instead, it described a heuristic view of science that became a part of the collective educational consciousness of the 1970s; we felt it would have been more appropriate to the secondary content roster. Since it was formatted under the Process/Attitude Grid, we have kept the ratings in this section to maintain consistency, but a comparison between its ratings and those of Section 1 (History and Philosophy...), "Other Science Content" would offer a more complete picture of this area of curricula.

Characteristics of Science Curricula in the United States

The decentralized structure of education in this Nation is one of its most entrenched strengths; it is also, upon occasion, the bane of descriptive studies that endeavor to distill local scenarios into a fair depiction of national characteristics. In the attempt to delineate the state of science curricula in the United States, we encountered numerous exceptions that exist for every generalization that could be made. On the other hand, by selecting just the prevailing conditions, the predicament arose of contributing nothing of significance to what was already known.

The conclusions in this section were determined by the survey results of the curriculum analysis; yet, it must be realized that some statements will reflect conundrums of the type just depicted.

An evaluation of the data yielded some anticipated outcomes as well as others which were less expected. In general, coverage of science content and utilization of science-related skills in planned curricula increased with age. Other seemingly obvious factors related to age progression: the proportion of chemistry and physics content in general science curricula increased from elementary to high school; contents of subject matter and objectives in science across the nation grew more uniform from the lower to higher grade levels.

What was less anticipated was the impact of the relatively new areas of curricula (applied/integrated science) in the planned science experiences of all main populations. The expectation was to find the greatest emphasis of applied or integrated material in the primary years, when, in fact, the ratio between the coverage of traditional science to "other" science contents remains almost constant across all grade levels. Of the five defined areas, the environmental section ranked highest nationally in science program inclusion; its contents were covered (in classroom hours) about equally with the traditional sciences; in fact, in most instances, there was greater emphasis placed upon this subject area than there was in most of the physical sciences in populations 1, 2, and 3/3N.

The coverage of science skills in the curricula was also somewhat surprising. When compared to subject matter in both the traditional and applied or integrated areas, greater relative importance was placed on fundamental cognitive, practical and investigative science skills (Knowledge and Comprehension, Observing and Measuring, and Manual Skills) in the Instructional Objectives Grid than on inclusion of explicit science content. This dictum applied to most science curricula, whether they were designed for general students or for the more academically oriented, who elected science in their final year of high school. The disparity in emphasis between these components of curricula was greatest for the 9th grade; followed by the 5th, and finally, the 12th grade. The relationships changed when mean scores for all seven process-skill categories were combined into one grand mean for process coverage, rather than clustered into sub-groups as they were above. When grand means were compared between Science Content (traditional disciplines averaged together) and Process Skills (all cognitive, practical, and inquiry skills, averaged together) at each population, Populations 2 and 3/3N had higher emphasis in Processes, Population 1 had almost equal emphasis in Process and Science Content, and Populations 3E, 3B, 3C, and 3P all placed greater emphasis on Science Content. The articulation of the basic curricula components, science information with science-related aptitudes, has apparently experienced a subtle readjustment. Whereas the priorities of a decade or two ago were on nurturing science-related abilities (skills) in the classroom, the picture of science curricula in the 1980s is one of greater parity between learning both the subject matter of science and the competencies that go into learning via doing science.

The inquiry approach in science has indeed left some residual imprints in the traditional science of secondary school, where, twenty years ago, it was first introduced. The students between elementary and high school, however, seem to be the main heirs of the learning modes from that era, while grade school children are presented with a wider variety of both content and skills, together.

One important distinction should be noted regarding the nature of the process skills being emphasized. The projects developed through NSF sponsorship often focused on higher level critical thinking tasks, comparable to those in the formal operational block described by Jean Piaget. A deliberate effort was made to present science in broadly conceptual, universal, and consequently more abstract light. Students were encouraged to use their senses to appraise, infer, generalize and formulate constructs (hypothesize) in the laboratory, and experiments were structured to be open-ended rather than conclusive and "neat." These characteristics of NSF inquiry-based program objectives underscore the important similarities and differences between past and present aims in science curricula. The areas of process which are most prominent in the 1980s are rooted in more elementary types of science ability, such as recognizing, identifying, classifying, summarizing, or processing information from a limited field of data. The higher level skills of science investigation and science research are frequently contained in second-year programs of traditional science, but the overwhelming majority of American students do not participate in these special elective courses.

The ratings for some areas of curricula content reflected too much ambiguity to quantify or summarize neatly. Three examples were in the applied science domains and concerned vital areas of new curricula: technological and societal issues in science; moral implications in and of science research; the impact of science related software in planned science programs. Although some insight was gained through this analysis regarding their coverage, little was determined regarding the actual contents within each of these broadly defined categories. Some future attempts should be directed toward clarifying their status in American science programs.

Future research might likewise include studies comparing the different stages of curricula--Intended, Translated and Achieved--to examine curricula factors that correlate with student performance. Process-related questions in SISS test instruments may be directly matched to rating scores of specific skills at each population, for example, or patterns of student performance levels from the first and second international assessments and the processes emphasized in curricula of the 1980s could provide us with benchmarks for strategies in curricular design for the future. Perhaps patterns of achievement might be examined in different national populations, to determine the effect of differentially planned emphasis, or clusters of high or low curricula coverage between industrialized nations might be compared with their national objectives in science education. We may be able to identify factors different from, or in addition to, those we already recognize as important correlates of science performance.

This nation has undergone some dramatic social, economic, and political changes in the past decade and a half since the last international science evaluation. During this time, our educational system has also experienced some upheavals, from student-staged uprisings to retracting, then reinstating, more rigorous requirements for high school graduation. It's business as usual for America. Establishment practices have always followed in the paths breached by visionaries from different sectors of our society.

Science education of the late 1960s and 1970s stressed the understanding of science through student interaction with the objectives and methods of scientific inquiry, whereas descriptive lessons based on "known" phenomena (observations of factual science) reflected the organization of pre-Sputnik instructional programs in America. The thrust in curriculum development was directed towards organizing science into conceptual frameworks in lieu of uniform descriptive topics, and emphasis was on the quantitative examination of these unifying themes through investigative applications of scientific methods. Technology was viewed at that time as the practical application of science to societal problems.[10]

By way of contrast, the objectives of curriculum in the 1980s place greater emphasis on preparing students to function adequately in an increasingly technological society. This requires learning science as a means to gaining personal insight, as opposed to learning science as a replica of the discipline itself. Scientific literacy is advocated so that technological and social progress will be shaped by logical arguments and decided by informed, thinking individuals in the community. The tendency is to attempt to introduce more "applied" areas of content into core science programs, particularly for the general student population, so that the interaction of research, technology, society, and the ramifications of this interaction, may be studied along with relevant curriculum in the branch sciences.[11]

Now, as in the past, educators are reflecting upon the changes that must be made to address new goals. A "back to basics" movement heralds the return to different standards, "core" programs in secondary schools, stringent course requirements, and minimum competency assessments at several points in the student's K-12 schooling. Parts of these changes have already been recorded in our analysis of science education. Quite possibly, the reading and math scores of our children will begin to rise as a result of this concerted effort. But, we should have learned that there are no easy or permanent solutions to the issues that confront this nation, particularly because the principles we value in education are as complex as they are, upon occasion, incompatible.

Addressing a few pertinent questions is recommended before engraving the goals for the next generation of students in stone. First, should educational aims be common to all, or should they reflect the local needs of its citizenry, the needs of the individual? How "differentiated" should curricula be to meet these needs? Will the educational policy decisions result in a "net gain" for all, some, or relatively few, and what effect will they have on the residual student population? The point to be made is that American education is exceptional. It attempts to offer opportunities of educational significance to all its students; as such, it is also more open to charges of catering to varied interests without having a clear vision of its own.

In the course of conducting this analysis, it was necessary to determine key elements that made American science education unique. The answers reside in the apparent diversity of programs offered the students, particularly after the elementary school grades. While country-wide similarities abound, enough evidence of differences in curricula were identified to convince this investigator that programs vary widely in content, purpose and articulation. The "discovered" answers have brought us back full cycle to ask, once more: Is this what we, as parents and students, educators, and Americans want?

The Second International Science Study will lend us insight for guiding our future course in science education. It will provide us with some current data on what other nations are doing in addressing these same questions. But, care must be taken to avoid interpreting the outcome in the narrow light of international competition, and to choose a course of action for this nation with some rational thought given to the nature of the qualities we wish to change.

It would be prudent to begin with a critical look at the students filling our classrooms--their strengths, weaknesses, and long-range plans, particularly with regard to post-high-school ambitions. Simplistic remedies, such as raising (science) requirements, address limited concerns while leaving significant problems untouched. What, indeed, will the consequences be for students whose academic abilities test below grade level? What effect will it have on the vast majority of students who do not pursue science as a profession? At the very least, science curricula for these groups must have different exit goals from those of traditional programs in the past.

The role of science education is not single-purposed and related solely to subject proficiency. Its broad function is to provide students with perceptions, information, and skills to adjust to and thrive in a rapidly evolving post-industrial society. Somewhere in this simple and self-evident fact, educators must find the clue to designing science programs that are relevant, appropriate, and challenging.

Mean and Standard Deviation Scores

of Traditional Science Content Areas

Population Levels: 1, 2, 3N, 3E, 3B, 3C, 3P

Curriculum: General Science (1,2,3N); Specialized Science (3E,3B,3C,3P)

(*) Items are U.S. Options

Content Area	1	2	3N	3E	3B	3C	3P	
EARTH SCIENCE								
1 Solar System	2.1	2.4	2.2	2.1	0.2	0.3	0.6	($\bar{x}$)
	1.0	0.8	1.1	1.3	0.8	0.8	1.1	(sd)
2 Stellar Systems	1.6	1.9	1.6	2.0	0.1	0.2	0.4	
	1.1	0.8	1.2	1.3	0.5	0.6	0.7	
* 2a Space Exploration and Recent Discoveries in Space	1.5	2.1	1.9	1.7	0.3	0.3	0.6	
	1.1	0.8	1.1	1.3	0.8	0.8	1.1	
3 Meteorology	1.8	2.3	1.8	2.4	0.3	0.2	0.3	
	1.1	0.8	1.1	1.1	0.6	0.6	0.6	
* 3a The Water Cycle	1.7	-	-	-	-	-	-	
	1.1							
4 Constitution of the Earth	1.9	2.0	1.7	2.3	0.2	0.3	0.3	
	1.0	0.8	1.0	1.1	0.4	0.6	0.6	
5 Physical Geography	1.2	2.0	2.0	2.3	0.2	0.3	0.3	
	0.9	0.9	1.1	1.1	0.5	0.6	0.6	
* 5a Causes of the Ice Ages	-	1.7	1.5	1.9	0.2	0.2	0.1	
		0.9	1.2	1.2	0.5	0.6	0.5	
6 Soil Science	0.5	1.0	1.1	1.5	0.3	0.3	0.1	
	0.7	0.9	1.1	1.1	0.4	0.5	0.3	
* 6a Soil Formation and Analysis	0.5	1.0	-	-	-	-	-	
	0.7	0.9						
BIOLOGY								
7 Cell Structure and Function	1.4	2.2	2.5	0.3	2.9	0.3	0.2	
	1.2	0.9	0.7	0.9	0.3	0.8	0.8	

NOTE:

The horizontal axis of each grid shows the populations of students involved in the curricular survey and the vertical axis lists the specific item, or feature, of curricula that was rated. Numerical scores thus represent the mean rating of the curricula item for a specific grade level or specialized group of students.

Ratings were based on a 4 point scale, which ranged between 0 (nil coverage in science curricula) to 3 (high coverage).

Traditional Science Content Scores

Content Area	1	2	3N	3E	3B	3C	3P	
8 Transport of Cellular Material	0.6	1.6	2.0	0.3	2.9	0.2	0.2	($\bar{x}$)
	1.0	0.9	1.0	0.9	0.3	0.8	0.8	(sd)
9 Cell Metabolism	0.5	1.8	2.2	0.3	2.9	0.3	0.2	
	1.0	0.9	1.0	0.9	0.3	0.8	0.8	
* 9a The Sun and Food Production	1.9	-	-	-	-	-	-	
	1.0							
10 Cell Responses	0.6	1.7	1.9	0.2	2.5	0.1	0.1	
	1.0	1.0	0.9	0.6	0.6	0.5	0.5	
11 Concept of the Gene	0.6	1.9	2.2	0.2	2.9	0.2	0.1	
	1.1	1.0	1.0	0.6	0.3	0.6	0.5	
12 Diversity of Life	2.1	2.2	2.4	0.3	2.9	0.3	0.2	
	0.9	1.0	0.9	0.9	0.3	0.8	0.8	
13 Metabolism of the Organism	1.6	2.0	2.2	0.3	2.8	0.4	0.3	
	1.1	0.9	0.9	0.9	0.4	0.8	0.8	
14 Regulation of the Organism	0.8	1.7	2.0	0.1	2.5	0.1	0.1	
	1.0	1.0	1.0	0.3	0.5	0.3	0.3	
15 Coordination and Behavior of the Organism	1.6	1.7	2.1	0.2	2.6	0.1	0.1	
	1.0	0.9	0.9	0.6	0.5	0.5	0.5	
16 Reproduction and Development of Plants	1.8	2.0	2.1	0.3	2.7	0.2	0.2	
	1.1	0.9	1.0	0.9	0.6	0.8	0.8	
17 Reproduction and Development of Animals	1.7	1.8	2.3	0.3	2.8	0.2	0.2	
	1.2	1.0	1.1	0.9	0.4	0.8	0.8	
18 Human Biology	2.0	1.9	2.4	0.3	2.9	0.3	0.2	
	1.1	0.9	0.9	0.9	0.3	0.8	0.8	
19 Natural Environment	2.1	2.1	2.2	0.7	2.8	0.3	0.3	
	0.9	0.9	1.1	1.1	0.4	0.8	0.8	
20 Cycles in Nature	1.8	2.1	2.3	0.7	2.6	0.5	0.2	
	0.9	0.9	1.0	1.0	0.5	0.8	0.8	
*20a Producers, Consumers, Decomposers; N_2, O_2, CO_2 cycles	-	1.6	-	-	-	-	-	
		1.2						

Traditional Science Content Scores

Content Area	1	2	3N	3E	3B	3C	3P	
21 Natural Groups and Their Segregation	0.2	1.0	1.7	0.2	2.4	0.1	0.1	($\bar{x}$)
	0.4	1.0	1.1	0.6	0.7	0.5	0.5	(sd)
22 Population Genetics	0.1	0.8	1.7	0.2	2.3	0.1	0.1	
	0.3	0.8	0.9	0.6	0.8	0.5	0.5	
23 Evolution	0.7	1.2	1.7	0.5	2.4	0.1	0.1	
	1.9	1.1	1.1	0.9	0.7	0.5	0.5	
*23a Adaptation and Variation in Plants and Animals	1.3	-	-	-	-	-	-	
	0.9							
CHEMISTRY								
24 Introductory Chemistry	1.5	2.1	2.1	0.5	1.2	2.8	0.4	
	1.0	0.9	0.9	1.0	1.2	0.4	0.8	
*24a Physical and Chemical Properties Simple Chemical Interactions	1.6	-	-	-	-	-	-	
	1.0							
25 Electro-chemistry	0.2	0.9	1.4	0.3	0.4	2.6	0.6	
	0.5	1.0	1.2	0.6	0.7	0.5	1.0	
*25a Electrons, Protons, Atomic Model	1.0	-	-	-	-	-	-	
	1.2							
26 Chemical Laws	-	1.7	1.7	0.4	0.5	2.9	0.4	
		0.9	1.1	0.7	0.8	0.3	0.7	
27 Chemical Processes	0.6	1.6	1.5	0.5	1.1	2.8	0.3	
	0.8	1.0	1.0	0.8	1.0	0.6	0.7	
*27a Simple Chemical Reactions; Rusting, Burning	1.7	-	-	-	-	-	-	
	0.9							
28 Periodic System	0.3	1.8	1.7	0.2	0.5	2.9	0.4	
	0.6	0.8	1.1	0.6	0.7	0.3	0.9	
*28a Classification and Serial Ordering	0.9	-	-	-	-	-	-	
	1.1							
29 Energy Relationships in Chemical Systems	0.2	1.0	1.4	0.5	0.5	2.6	0.7	
	0.5	0.7	1.1	0.7	0.7	0.5	1.0	

Traditional Science Content Scores

Content Area	1	2	3N	3E	3B	3C	3P	
*29a Heat and Chemical Reactions; Celsius Scale	1.2	-	-	-	-	-	-	
	1.0							
30 Rate of Reaction	0.1	1.0	1.4	0.2	0.5	2.6	0.4	($\bar{x}$)
	0.5	0.9	1.2	0.6	0.7	0.5	0.9	(sd)
31 Chemical Equilibrium	0.1	0.4	1.4	0.4	0.5	2.8	0.4	
	0.2	0.7	1.3	0.9	0.9	0.4	0.9	
*31a Evaporation of Solutions	0.9							
	0.7	-	-	-	-	-	-	
32 Chemistry in Industry	0.5	1.1	1.3	0.2	0.3	1.8	0.1	
	0.7	0.9	0.9	0.6	0.6	0.7	0.3	
33 Chemical Structure	0.6	1.9	1.8	0.6	0.9	2.9	0.1	
	0.8	0.9	1.1	0.9	1.1	0.3	0.3	
*33a Chemical Structure of Solids; Crystal Growing	0.7	-	-	-	-	-	-	
	0.8							
34 Descriptive Inorganic Chemistry	0.5	1.2	1.6	0.5	0.6	2.5	0.0	
	0.7	1.0	1.0	0.7	0.9	0.7	0.0	
35 Organic Chemistry	0.7	0.5	1.4	0.4	0.7	2.2	0.0	
	1.0	0.5	1.1	0.7	0.8	0.6	0.0	
*35a Flammable and Non-flammable Substances	1.1							
	1.0	-	-	-	-	-	-	
36 Environmental Chemistry	0.4	1.3	1.7	0.5	0.8	1.7	0.1	
	0.7	0.9	0.9	0.7	0.9	0.8	0.3	
*36a Common Pollutants	1.1							
	1.0	-	-	-	-	-	-	
37 Chemistry of Life Processes	0.2	1.2	1.7	0.2	1.5	1.5	0.0	
	0.5	0.8	0.9	0.6	1.2	1.0	0.0	
38 Nuclear Chemistry	0.2	1.1	1.5	0.4	0.4	2.1	0.8	
	0.5	0.9	1.0	0.7	0.6	0.7	1.1	

Traditional Science Content Scores

Content Area	1	2	3N	3E	3B	3C	3P
PHYSICS							
39 Measurement	1.7 1.1	2.5 0.9	2.4 1.0	1.0 1.3	0.9 1.3	1.1 1.4	2.8($\bar{x}$) 0.5(sd)
*39a The Metric System	1.9 1.0	-	-	-	-	-	-
40 Time and Movement	1.2 1.2	1.[illegible] 1.[illegible]	1.9 1.1	0.6 0.8	0.2 0.6	0.3 0.6	2.7 0.7
*40a Methods of Measuring Time	1.5 1.1	-	-	-	-	-	-
41 Forces	1.3 0.9	1.3 0.9	1.7 1.1	0.9 1.2	0.4 0.9	0.3 0.8	2.8 0.7
42 Dynamics	0.5 0.7	2.2 1.0	1.6 1.3	0.6 1.2	0.3 0.8	0.4 0.8	2.8 0.6
*42a Gravity; Starting and Stopping	1.3 1.0	-	-	-	-	-	-
43A Energy	1.6 0.9	1.6 1.0	2.2 1.1	0.4 0.9	0.7 1.1	1.1 1.3	2.7 0.6
*43a Electrical Energy to Mechanical Energy, Light and Heat	1.3 0.8	1.9 0.9	-	-	-	-	-
43B Machines-Simple	1.7 1.0	1.9 0.9	1.8 1.1	0.2 0.6	0.2 0.6	0.3 0.6	2.1 1.1
44 Mechanics of Fluids	0.9 1.1	1.3 1.0	1.2 0.9	0.3 0.6	0.3 0.6	0.3 0.7	1.6 1.1
45 Introductory Heat	1.5 0.9	1.9 1.0	1.6 1.0	0.4 0.8	0.3 0.6	0.8 1.0	2.4 0.8
*45a Insulation	-	1.5 1.2	-	-	-	-	-
46 Changes of State	1.7 1.1	2.2 1.0	1.9 1.1	0.7 1.3	0.5 1.0	1.4 1.4	2.3 0.8
*46a Freezing	-	1.8 1.2	-	-	-	-	-

Traditional Science Content Scores

Content Area	1	2	3N	3E	3B	3C	3P	
47 Kinetic Theory	0.5	1.7	1.8	0.3	0.3	1.3	2.4	($\bar{x}$)
	0.8	0.9	1.1	0.6	0.6	1.4	0.8	(sd)
48 Light	1.2	1.8	1.9	0.5	0.3	0.6	2.7	
	1.0	0.9	1.0	0.8	0.7	0.8	0.7	
49 Vibration and Sound	1.9	1.7	2.0	0.6	0.3	0.3	2.6	
	1.0	0.8	1.0	0.9	0.6	0.6	0.7	
50 Wave Phenomenena	0.5	1.2	1.6	0.6	0.3	0.6	2.4	
	0.8	1.0	1.2	0.9	0.6	1.0	0.8	
*50a Polarization	0.8	1.3	1.4	0.2	0.3	0.4	1.8	
	1.0	1.0	1.1	0.6	0.6	0.8	1.1	
51 Spectra	1.4	1.7	1.8	0.5	0.2	0.9	2.4	
	1.1	0.9	1.1	0.8	0.6	1.0	0.7	
*51a Glass Prisims; Diffraction Gratings	1.3	1.1	-	-	-	-	-	
	1.1	0.9						
52 Static Electricity	1.7	2.1	1.7	0.3	0.2	0.5	2.2	
	1.1	0.8	1.2	0.6	0.6	0.7	1.1	
*52a Electrostatic Generators	-	1.6	1.0	0.2	0.1	0.3	1.8	
		1.1	1.1	0.6	0.5	0.6	1.1	
*52b Generation of Electricity	1.4	1.9	1.6	0.2	0.1	0.8	2.1	
	1.0	0.8	1.0	0.6	0.5	1.1	0.8	
53 Current Electricity	1.7	2.0	1.9	0.2	0.2	0.3	2.4	
	1.1	0.8	1.0	0.6	0.6	0.6	0.8	
*53a Series and Parallel Circuits	1.4	-	1.4	0.2	0.1	0.2	2.2	
	1.1		1.1	0.4	0.4	0.4	0.8	
54 Electromagnetism and Alternating Currents	1.4	1.8	1.7	0.2	0.2	0.3	2.6	
	1.3	1.0	1.0	0.6	0.6	0.6	0.7	
55 Electronics	0.3	0.8	1.3	0.2	0.1	0.3	1.8	
	0.7	1.0	1.0	0.6	0.3	0.6	0.9	
*55a Vacuum tubes; Radio: Television	-	0.4	0.9	0.1	0.0	0.1	1.1	
		0.9	1.1	0.6	0.0	0.3	0.5	

Traditional Science Content Scores

Content Area	1	2	3N	3E	3B	3C	3P	
56 Molecular and Atomic Physics	0.5	1.1	1.6	0.4	0.2	0.2	1.9	$(\bar{x})$
	0.9	0.9	1.1	0.9	0.6	0.4	0.8	(sd)
57 Theoretical Physics	0.0	0.3	0.9	0.1	0.1	0.1	1.7	
	0.0	0.6	1.2	0.6	0.3	0.3	1.1	
*58 Nuclear Energy	0.2	1.3	1.6	0.3	0.2	0.9	1.9	
	0.4	0.9	1.2	0.6	0.4	1.2	0.6	
*59 Nuclear Weapons and Their Control	0.2	0.5	1.1	0.2	0.1	0.6	0.9	
	0.5	0.8	0.9	0.6	0.3	0.9	0.9	

Mean and Standard Deviation Scores
of Other Science Content Areas

Population Levels: 1, 2, 3N

Curriculum: General Science

(*) Items are U.S. Options

Other Science Content Area	1	2	3N	
HISTORY AND PHILOSOPHY OF SCIENCE				
1 Historical Development of Science Biographies of Scientists	1.0	1.4	1.4	($\bar{x}$)
	1.1	0.8	0.9	(sd)
2 Nature of Science Stages of the Scientific Method	1.4	2.1	2.3	
	1.1	0.9	0.9	
*3 a Sociology of Science	0.4	0.9	1.4	
	0.6	0.8	1.2	
b Controversies Associated with Science and Technology	0.7	1.2	1.4	
	0.8	1.0	1.1	
ENVIRONMENTAL SCIENCE				
4 Energy Resources Finite resources; coal, oil, nuclear Non-finite resources: solar, wind, tide, biomass	1.7	2.2	2.1	
	1.0	0.9	0.7	
5 Energy Use Patterns of energy use; costs and benefits of alternative energy sources	1.2	1.6	1.7	
	1.0	1.0	0.9	
6 Environmental Impact Air pollution; water pollution; packaging; domestic waste products; Environmental effects of population growth and distribution; Environmental effects of leisure activities and tourists	1.8	1.9	2.0	
	0.8	0.8	0.7	
7 Habitats Preservation of habitats; Local flora and fauna	1.7	1.8	2.1	
	1.0	1.1	0.9	
*8 a Population and the Environment	0.9	1.6	1.7	
	0.9	1.0	0.7	

Other Science Content Scores

Other Science Content Area	1	2	3N	
TECHNICAL AND ENGINEERING SCIENCE				
9 Vehicles				
Cars, trains, planes, ships, etc.				
Internal combustion engines, steam engines,	1.1	1.4	1.3	($\bar{x}$)
Electric motors, aerodynamics, gears...	0.7	0.7	0.9	(sd)
10 Manufacturing Processes				
Steel and steel products, food processing,	0.5	1.0	1.1	
plastics, clothing manufacture, paper, ...	0.7	0.7	0.9	
11 Microprocessors and Computers				
Structure and function (hardware)				
Programming languages (software)	0.2	0.9	1.2	
Computer simulation of science experiments;	0.6	0.9	0.9	
Student produced computer programs for science				
	0.3	0.8	1.3	
*12 a Relationships Between Science and Technology	0.5	0.8	0.9	
RURAL SCIENCE				
13 Animal Husbandry	0.8	0.5	0.4	
Breeding, feeding, shelter	1.0	0.7	0.5	
14 Plant Husbandry	0.6	0.5	0.4	
Crop management, pesticides	0.8	0.7	0.5	
15 Housing and Rural Amenities				
Housing: materials, construction, techniques	0.6	0.6	0.5	
Water: drinking water, irrigation, drains	0.9	0.8	0.7	
	0.2	0.2	0.3	
*16 a Mechanization of Agriculture	0.4	0.4	0.5	
b Modes of Tillage	0.2	0.4	0.5	
	0.4	0.8	0.9	
	0.2	0.4	0.6	
c Fertilizers	0.4	0.6	0.8	

Other Science Content Scores

Other Science Content Area	1	2	3N	
HEALTH SCIENCE				
17 Personal Health				
Food, diet, nutrition				
Exercise and recreation	2.2	2.2	2.2	($\bar{x}$)
Illness and disease, injury and first aid	1.0	1.0	0.9	(sd)
Drugs, narcotics, alcohol				
18 Interpersonal Relationships				
Personal growth and development skills	1.5	1.8	1.7	
Sex education	1.2	1.2	1.0	
19 Community Health				
Basic community health provision:				
water, sewerage, housing				
Disease prevention: rubella, smallpox, malaria	1.4	1.5	1.4	
Population limitation programs	1.0	1.0	0.9	
	0.4	0.6	0.6	
*20 a Death and Dying	0.6	0.7	0.9	

Mean and Standard Deviation Scores
of Science Process Areas

Population Levels: 1, 2, 3N, 3E, 3B, 3C, 3P

Curriculum: General Science (1,2, 3N); Specialized Science (3E,3B,3C,3P)

(*) Items are U.S. Options

Process Area	1	2	3N	3E	3B	3C	3P	
A KNOWLEDGE AND COMPREHENSION								
A1 Knowledge of Specific Facts	2.6 0.6	2.9 0.4	2.7 0.5	2.8 0.4	2.7 0.6	2.8 0.4	2.7 0.5	($\bar{x}$) (sd)
A2 Knowledge of Scientific Terminology	2.0 0.8	2.8 0.4	2.6 0.5	2.7 0.5	2.5 0.5	2.8 0.4	2.6 0.5	
A3 Knowledge of Concepts of Science	1.9 1.0	2.6 0.6	2.7 0.5	2.6 0.7	2.7 0.5	2.9 0.3	2.8 0.4	
A4 Knowledge of Conventions	1.1 1.0	1.9 0.7	2.0 0.7	2.1 0.7	2.3 0.7	2.7 0.6	2.6 0.5	
A5 Knowledge of Trends and Sequences	1.1 1.0	1.9 0.8	2.1 0.8	2.4 0.8	2.3 0.7	2.8 0.4	2.6 0.7	
A6 Knowledge of Classifications, Categories, and Criteria	1.9 0.9	2.4 0.8	2.6 0.5	2.6 0.5	2.5 0.6	2.8 0.4	2.3 0.4	
A7 Knowledge of Scientific Techniques and Procedures	1.8 1.0	2.2 0.8	2.4 0.5	2.3 0.5	2.5 0.5	2.8 0.4	2.6 0.6	
A8 Knowledge of Scientific Principles and Laws	1.6 0.9	2.3 0.8	2.6 0.6	2.5 0.7	2.4 0.7	2.9 0.3	2.8 0.4	
A9 Knowledge of Theories or Major Conceptual Schemes	1.1 0.9	2.3 0.9	2.4 0.6	2.4 0.7	2.6 0.5	2.6 0.8	2.7 0.5	
A10 Identification of Knowledge in a New Context	0.8 0.8	1.5 1.0	1.8 0.8	1.7 0.8	1.8 0.9	1.9 0.7	1.9 1.0	
A11 Translation of Knowledge From One Symbolic Form to Another	0.7 0.9	1.4 [illegible]	1.6 0.8	1.5 1.1	1.5 0.7	2.1 0.8	1.9 0.8	

Science Process Scores

Process Area	1	2	3N	3E	3B	3C	3P	
B PROCESS OF SCIENTIFIC INQUIRY I: OBSERVING AND MEASURING								
B1 Observation of Objects and Phenomena	2.3	2.7	2.9	2.7	2.8	2.7	2.7	$(\bar{x})$
	1.0	0.6	0.4	0.5	0.4	0.5	0.5	(sd)
B2 Description of Observations Using Appropriate Language	2.0	2.3	2.6	2.5	2.8	2.7	2.4	
	1.2	1.0	0.6	0.5	0.4	0.5	0.8	
B3 Measurement of Objects and Changes	2.1	2.5	2.6	2.4	2.3	2.7	2.7	
	1.1	0.6	0.5	0.5	0.6	0.6	0.6	
B4 Selection of Appropriate Measuring Instruments	1.7	2.1	2.3	2.3	2.1	2.4	2.1	
	1.0	0.9	0.7	0.7	0.9	0.8	1.1	
B5 Estimation of Measurements and Recognition of Limits in Accuracy	1.2	2.0	2.3	2.1	1.7	2.4	2.3	
	1.0	0.9	0.8	0.9	1.1	0.8	0.9	
C PROCESSES OF SCIENTIFIC INQUIRY II: SEEING A PROBLEM AND SEEKING WAYS TO SOLVE IT								
C1 Recognition of a Problem	1.4	1.9	2.4	2.1	2.2	2.5	2.3	
	1.0	0.9	0.7	0.7	0.7	0.6	0.9	
C2 Formulation of a Working Hypothesis	1.3	1.5	2.1	2.1	1.9	2.0	2.1	
	1.1	1.0	0.7	0.7	1.0	0.9	0.9	
C3 Selection of Suitable Tests of a Hypothesis	0.8	1.4	1.9	1.5	1.9	2.0	1.9	
	0.8	1.0	0.8	1.1	0.8	0.5	0.9	
C4 Design of Appropriate Procedures for Performing Experiments	0.8	1.3	2.0	1.6	1.7	1.9	1.9	
	0.8	0.8	0.7	1.1	1.1	1.0	1.0	

Science Process Scores

Process Area	1	2	3N	3E	3B	3C	3P	
D PROCESSES OF SCIENTIFIC INQUIRY III: INTERPRETING DATA AND FORMULATING GENERALIZATIONS								
D1 Processing of experimental data	1.2	1.6	2.1	2.0	2.1	2.5	2.4	(x̄)
	1.0	1.0	0.6	0.8	0.8	0.6	0.6	(sd)
D2 Presentation of data in the form of functional relationships.	0.9	1.4	1.9	1.9	2.1	2.3	2.4	
	1.0	1.0	0.8	0.9	0.9	0.7	0.7	
D3 Interpretation of experimental data and observations	0.9	1.8	2.1	2.2	2.3	2.6	2.4	
	0.9	1.0	0.8	0.6	0.6	0.5	0.7	
D4 Extrapolation and Interpolation	0.8	1.5	2.1	2.0	1.8	2.2	2.3	
	1.0	0.9	0.8	0.7	0.8	0.8	0.6	
D5 Evaluation of a hypothesis under test in light of data	0.9	1.5	2.0	1.7	1.9	1.9	1.9	
	0.9	0.8	0.8	0.9	0.9	1.0	0.8	
D6 Formulation of generalizations warranted by the relationships obtained	0.9	1.5	1.9	1.7	2.0	2.1	1.8	
	1.0	0.9	0.8	0.9	0.9	1.1	1.0	
E PROCESSES OF SCIENTIFIC INQUIRY IV: BUILDING, TESTING, AND REVISING A THEORETICAL MODEL								
E1 Recognition of the need for a theoretical model	0.5	1.4	1.7	1.8	1.8	2.0	1.9	
	0.8	1.1	0.9	0.9	1.1	1.0	1.0	
E2 Formulation of a theoretical model to accumulate knowledge	0.5	1.1	1.3	1.4	1.4	1.4	1.5	
	0.7	1.0	0.9	1.0	1.1	1.0	1.0	
E3 Specification of relationships satisified by a model	0.5	1.2	1.3	1.1	1.2	1.4	1.6	
	0.8	1.0	0.8	0.9	0.9	1.0	1.1	
E4 Deduction of new hypotheses from a theoretical model	0.5	0.9	1.4	1.1	1.2	1.2	1.3	
	0.7	0.9	1.0	1.0	1.1	0.9	1.0	
E5 Interpretation and evaluation of tests of a model	0.5	1.0	1.4	1.1	1.2	1.4	1.6	
	0.7	0.9	0.9	1.0	0.9	1.0	0.9	

Science Process Scores

Process Area	1	2	3N	3E	3B	3C	3P	
E6 Formulation of a revised, refined, or extended model	0.3	0.8	1.[illegible]	0.9	0.9	1.3	1.1	($\bar{x}$)
	0.6	1.0	0.9	1.0	0.9	0.9	0.8	(sd)
F APPLICATION OF SCIENTIFIC KNOWLEDGE AND METHODS								
F1 Application to new problems in the field of science	0.5	1.2	1.8	1.3	1.8	1.6	2.1	
	0.7	0.8	0.7	0.9	0.7	0.7	0.8	
F2 Application to new problems in a different field of science	0.3	0.9	1.3	0.9	1.2	1.3	1.3	
	0.6	0.8	0.9	1.1	0.9	0.8	0.8	
F3 Application to problems outside of science (including technology)	0.4	1.0	1.3	1.1	1.2	1.3	1.1	
	0.5	0.9	1.0	0.9	0.9	0.9	0.8	
G MANUAL SKILLS								
G1 Development of skills in using common laboratory equipment	1.7	2.4	2.5	2.1	2.6	2.7	2.7	
	0.9	0.8	0.5	0.9	0.5	0.6	0.5	
G2 Performance of common laboratory techniques with care and safety	1.3	2.3	2.7	2.3	2.7	2.8	2.8	
	1.0	0.7	0.5	0.9	0.5	0.6	0.4	
H. ATTITUDES AND INTERESTS								
H1 Manifestation of favorable attitudes towards science and scientists	1.6	2.1	2.2	2.1	2.5	2.3	2.2	
	1.0	0.8	0.6	0.7	0.5	0.7	0.7	
H2 Acceptance of scientific inquiry as a way of thought	1.2	2.0	2.3	2.0	2.1	2.3	2.2	
	1.2	1.1	0.9	0.9	1.0	1.0	1.0	
H3 Adoption of 'scientific attitudes'	1.1	2.0	2.2	2.0	2.2	2.3	2.1	
	1.0	0.7	0.7	0.7	0.7	0.8	0.7	

Science Process Scores

Process Area	1	2	3N	3E	3B	3C	3P	
H4 Enjoyment of science learning experiences	2.1	2.1	2.2	2.1	2.4	2.3	2.1	($\bar{x}$)
	1.1	0.7	0.7	0.6	0.5	0.6	0.7	(sd)
H5 Development of interests in science and science-related activities	1.8	1.9	2.2	2.0	2.2	2.3	2.2	
	0.9	0.6	0.6	0.5	0.7	0.6	0.7	
H6 Development of interest in pursuing a career in science	1.1	1.8	1.8	1.9	2.1	1.9	2.1	
	0.8	0.5	0.7	0.8	0.7	0.7	0.7	

I ORIENTATION

I1 Relationships among various types of statements in science	0.6	1.4	1.8	1.3	1.5	1.7	1.7
	0.8	0.9	1.0	1.3	1.1	1.0	0.9
I2 Recognition of the philosophical limitations and influence of scientific inquiry	0.5	1.2	1.6	1.0	1.3	1.7	1.3
	0.6	1.0	1.0	1.2	1.0	1.2	0.9
I3 Historical perspective: recognition of the background of science	0.5	1.4	1.8	1.3	1.7	2.2	1.7
	0.7	1.0	1.0	1.2	0.9	0.8	0.8
I4 Realization of the relationships among science, technology, and economics	0.3	1.2	1.5	1.2	1.2	1.5	1.4
	0.5	0.9	0.9	1.3	0.9	1.0	1.1
I5 Awareness of the social and moral implications of scientific inquiry and its results	0.4	1.1	1.6	1.1	1.8	1.4	1.2
	0.5	1.0	0.9	1.1	1.0	0.9	1.0

FOOTNOTES

Chapter III

1. American Chemical Society, *Tomorrow - The Report of the Task Force For the Study of Chemistry Education in the United States*, (Washington, D.C.: American Chemical Society), p. 2.

2. Leo Klopfer in: Benjamin Bloom, J. Thomas Hastings, George F. Madaus, *Handbook on Formative and Summative Evaluation of Student Learning*, (New York: McGraw-Hill Book Co.), 1971, pp. 559-641.

3. Iris Weiss. *Report of the 1977 National Survey of Science, Mathematics, and Social Studies Education*, Washington, D.C.; US. Government Printing Office, 1978, p. 126.

4. Ibid., p. 51.

5. Ibid., pp. B-45.

6. Ibid.

7. U.S. Bureau of the Census, *Statistical Abstract of the United States*, 1985 (Washington, D.C.: U.S. Government Printing Office, 1985), p. 145.

8. Wayne W. Welch, Linda J. Harris, Ronald E. Anderson, "How Many Are Enrolled in Science?" *The Science Teacher* 51 (December 1984), p. 16.

9. Ibid., p. 16.

10. National Science Teachers Association, "The NSTA Position on Curriculum," *The Science Teacher* 29 (December 1962), pp. 32-37.

11. National Science Teachers Association, "An NSTA Position Statement-Science-Technology-Society: Science Education for the 1980s" (Washington, D.C.: 1982).

Chapter IV

THE UNITED STATES SCIENCE CURRICULUM CASE STUDY

Education in the United States is characterized by great variety. It is essentially decentralized with education policies made by each of the 50 states and sometimes by communities within these states. Children begin their education at the age of five or six and the majority finish secondary school, although education is only compulsory to the age of 16.

Historically, there has been a general commitment to providing education for everyone. In most states, communities are mandated to provide education for all children and young people.

Section 1: Introduction

1. System Structures

In the Constitution of the United States, the Tenth Amendment allowed states to retain all powers that were not specifically empowered to the federal government; among those powers deliberately withheld from federal control was that of providing education. To this day, most educational policies are directed through the 50 State Departments of Education or local county or district agencies. Of the entire 50 states, only the State of Hawaii has a uniform system throughout its various islands

The standard three tiers into which education is grouped in the U.S. are: kindergarten through grade six; grades 7 through 9; and grades 10 though 12. Less commonly, some school systems are organized as elementary (K-8) and secondary (9-12). Occasionally, a third pattern consists of elementary school encompassing grades 1 through 5, a middle school containing grades 6 through 8, and a high school with grades 9 through 12. Some states include guidelines for preprimary education and many elementary schools include a kindergarten, or "K" level, within their formal school sequence.

In 1867, an Act of Congress founded the original U.S. Department of Education, the closest equivalent to a ministry of education in other countries. Its main function, then as now, is to collect data and oversee the condition and progress of education and provide support for special programs in the field of education.

2. Administration and Funding

Most of the funds for public education in the United States come from the taxation of real property by the local school districts and from various revenues, such as the income tax, imposed by communities and states. By contrast, the majority of funds for non-public education come from tuition paid by parents. In 1983, about $215.4 billion was expended on public and non-public education in all schools from pre-primary through graduate school.[1] The federal government helps support special programs, such as programs for exceptional students, bilingual education, and projects for the improvement of education, although funding patterns and allocations vary from year to year.

3. School Types

About 90% of school-aged children attend public school, while the remainder attend non-public institutions run by religious organizations or private associations. Science programs in the non-public sector do not significantly differ from those taught elsewhere. At the elementary level, general or integrated science, consisting mainly of biological and physical sciences, are emphasized, although the actual time devoted to instruction is significantly less than that devoted to the teaching of reading, mathematics, and social studies. At the lower and upper secondary levels, the programs are more commonly grounded in study of specific science domains. Contents and sequence of science courses are similar in most types of schools, with the exception of a small number of fundamentalist religious schools. Most secondary schools are considered to be "comprehensive" schools. Larger school districts have develped specialized schools, the majority of which contain voactional/technical programs.

4. External Examinations

Terminal uniform examinations are not mandated nationwide as they are in many other nations. In 1983, however, 40 states had minimum-competency examinations administered to public school children at designated grades in the K-12 sequence. Most of these states planned to use these examinations as one criterion for high school graduation, and some states had already instituted this requirement.[2]

Apart from state mandates, some local school districts use their own competency examinations with their student population at periodic intervals and adopt local regulations for grade promotion and graduation.

5. National Plans

Because of state and regional differences, it is difficult to describe a national program of science education in the United States. There are exceptions to almost any general statement about education in the U.S. Despite the diversity found in United States educational systems, apparent similarities in schooling and learning experiences do exist.

The decentralized system of education in the United States precludes direct supervision or control of most aspects of school instruction by the federal government. State revenues accounted for the principal share of aid to schools, followed by local revenues and finally, federal support.[3]

6. Pressures

The cry for national reform, for "excellence in education," is the most often cited goal of the 1980s regarding present and future needs in the field. Widely publicized status reports from influential public and private sectors in the early part of the decade described steadily declining test scores of students in mathematics and reading over the previous 10 years. Many urged a greater emphasis on basic required skills, suggested criteria for grade promotions at all levels and urged the reinstatement of tougher graduation requirements. It was generally felt that the alarming shortages of well trained teachers in math and science contributed to the problem, particularly at the secondary level.

Added to this was growing public awareness of the erosion of the nation's technological leadership in the international marketplace. In part, this was perceived to be the result of poorly prepared students entering the workforce at the secondary and post-secondary levels.

These forces created the demand for more stringent educational guidelines. In science education, the effect has been felt in the doubling of high school graduation requirements in science coursework (from one year to two years) in approximately 25 states. Many of the remaining states were considering similar requirements. State revenues have also been directed toward teacher preparation, certification, and retention, particularly in the areas of math and science at the secondary level.[4]

Section 2: Aims and Objectives of Science Education

1. Aims

Goals of science education for the 1980s focus on making all students "scientifically literate". In order to achieve this end, curricula have been developed using the following criteria:[5]

1. Academic Knowledge of Science and Technology: this knowledge should encompass the factual information within the disciplines and the technological ramifications of science research. However, while most organizations and agencies affiliated with science education agree in principle to the inclusion of technology, less consensus exists upon the contents of such in on-going science programs. Additionally, many experts feel a separate course offering should be developed for non-academic students.

2. Practice and Application of Science Process Skills: these skills involve developing laboratory aptitudes (e.g., observation, measurement, classification, data collection) and cognitive abilities used to objectively examine physical phenomena (e.g., hypothesis formulation, data analysis and interpretation, verification, generalization).

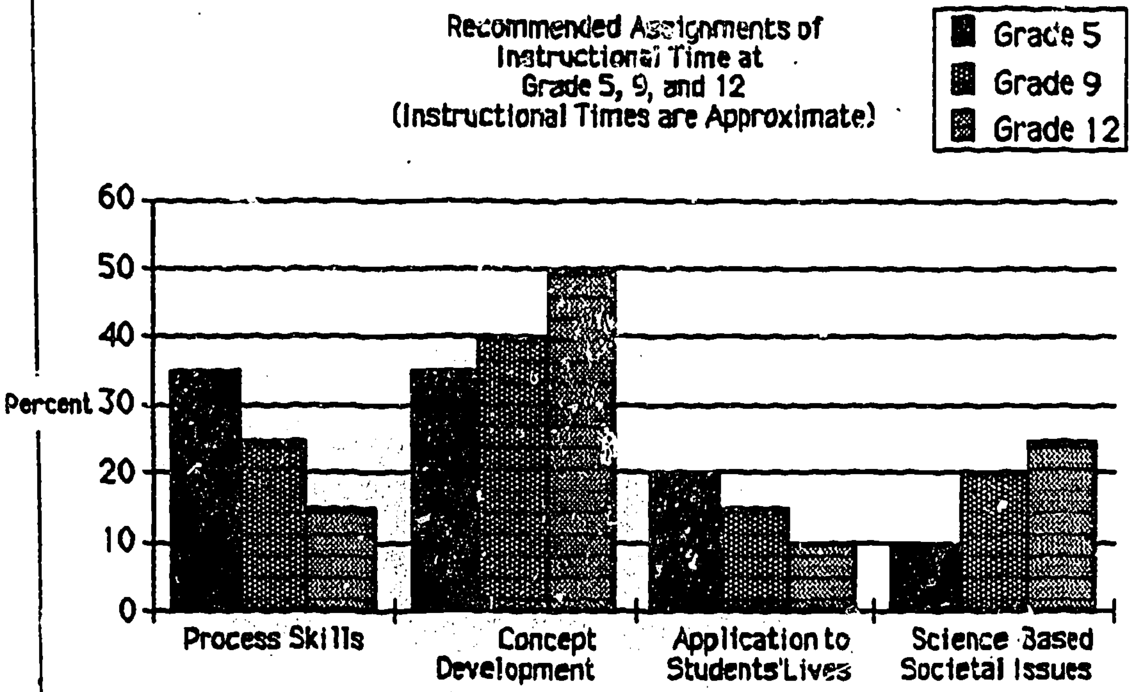
3. Application of Knowledge and Skills in Daily Life and Society: the relevancy of learning science should extend beyond the subject domain to areas that affect the course of personal and societal development (for example, ramifications or implications of science in personal health, career choices, the environment, technology). An "informed citizenry" that can make prudent decisions on issues having significant scientific/technological dimensions is one important outcome of this.

These broadly described goals for science education in the 1980s were categorized by the National Science Teachers Association into four general blocks:

- Process Skills
- Concept Development
- Application to the students' personal lives
- Science-Based Societal Issues

Instruction at all levels should encompass all four categories. However, the recommended emphasis of each cluster varied with respect to grade level. The figure below shows recommended allotment of instructional time at grades 5, 9, and 12.[6]

FIGURE 7



Section 3: Curriculum Development and Content

1. Curriculum Content

Two common patterns for science education are shown in Figure 8. An important difference prevails between the organization of science in United States secondary schools when compared to many other national educational systems. In many countries, the various sciences are studied each year of the secondary school. In the United States, a different science is studied each year. For example, a common pattern is to have earth science in the 9th grade, biology in the 10th grade, chemistry in the 11th grade and physics in the 12th grade.

• Upper Elementary Level - Grade 5

Science programs are not standardized to a great extent at this level in U.S. schools. Content may include units from any one, or all of the basic or applied sciences. Frequently, however, the content is grouped by broadly conceptual themes, such as "Circulation" or "Systems of the Body." which reflect a focus on one of the physical or biological/environmental fields.

Process skills, particularly those associated with basic laboratory experiences, such as classification, observation, and measurement of phenomena, are considered essential elements of science instruction. These are introduced and reinforced through "hands-on" activities, in which students use these skills to draw tentative conclusions about the objects being examined. As reflected in the curricula for Population 1, acquisition of practical skills, along with attainment of knowledge and comprehension of factual content, are the areas of greatest concern in the science curricula.

• Lower Secondary Level - Grade 9

At the lower secondary level, courses in general science, physical science, earth science, and biological science are often offered. Less frequently, a unified or integrated science course is offered.

Laboratory skills are highly stressed in planned science curricula at this level. Attendant process skills related to scientific methodology and data gathering are regarded with equal importance, and included within the science curricula.

• Upper Secondary Level - Grade 12

Consensus with respect to the content of science programs at the upper secondary level is greater than that at the lower secondary level. The science curriculum at the terminal year of secondary school is usually a full year sequence in one branch of science. Most often, the science offered is physics, but many schools also include a second year

FIGURE 8

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

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

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

of biology or chemistry. Since many states require no more than two years of upper secondary science credit for graduation, the numbers of students enrolled in science courses at grade 12 are much fewer than for Populations 1 or 2.

The curriculum ratings indicated a high level of emphasis on fundamental process skills for this grade level. A prime reason for this is state guidelines, which generally require a block of instructional time in student-centered laboratory work. Although apportionment differs, at least one or two periods of laboratory work per week are recommended in experimental activity. Experiments undertaken by students often focus directly upon reinforcing their understanding of the factual contents of science rather than reflecting the inquiry nature of science. The cognitive skills that were most heavily emphasized in the curricular ratings were in the areas of knowledge acquisition of known or accepted phenomena (terminology, laws, concepts, procedures).

2. Curriculum Development

There is no standard method for developing science curricula in the United States; rather, several approaches are commonly employed. Dedicated professionals--teachers and supervisors--work diligently developing science curricula for their school systems, often adapting state or city guidelines to the needs of local student bodies. However, from the late 1950s through the early 1970s, major curriculum development projects funded by government agencies, such as the National Science Foundation, spawned reforms in the approaches to instructional development. Wayne Welch, in reviewing these projects, suggested that the efforts had the following characteristics:

a. Although projects were often identified with prominent scientists, almost all involved the cooperation of a large number of scientists, teachers and administrators.
b. Many of the projects were classroom tested, but the results did not necessarily influence subsequent versions in any significant manner.
c. Mechanisms such as summer institutes and short-term workshops were set up to familiarize teachers and administrators with the new curriculum materials.
d. Commercial publishers were selected to print and market the materials.

Since the intense activity in science curriculum development in the 1960s and early 1970s, there has been a sharp diminution of funded curriculum projects. Teachers, science educators, and scientists continue to generate science curriculum materials, but they must frequently rely on their own resources for these endeavors. School systems continue to produce science materials as well.

Science curriculum materials are also written commercially by teams of teachers, science educators, scientists, editors, and media specialists, which are then produced and distributed by commercial publishers. Because publishers are anxious to enhance sales, they tend to promote text materials similar to those that have been selected by teachers and school systems in the past. There is a hesitancy to depart radically from that which has proven market value; hence, the materials produced by different publishers are often quite similar. The textbook tradition is deeply entrenched. Even the process-oriented science programs of the 1960s and 1970s eventually generated textbooks for classroom use. Since 90% to 95% of the teachers use textbooks as a major educational resource 90% of the time, there is a tendency toward homogeneity in the experiences students have in the United States.[7]

More attention is being focused on developing specialized science materials for the educable mentally handicapped, the gifted, and in non-traditional areas, such as environmental and computer science. However, major agencies like the National Science Foundation reduced their support of science curriculum development in the late 1970s and early 1980s.

3. Curriculum Implementation

In most districts, the text and/or curriculum materials "are usually selected by individual teachers and teacher committees. Principals and supervisors are sometimes involved in text selection,"[8] but parents, students, and school board members are seldom involved. In some states, a text-adoption procedure is used which requires that books purchased with state funds must be selected from the state's approved list.

Despite the fact that the choice of the text is usually theirs, "many teachers criticize the text they are using as having too difficult a reading level for many students."[9] The decentralized system of education provides considerable latitude for teachers to modify the curriculum for their students and communities. Because of this freedom, articulation of science curricula between grades, within schools and between different schools of the same grade level, is a problem area. Not surprisingly, within any classroom, "the science taught and the way it is taught is dependent primarily on what the individual teacher believes, know, and does."[10] Implementation of new curricular materials can only take place at the local level and then only if teachers are prepared and willing to use them. Supervisors and admninstrators can be very influential in facilitating changes and supporting and monitoring their continuance.

Section 4: Teacher Education

1. Pre-service Education

Teacher certification guidelines are established by the states and a different course of collegiate study is generally prescribed for elementary school accreditation and secondary school accreditation. Preservice teacher education is carried out in many of the 3,134 colleges, universities, and branch campuses across the nation. Classroom teachers are trained by undergraduate and graduate institutions. The teacher education institutions are concerned that their graduates be recruited by school systems, and many try to prepare the types of teachers that school systems say they need. This feedback process is one of the factors that leads to some uniformity. About 2.5 million teachers work in elementary and secondary schools, although the numbers of college students expressing an intention to teach have significantly declined from 1973. In 1981, 108,000 Baccalaureate degrees were awarded in education as compared to 194,000 awarded in 1973.[11] Almost all public school teachers are college graduates. Over 99% have at least a Bachelor's degree, 49.3% have a Master's degree or a six-year diploma, and 0.3% a Doctor's degree.[12]

In many states, there are two steps or levels of certification:

1. provisional (temporary or probationary) and
2. permanent (life) certificates

A general pattern of requirements for the second level of certification is a Master's degree (or 30 semester hours beyond the Bachelor's degree) and several years of teaching experience.

2. Pre-service Science Education

Elementary school teachers generally perceive themselves as less well-qualified to teach science than mathematics, reading, and social studies.[13] This may be because they usually have taken little or no science in academic coursework. States seldom require that elementary school teachers take science courses before being certified.

To be certified to teach at the elementary level, a student must complete a four-year Baccalaureate program. Some colleges offer elementary education degree programs that lead to state certification, while others require students to pursue a broad liberal arts background augmented with special courses in education. Many state requirements for elementary certification have the following pattern:

Baccalaureate degree, including

a. 24 semester hours of education courses
b. one semester of supervised student teaching in an elementary school

Secondary school science teachers have considerably stronger preparation in the sciences. For example, in the State of New York a minimum of 36 semester hours of college level work in the sciences is required for certification to teach science.[14] Many science teachers have a more substantial background in the academic sciences. The general pattern of preparation for secondary science teachers is:

Baccalaureate degree, including

a. at least 36 semester hours of science,
b. 12 semester hours of education courses,

c. one semester of supervised student teaching in science in a secondary school

A few states have separate certification requirements for middle/junior high school teachers, but the vast majority have only the elementary (N-6 or N-8) and secondary (7-12 or 9-12) level certificates.

3. In-service Science Education

In-service education is sometimes undertaken by the individual teacher without institutional support. It may take the form of independent study, work on the curricula of the school, special workshops, short institutes and graduate work at universities. Local school systems also provide opportunities, such as conferences and workshops, to help teachers update their knowledge. The institutes, workshops, and conferences sponsored by the National Science Foundation were a significant contribution to in-service education during the 1970s. Forty-seven percent of the high school science teachers, 32% of the junior high school teachers, and 12% of the teachers of grades four through six had participated in at least one of these activities.[15] A recent survey showed that more than 40% of all science, mathematics and social studies teachers had taken a course for college credit during the preceding year.[16]

The salary structure of teachers is low when compared to those of other professions in the United States. The national average for a beginning teacher was $14,000 in 1984-1985, while the average salary of all teachers was $23,546. In the mid-1980s, teacher salaries began to rise relative to the rate of inflation after losing ground between 1974-1983. Actual purchasing power from teacher's salaries in 1985 was about equal to that of 1973, the peak for teachers across the nation. To alleviate teacher shortages, some states and large municipalities implemented higher starting salaries to bring them up to a more competitive level. In 1985, for example, New Jersey adopted a statewide minimum of $18,500. These gains, however, were not representative of the national wage scale for most entry-level teaching positions.[17]

There is a growing concern that teacher shortages, particularly in mathematics and science, will reach crisis proportions in the 1990s as states raise their academic standards for high school graduation. To attract and keep bright, able graduates in the teaching profession, a number of strategies have been instituted by state education agencies. Scholarships and fellowships in math and science education have been offered to deserving undergraduate and graduate degree candidates.

Regulations regarding in-service training of teachers are not uniform, although a small proportion of cities and school districts have established guidelines designating the number and content of in-service experiences for teachers.

Among the initiatives undertaken in the 1980s by separate states, 20 reported that some form of program for the professional development of teachers had been enacted or approved, while 21 others were contemplating such programs. Incentives to teachers to continue professional growth in the form of career ladders and Master Teacher awards were implemented by 6 states, and proposed for consideration by 24 others.[18] In the vast majority of school systems however, no requirement or incentive currently exists to expand one's knowledge, background or skills once a permanent license has been obtained.

Section 5: Science Teaching

1. Teaching Patterns

Science in the elementary school is usually taught by the generalist classroom teacher in the self-contained classroom. This teacher has the responsibility for instruction in reading, mathematics, social studies, science, art, music, and other subjects. Most often, the teacher does not have a strong backround in any of the sciences. Relatively little time is devoted to science in the elementary schools. It is reported that the average number of minutes a day spent teaching science (K-3) is 17. In grades four to six, an average of 28 minutes a day is devoted to science.[19]

Beginning with the middle or junior high school, instruction becomes "departmentalized." This means that instruction is provided by a teacher specifically certified in an academic field, such as biology, earth science, chemistry, or physics.

In the middle/junior high years, science is becoming a required full year course in each of the grades. In some schools and states, junior high science is still a "half-year course." In these cases, students study health, industrial arts, etc., in the remainder of the school year.

At the high school level, science curriculum also has a lower priority than subjects such as English and social studies. Since 1983, most states have moved toward increasing graduation requirements. In 1989, at least 24 states will require two years of science, as compared to four for English and three for social studies.[20]

2. Teaching Methods

The following teaching and learning practices characterize science education in the elementary and secondary schools in the United States.[21]

1. "Hands-on" or manipulative materials were used in 48% of classes at least once a week.[22] Science educators are concerned about science classes where manipulative materials are never or seldom used and that the amount of "hands-on" experiences will be further reduced by declines in school budgets.
2. The textbook continues to occupy a central role in science instruction. Textbooks are used in virtually all science classes with approximately one-third of the classes using multiple texts.[23]

3. Lecture and discussion are the predominant techniques used in science classes.[24]
4. Alternate activities such as library work, student projects, field trips, and guest speakers are other approaches to science instruction.[25]
5. Films, filmstrips, film loops, slides, tapes, and records are used. Calculators, computers, television, and other technological developments are also influencing science instruction.[26]
6. In reviewing the three studies of science education, a committee of the National Science Teachers Association concluded that the "teacher is the key" to good science instruction, and that more support must be given to the teacher to make good science instruction possible.[27]

From data collected in the SISS, it appears that the field trip is becoming an "endangered species." At all levels, the majority of teachers (68% at grade 5, 89% at grade 9, and 93% at grade 12 physics) reported that they rarely or never schedule field trips for their science classes. The "lecture," "question-answer," and "same assignment" modes form their teaching strategy. Such a pattern is easily interpreted as a "textbook dominant," approach. On the same instrument (SISS Teacher Questionnaire), all teachers reported that they "occasionally or frequently" present science demonstrations (74.0% in grade 5, 85% in grade 9, and 93% in grade 12 physics). Students performing laboratory experiments was done "frequently" in 19% of the grade 5 classes, 55% of the grade 9 classes, and 70% of the physics classes. Perhaps, a number of U.S. science teachers have evolved an eclectic approach, incorporating the demonstration and laboratory with the textbook, lecture, and question/answer format.

3. Student Assessment

As there are no national examinations and only one state-administered science examination system (New York), the schools and teachers have the major responsibility for developing an appropriate assessment plan.

The following information was collected with the SISS Teacher Questionnaire. At all levels, teachers reported that they rarely or never used "standardized tests produced outside the school" (74% at grade five, 66% at grade nine, and 64% for physics courses). The most common assessment procedure was "teacher-made objective (short answer) tests." This was reported to be used "frequently" by 56% of the grade five teachers, 72% of the grade nine teachers, and 62% of the physics teachers. In contrast, only 14%-17% of these teachers used "teacher-made essay tests (requiring at least one paragraph of writing)." The "use of performance on homework assignments" in assessing students was a "frequent" or "occasional" practice reported by the majority of the teachers sampled (76% at grade five, 80% at grade nine, 85% in physics). Consistent with the demonstration/ laboratory approach cited earlier, these teachers reported "frequent use of performance on laboratory exercises and/or projects" (24% at grade five, 50% at grade nine, and 66% in physics) in assessment.

4. Assistance and Supervision

About 75% of schools with grades 10 through 12 have science department chairs who supervise science instruction. More than half of all elementary and junior high schools have no such supervision. At the elementary school level almost 20% of the school principals do not feel well qualified to supervise science instruction.[28]

In U.S. schools, science teachers are provided very little direct assistance and/or supervision. From the SISS School Questionnaire results, it is clear that laboratory assistants or technicians are almost non-existent. The vast majority of schools (91% at grade 9 and 87% at grade 12) reported that "none" of these personnel were employed at their schools. Few principals are trained in science, and they are unable to provide specific guidelines or recommendations. Larger schools and districts employ science supervisors, consultants, or directors. These specialists have few if any teaching responsibilities. The scope of their duties ranges widely, but could include equipment requisition, hiring and evaluation of teachers, working with teachers on curriculum revision, student program development, and the development of programs for student assessment. In most schools, an experienced science teacher is appointed as a science department head, chair, or team leader. These people have primary responsibilities as classroom teachers with one or more periods "released" to coordinate departmental activities. With the small amount of time allotted, much of what they do is order equipment and supplies, requisition textbooks and lab books, and schedule classes and labs. Approximately 27% of elementary schools, 45% of lower secondary schools, and 75% of upper secondary schools have department heads in science.[29]

At the state level, the State Education Departments employ specialists in science education for advice and assistance to the science programs in science education. In a few states, there are regional "educational service centers," which provide some of these services. The monitoring or "inspection" role of these state/regional science specialists is minor.

5. Professional Associations

The major professional association for science teachers is the National Science Teachers Association (NSTA). The NSTA schedules a national meeting and three regional meetings each year at which science teachers can present and learn about local, state, and national projects, activities and developments and can view the latest in science textbooks and equipment. Published through the NSTA are three journals: Science and Children (for elementary and middle school teachers), The Science Teacher (for secondary teachers), and the Journal of College Science Teaching. Further, the NSTA publishes a wide variety of materials for teachers.

There are several more specialized organizations affiliated with NSTA: the Association for the Education of Teachers in Science (AETS), the Council for Elementary Science International (CESI), the Council of

State Science Supervisors (CSSS), the National Association for Research in Science Teaching (NARST), the National Science Supervisors Association (NSSA), and the Society for College Science Teachers (SCST). Science Education and the Journal of Research in Science Teaching are important research journals.

Science teachers at the secondary level may be active in one or more of the following: the National Association for Biology Teachers (NABT), the American Association of Physics Teachers (AAPT), and the Division of Chemical Education of the American Chemical Society, etc. These specialist teacher groups are affiliated with their respective scientific organizations, such as the American Institute for Biological Science (AIBS), American Chemical Society (ACS). Again, journals and conferences are the main methods of communication among members.

Section 6: Other Topics

1. Laboratories

Laboratory facilities for science are usually not provided at the elementary level. Only nine percent of elementary science classes in grades four through six are conducted in labs and special science rooms. Most students (54%) are taught science in rooms containing "portable science materials," while over one third learn in rooms that contain no special facilities whatever.[30] There is a greater emphasis upon laboratory experiences at the secondary level. Forty-three percent of upper secondary level students taking science have some aspect of laboratory work or projects incorporated fairly often, or frequently, in their coursework.[31] Allocation and upkeep of special laboratory rooms for science instruction, at all grade levels, is heavily dependent upon space availability and perception of need by the individual school districts or educational systems.

2. Equipment and Supplies

A frequent complaint of U.S. science teachers is that a dearth exists of functioning, modern equipment and adequate supplies of materials to conduct high quality, activity-oriented science programs. The underlying problem is a lack of money in the school budget for such items. Relatively few schools have budgets specifically allocated for science equipment and supplies, although the likelihood of the existence of such budgets increases at the higher school levels or grades. In general, more funding is allotted for the purchase of supplies than science equipment. In a national survey taken in the late 1970s, 20% of elementary, 29% of lower secondary, and 57% of upper secondary schools indicated that specific budgets were set aside for the purchase of science supplies.[32]

3. Talented Students

At the elementary and middle/junior high levels, relatively few special programs exist for students talented in science. At the high school level, many schools offer talented students the opportunity to accelerate their science program by taking the traditional 10th grade course as a 9th grader with further acceleration throughout the high school years. Their acceleration usually results in the students electing one or more of the advanced (second year) science courses. The most frequently offered advanced science course is Second Year (or Advanced Placement) Biology. Students can earn college credit for these courses, if they score high enough on the advanced placement test.

A few large schools, counties, and/or states have established special schools for students talented in science. Perhaps the most well-known of these is the Bronx High School for Science in the New York City School System. More recently, the North Carolina School of Science and Mathematics was established. Many summer science programs are offered to students with special abilities. These are often supported by the National Science Foundation (NSF), private or public corporations, universities, or other funding sources. Most of these are short-term projects which focus on specialized topics and suffer from a lack of "follow-through."

A number of scholarships and competitions are available for talented science students. The Westinghouse Talent Search and National Merit Scholarships reward outstanding science students. The winners are awarded scholarships for college study. A more recent development is the National Science Olympiad. A series of individual and team events assessing knowledge of science facts, concepts, processes, skills, and applications are scheduled. Teams from schools representing each state compete against each other.

4. Special Groups

Many programs have been developed to provide activities and curricula for students who are mentally, visually, physically, or hearing handicapped. These exemplary programs help students learn science through the senses or abilities they possess. Many of these projects are supported by the U.S. Department of Education and other agencies.. The products of the programs (activities and curricula) have been found to be useful for other groups of students as well.

5. Computers

Computers have become familiar objects in American schools. About 82% of all elementary, 93.1% of all junior high schools, and 94% of all senior high schools were using microcomputers by the fall of 1984.[33]

The data collected in the SISS Teacher Questionnaire (in the spring of 1983) indicated "access to a computer at school" in 34% of the grade 5 schools, 53% of the grade 9 schools, and 64% of the grade 12 schools.

Computer literacy programs for students as well as instructors represent its most common use, followed by drill and practice, tutorials, and simulation exercises.[34]

In science, interactive courseware has been created that extends the range of computer applications. Laboratory experiments can be conducted, for example, in which the computer can be used to measure, record and graph data as it is received from heat, light, or sound sensor probes connected to the terminal. Additional uses in science include its utilization in word processing and database management for student projects.

6. Out-of-School Science

Opportunities to pursue science interests outside the classroom are available for both secondary and elementary students. Universities, museums, planetariums, zoos, botanical gardens, science academies, and national science or science-related organizations, societies and councils sponsor programs which youngsters can attend after school or on weekends.

There are statewide and nationwide competitions in which the best students report the outcome of science research. Winners are often rewarded with college scholarships.

Institutions in the private sector also initiate programs which donate money, equipment, personnel, or facilities to nurture science interest and talent in the school-aged population. On a volunteer basis, internships, mentorships, and apprenticeships are often established with health care professionals, laboratories, and hospitals.

FOOTNOTES

Chapter IV

1. U.S. Bureau of the Census, Statistical Abstract of the United States: 1985, (Washington, D.C.: U.S. Government Printing Office) p. 129 (No. 205).

2. National Center for Education Statistics, The Condition of Education, 1984, Vance Grant and Valena W. Plisko, Eds., (Washington, D.C.: U.S. Department of Education), p. 152.

3. U.S. Department of Education, The Nation Responds, 1984 (Washington, D.C.: U.S. Office of Documents), pp. 144-146.

4. Ibid.

5. This discussion of goals for science education is adapted from: National Science Teachers Association position statement, Science-Technology-Society: Science Education for the 1980s (Washington, D.C.: National Science Teachers Association, 1982), and Willard J. Jacobson, "Goals for Science Education," Studies in Science and Mathematics Education: An International Research Journal, vol. 1., no. 1 (New Delhi, India: National Council of Educational Research and Training, 1978), pp. 1-6.

6. National Science Teachers Association, Science-Technology-Society for the 1980s, (Washington, D.C.: National Science Teachers Association, 1982), p. 3.

7. Norris C. Harms and Robert E. Yager, eds., What Research Says to the Science Teacher, vol. 3 (Washington D.C.: National Science Teachers Association, 1981), p. 115.

8. James V. DeRose, J. David Lockard, and Lester G. Paldy, "The Teacher is the Key: A Report of Three NSF Studies," in What are the Needs in Precollege Science, Mathematics, and Social Science Education? Views from the Field, ed. National Science Foundation (Washington D.C.: U.S. Government Printing Office, 1980), p. 44.

9. Ibid.

10. Ibid., p. 49.

11. American Chemical Society, Tomorrow - The Report of the Task Force for the Study of Chemistry Education in the United States, (Washington, D.C., American Chemical Society, 1984), p. 1.

12. U.S. Bureau of the Census, Statistical Abstract of the United States: 1985, (Washington, D.C.: U.S. Government Printing Office) p. 140 (No. 225).

13. Iris R. Weiss, *Report of the 1977 National Survey of Science, Mathematics and Social Studies Education*, (Washington, D.C.: U.S. Government Printing Office, 1978, p. 142.

14. The University of the State of New York, *Teacher's Certificates* (Albany, New York: The State Education Department, 1973), p. 10.

15. Iris R. Weiss, *Report of the 1977 National Survey of Science, Mathematics, and Social Studies Education*, (Washington, D.C.: U.S. Government Printing Office, 1978), p. 69.

16. Ibid., p. 140.

17. Jonathan Friendly, "After Lag, Teachers Start to Catch Up on Pay," *New York Times*, Vol. CXXXIV, (Aug. 31, 1985), pp. 1 and 5.

18. U.S. Department of Education, *The Nation Responds*, 1984 (Washington, D.C.: U.S. Office of Documents), pp. 144-146.

19. Iris R. Weiss, *Report of the 1977 National Survey of Science, Mathematics, and Social Studies Education* (Washington D.C.: U.S. Government Printing Office, 1978), p. 51.

20 U.S. Department of Education, *The Nation Responds*, 1984 (Washington, D.C.: U.S. Office of Documents), pp. 144-146.

21. The major source for these statements is: Iris R. Weiss, *Report of the 1977 National Survey of Science, Mathematics and Social Studies Education*, (Washington, D.C.: U.S. Government Printing Office), 1978.

22. Ibid., p. 107.

23. Ibid., p. 89.

24. Ibid., p. 106.

25. Ibid., p. 103.

26. Ibid., p. 112.

27. James V. DeRose, J. David Lockard, and Lester G. Paldy, "The Teacher is the Key: A Report of Three NSF Studies," in *What are the Needs in Precollege Science, Mathematics, and Social Science Education? Views from the Field*, ed. National Science Foundation (Washington D,C,: U.S. Government Printing Office, 1980), p. 49.

28. Iris R. Weiss, *Report of the 1977 National Survey of Science, Mathematics, and Social Studies Education* (Washington D.C.: U.S. Government Printing Office, 1978), p. 51.

29. Unpublished results from Second International Science Study, New York: Teachers College, Columbia University.

30. Iris R. Weiss, Report of the 1977 National Survey of Science, Mathematics, and Social Studies Education, (Washington, D.C.: U.S. Government Printing Office, 1978), p. 129.

31. The National Science Board Commission on PreCollege Education in Mathematics, Science and Technology, Science and Engineering Education: Data and Information, (Washington, D.C.: Office of Scientific Engineering Personnel and Education, 1982), p. 19.

32. Ibid., p. 15.

33. National Center for Education Statistics, Condition of Education, 1985, Valena White Plisko and Joyce D. Stern, eds. (Washington, D.C.: U.S. Department of Education), errata sheet, Table 1.14.

34. A Report by the Office of Technology Assessment, Informational Technology and its Impact on American Education, (Washington, D.C.: U.S. Government Printing Office, November, 1982), p. 143.

BIBLIOGRAPHY

American Chemical Society, Tomorrow - The Report of the Task Force for the Study of Chemistry Education in the United States, (Washington, D.C., American Chemical Society, 1984).

Board of Education of the City of New York. Science: Grade 7. Bureau of Curriculum Development. New York City, New York: 1967.

---. Science: Grade 8. Bureau of Curriculum Development. New York City: 1967.

---. Science: Grade 9. Bureau of Curriculum Development. New York City: 1967.

Comber, L.C., and Keeves, J.P. Science Education in Nineteen Countries. New York: John Wiley & Sons, 1973.

DeRose, James V.; Lockard J. David; and Paldy, Lester G. "The Teacher is the Key: A Report of Three NSF Studies," in What are the Needs in Precollege Science, Mathematics, and Social Science Education? Views from the Field, ed. National Science Foundation (Washington D.C.: U.S. Government Printing Office, 1980).

Doran, Rodney L. Basic Measurement and Evaluation. Washington, D.C.: National Science Teachers Association, 1980.

Friendly, Jonathan "After Lag, Teachers Start to Catch Up on Pay," New York Times, Vol. CXXXIV, (Aug. 31, 1985).

Gerlovich, Jack A. and Howe, Trevor G. "Where the Jobs Are." The Science Teacher 50 (March 1983): 58, 59.

Grant, Vance W., and Eiden, Leo V. Digest of Education Statistics. 1980, Washington D.C.: U.S. Government Printing Office, 1980.

Harms, Norris C., and Yager,Robert E.(eds). What Research Says to the Science Teacher, Volume III. Washington, D.C.: National Science Teachers Association, 1981.

Helgeson, Stanley; Blosser, Patricia; and Howe, Robert. The Status of Pre-College Science, Mathematics and Social Science Education: 1955-1975, Volume 1: Science Education. Center for Science and Mathematics Education, The Ohio State University, Columbus, Ohio, 1977. Washington, D.C.: U.S. Government Printing Office, 1977.

Hueftle, Stacey J.; Rakow, Steven J.; and Welch, Wayne W. Images of Science - A Summary of Results from the 1981-82 National Assessment in Science. Minnesota Research and Education Center, University of Minnesota, 1983.

Jacobson, Willard J. "Goals for Science Education." Studies in Science and Mathematics Education: An International Research Journal, Vol. 1, No.1 New Delhi, India: National Council of Educational Research and Training, 1978.

---. "U.S.A. Post-Sputnik Science Curricula." Strategies for Curriculum Change: Cases from 13 Nations. ed. R. Murray Thomas et al. Scranton, Pennsylvania: International Textbook Company, 1968.

Lockard, David J. (ed.). Twenty Years of Science and Mathematics Curriculum Development. Science Teaching Center, U. of Maryland, College Park: The International Clearinghouse, 1977.

Mechling, Kenneth; Stedman, Carlton; and Donnellan, Kathleen M. "Preparing and Certifying Science Teachers." An NSTA Report Science and Children, 20, No. 2, (Washington, D.C.: National Science Teachers Association, October 1982), p. 10.

Miller, J.K. "An Analysis of Science Curricula in the United States." Ed.D. dissertation, Columbia University, 1985.

National Academy of Sciences and National Academy of Engineering. Science and Mathematics in the Schools: Report of a Convocation. Washington, D.C.: National Academy Press, 1982.

National Assessment of Educational Progress. Three Assessments of Science, 1969-1977: Technical Summary. Denver, Colorado: Education Commission of the States, 1979.

National Assessment of Educational Progress. Science Achievement in the Schools, A Summary of Results from the 1876-1977 National Assessment of Science. Denver, Colorado: Education Commission of the States, 1978.

National Center for Education Statistics, Condition of Education, 1985, Plisko, Valena White and Stern, Joyce D., eds. (Washington, D.C.: U.S. Department of Education).

The National Science Board Commission on PreCollege Education in Mathematics, Science and Technology, Science and Engineering Education: Data and Information, (Washington, D.C.: Office of Scientific Engineering Personnel and Education, 1982).

National Science Foundation. Science and Engineering Education for the 1980s and Beyond: A Report to the President. Washington, D.C.: U.S. Government Printing Office, 1980.

---. Educating Americans for the 21st Century: A Report to the American People and the National Science Board. Washington, D.C.: 1983.

---. Science Education Databook. Washington, D.C.: U.S. Government Printing Office, 1980.

---. Science and Engineering Education: Data and Information. Washington, D.C.: U.S. Government Printing Office, 1982.

---. The Status of Pre-College Science, Mathematics, and Social Studies Educational Practices in U.S. Schools: An Overview and Summaries of Three Studies. Washington, D.C.: U.S. Government Printing Office, 1980.

National Science Teachers Association. "The NSTA Position on Curriculum," The Science Teacher. 29 (December 1962).

---. "School Science Education for the 1970s." The Science Teacher. 38 (November 1971), pp. 46-51.

---. "An NSTA Position Statement--Science-Technology-Society: Science Education for the 1980s." Washington, D.C.: NSTA, 1982.

"National Studies Involving Curriculum-An Annotated List of Research Surveys." Education Week, 1, No. 39 (July 1983).

Peng, Samuel S.; Fetters, William B.; and Kolstad, Andrew J. High School and Beyond - A National Longitudinal Study for the 1980s: A Capsule Description of High School Students, National Center for Education Statistics, Washington, D.C.: 1981.

A Report by the Office of Technology Assessment, Informational Technology and its Impact on American Education, (Washington, D.C.: U.S. Government Printing Office, November, 1982).

Stake, Robert, and Easley, Jack. Case Studies in Science Education, Volume 1: Washington, D.C.: U.S. Government Printing Office, 1978.

---. Case Studies in Science Education, Design, Overview and General Findings, Volume II, Washington, D.C.: U.S. Government Printing Office, 1978.

Toch, Thomas. "200,000 Reasons for Concern: A Profile of Those Who Teach Science." Education Week, 27 July 1983.

U.S. Bureau of the Census. Statistical Abstract of the United States: 1980. Washington, D.C.: U.S. Government Printing Office, 1980.

---. Statistical Abstract of the United States: 1981. Washington, D.C.: U.S. Government Printing Office, 1981.

---. Statistical Abstract of the United States: 1985, (Washington, D.C.: U.S. Government Printing Office), 1985.

U.S. Department of Education, The Nation Responds, 1984 (Washington, D.C.: U.S. Office of Documents).

University of the State of New York. The State Education Department - Bureau of Secondary Curriculum Development. Physics - A Syllabus for Secondary Schools. Albany, New York: 1971.

---. Chemistry - A Syllabus for Secondary Schools Albany, New York: 1981.

---. Biology - A Syllabus for Secondary Schools. Albany, New York: 1982.

---. Teachers Certification. Albany, New York: The State Education Department, 1973.

U.S. Department of Education. The Condition of Education, 1983 Ed. Washington, D.C.: U.S. Government Printing Office, 1983.

Weiss, Iris. Report of the 1977 National Survey of Science, Mathematics, and Social Studies Education. Washington, D.C.: U.S. Government Printing Office, 1978.

Welch, Wayne W. "Twenty Years of Science Curriculum Development: A Look Back." Review of Research in Education, 7, pp. 282-306.

Wolf, Richard M. Achievement in America-National Report of the United States for the International Education Achievement Project. New York: Teachers College Press. 1977.

Yager, Robert E.; Aldridge, Bill G.; and Penick, John. "Science Education in the United States." Science Teaching: A Profession Speaks - NSTA Yearbook. Washington, D.C.: National Science Teachers Association, 1983.