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ABSTRACT

Presented are five reviews of the National Assessment of Educational Progress results in science. Dr. Mildred Ballou discusses the objectives of the assessment by age level with concern over explanations for responses, social implications, and validity of testing exercises. Wilmer Cooksey comments on the results as viewed by the classroom teacher and interprets results at each age level with implications pertinent to science education. Dr. Richard Merrill discusses the limitations of the study and makes possible suggestions in overcoming those limitations. Dr. Elizabeth Wood defines difficulties and hazards of the project concerning the public and mass media problems with making broad generalizations from specific test items. Dr. Stanley E. Williamson discusses what the National Assessment of Educational Progress in the sciences means to American education and what the National Assessment Program means to science education in the areas of curriculum design and development, and strategies and techniques of teaching. (BB)

OBSERVATIONS AND COMMENTARY
OF A
PANEL OF REVIEWERS

NATIONAL ASSESSMENT OF EDUCATIONAL PROGRESS

A Project of the Education Commission of the States

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FOREWORD

The Education Commission of the States will issue National Assessment reports from time to time without interpreting the results or explaining their implications. This is partly because the National Assessment program is not an experimental design relating input variables to results and partly because the Commission does not want to assume the role of "authority" for what the reports may mean. The Commission will encourage through the years, however, thoughtful speculation about the implications of National Assessment for education.

To encourage examination of assessment results, the Commission has asked 10 people interested in science or citizenship education to give their reactions to National Assessment and to the results of the first two reports. It is hoped that these commentaries will assist others in evaluating the results.

These commentaries accompany the Science and Citizenship reports 1 and 2 (July, 1970), which should be read to place these commentaries in full perspective.

James A. Hazlett
Administrative Director for
National Assessment

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Executive Director
Education Commission of the States

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COMMENTARY: NATIONAL ASSESSMENT IN SCIENCE

Mildred Ballou

The results of National Assessment in the area of Science provide interested members of our society with valuable information regarding the knowledges, understandings, skills, and attitudes of our young people about science. The picture, of necessity, is incomplete; but, for the first time in the history of American education, we know how approximately 100,000 people (ages 9, 13, 17, and 26-35) responded to questions and problems carefully constructed to help determine the degree to which objectives identified through the cooperative efforts of science scholars, educators, and the lay public were achieved. As one scrutinizes the exercises which have been released and the responses made to each exercise by each age level, some implications for curriculum change emerge. This does not mean that results of National Assessment dictate curriculum or that a national curriculum will result. Rather, as students' strengths and weaknesses are uncovered, thoughtful educators will take a hard look at what students know and can do, interpret why, _and_ hypothesize possible reasons why certain weaknesses appear. Questions about what is worth learning will be raised, all of which adds up to a new appraisal of science education. An examined curriculum leads to a dynamic, rather than a static curriculum. By providing the impetus for critical examination of the effectiveness of education, National Assessment has done the educational community, and ultimately all of society, an invaluable service.

Educators have known for some time that elementary school children are extremely interested in science. Studies in this area indicate that 30 years ago the kindergarten-aged child's science interests tended to be limited to his immediate environment. Today's five-year-olds study a wide variety in physical science and considerable depth and breadth in the life sciences. Librarians report that science books are the most popular choices for children in primary and upper elementary grades. New science curricula tend to generate and sustain interests in science. These factors and others may contribute to an increase in science skills and information as measured by Cycle Two of National Assessment,

particularly in the 9- and 13-year-old groups. In any event, current results will provide a basis for comparison of change which has not been available previously.

This commentary will deal mainly with impressions. Do the released exercises appear to be germane to the objectives they were designed to assess? What are some possible explanations for responses given to selected exercises? Do some of the responses have social implications? Each of the four objectives in Science will be discussed by age level responses.

Know the Fundamental Facts and Principles of Science (Objective I) may be acquired in a number of ways. The methods and settings in which a student acquires them (memorization in isolation vs. development through a series of experiences) affect his ability to use them. Since simple recall is all that is required to respond correctly to many of the exercises, one should not get inordinately excited about the large number to which most or a good many 9-year-olds responded correctly. Many of the 85% who indicated they know that protein is important to the building of muscle might not select adequate amounts of protein or even recognize protein foods when given a choice. This does not negate the importance of knowing facts and principles. It must be clear, however, to educators and the lay public that the knowing and the doing are two different things. I would urge science teachers and parents to keep a constant vigil for behaviors which indicate that the student has integrated the fact or principle he can verbalize into his life style. Assessment of knowledge of facts and principles is much easier than assessment of resultant behaviors, and as one observes behaviors it is not safe to conclude that the person being observed understands the principle. The fact that 61% of the 9s know how to connect a bulb to a flashlight battery does not guarantee that they understand the principle. Overgeneralization about the significance of accumulated responses to Objective I is dangerous. Only 7% of the 9-year-olds responded correctly to the exercise in which they were asked what the temperature of a mix of equal amounts of 70 F and 50 F water would be. Few children have had an opportunity to try this, and in attempting to deal with it as an abstraction, they saw it as an arithmetic problem where you just might add the two numerals (69% thought the resulting mix would have a temperature of 120 F).

Exercises to which <u>most</u> 13-year-olds responded correctly were related to their life experiences: tooth brushing, rain clouds, a balanced meal, comfortable classroom temperature, and oxygen needed for a fire. Through vicarious experience they had learned that the lack of atmosphere on the moon would preclude such activities as building a bonfire or flying a kite, but would allow the launching of a rocket.

Those exercises to which <u>a good many</u> responded correctly raise some interesting questions. Does one need to know a scientific fact or principle to know that "The earliest men on earth were probably ...not city dwellers..."? Do tradition and observation, rather than knowledge of science, explain why 48% of the 13s thought that when a person faints you should lay him down and apply cold packs rather than the correct response (given by 32%): lay him down and keep him warm? The Adults probably would have responded similarly. Cold cloths have been, are, and apparently will continue to be applied to foreheads of people who have fainted. If educators and the lay public deem it important, 13s can learn that since the person who has fainted is likely to be chilling, covering him with a blanket will help him more than the cold pack. From the data given it is tenable to conclude that during the years in elementary school students have acquired a good bank of science facts and principles, but that an increase is highly desirable.

In spite of the fact that many 17-year-olds have only had one year of science instruction since they were 13, rather significant gains were made, according to responses given. To more nearly approximate an adequate assessment of knowledge of the career science student, as well as the student whose major interests and abilities lie in other areas, great diversity in difficulty of items was provided. The responses seem to point to a need for increased understanding of human reproduction. Only 41% knew that the function of the placenta is to carry nourishment to the baby. More shocking, particularly since half of the respondents were girls, was that only about one-fourth of the 17s knew that, on the average, in human females the egg is released 14 days after menstruation begins. With today's emphasis on population control, and an increase in illegitimate births, facts in the human reproduction area have tremendous personal and social significance. Curriculum revision and the development of more successful teaching techniques seem to be in order.

The responses of young adults indicate a general decline in information compared to 17s. A notable exception is an increase in knowledge regarding body function, which may be attributable to experience. The exercises to which few Adults responded correctly tended to be of a technical nature, such as atomic weights, uranium-lead dating, DNA, and the periodic table. Adults responded I-don't-know more frequently than other age levels, which may reveal that interests, success in areas other than science, and being away from the school environment make guessing less necessary to the preservation of an adequate self concept than for persons in school.

Objective II, Possess the Abilities and Skills Needed to Engage in the Processes of Science, is much more difficult to assess than Objective I. Yet it is in this area that the assessment people used the greatest amount of ingenuity, in my judgment, in devising and administering exercises which actually get at some of the skills and abilities involved in sciencing. The major changes in science teaching today are toward the development of process skills. The rate at which schools modernize their science programs is tangential to monies available, teacher training and retraining, leadership, and public acceptance. As balance beams and weights, thermometers (they're likely to be Celsius rather than Fahrenheit) for each student to use in experimentation, and other pieces of scientific equipment are available and properly used in classrooms, students should be recording data of many kinds in the form of graphs, charts, and tables, and using numerous techniques, which should contribute to data interpretation skills.

Nine-year-olds were presented with this chart:

Weights of some Chemical Elements
Found in a 100 pound Human

Calcium	2 pounds
Carbon	18 pounds
Hydrogen	10 pounds
Oxygen	64 pounds
Phosphorus	14 ounces
Sodium	2 ounces
Sulfur	4 ounces

They were asked which chemical element included in this chart is found in the greatest amount. Eighty percent correctly chose 64 pounds. When asked which was found in the least amount only 54% responded correctly: sodium, 2 ounces. Fourteen percent chose calcium, 2 pounds, which may indicate confusion between pounds and ounces. The "greatest amount" choice simply involved selecting the largest numeral.

That rather few (17%) of the 9-year-olds in the sample were able to reason, given the fact ice melts at 32 F, that water cooled down from 40 F would freeze at 32 F is not surprising. Ice starts to melt into water when the surrounding temperature goes above 32 F. The exercise itself is problematical.

Developing exercises assessing students' abilities limited to a single objective, at best, is difficult. The exercise in which 13s are given several choices why the paint on one side of a house is not lasting as well as the paint on the other sides may not get at the ability to engage in the process of science as much as it gets at other objectives. Thirteen-year-olds' inability to identify a thermometer as the laboratory equipment necessary to determine the boiling point of water probably reflects the lack of equipment and laboratory experience in many schools.

Seventeen-year-olds' responses to Objective II reflect the wide range of course choices available to high school students. That 68% answered the ecosystem disturbance item correctly is encouraging: many of the respondents have already completed their formal education, but with knowledge of the ecological system they possess a degree of scientific literacy in an area of great concern today and in the years ahead.

Adults responded to Objective II quite similarly to Objective I: they did best on day-to-day, life-use items, and on items of a more academic nature they often did less well than 17s. It was heartening to note that Adults, too, did rather well in ecological exercises.

Objective III, Understand the Investigative Nature of Science, provides some interesting ideas students and young adults have about differentiating scientific probing from other forms of data and information collection. Nine-year-olds recognize seed planting, combined with observation and keeping records of growth, as a possible science experiment. While one cannot

generalize on the basis of one released exercise, at least when asked to identify the most scientific statement among the choices given about why an inflated balloon which had been rubbed against the wall stayed there, 78% responded that there must be a reason other than magic or that the balloon wanted to stay. It is common for 4s, 5s, and often 6-year-olds to explain events in terms of magic and to assign human characteristics to inanimate objects. This one bit of evidence that most had moved from the make-believe, phenomenistic level of thinking, to looking for cause-effect relationships is encouraging. It is not surprising that 9s could not identify a scientific theory as an explanation of why some things act the way they do. Perhaps the definition given as the correct response is too limited. According to Compton's Illustrated Science Dictionary a scientific theory is:

> An established or accepted explanation of relationships among observed scientific facts, events or phenomena; also, the result of a verified hypothesis; also, sometimes, a hypothesis concerned with major phenomena.

It is not surprising that 13s had greater success identifying the unscientific than the scientific. J. D. Wienhold, in an unpublished doctoral dissertation completed in 1969, reported that attempts to measure unscientific attitudes of teachers were more successful than attempts to measure scientific attitudes. This may be related to the difficulties involved in the construction of an instrument.

The released exercises under Objective III for 17s and young adults are too few to provide a basis for drawing conclusions. It is interesting to note that the scientific theory exercise for Adults states, "A possible explanation...." Perhaps the simplification of the exercise for 9s by deleting the word possible resulted in complication!

Implications for curriculum improvement in the area of understanding the investigative nature of science are worthy of attention. Objective III is inexorably tied to Objective II. Perhaps as students do more active sciencing, and less rote learning about science, they will discover for themselves the investigative nature of science.

Objective IV, Have Attitudes about and Appreciation of Scientists, Science, and the Consequences of Science that Stem from Adequate Understandings, is another area that is difficult to assess. Many people who say they don't believe in astrology read their horoscopes daily - - and wonder! Released exercise results for 9s reveal only that many children are aware and suspicious of certain superstitions. Thirteen-year-olds upset a cultural bias as they responded that they believe most women can be successful scientists. Since only about 7% of the women scientists in the world are American, perhaps the responses of 13s provide an infinitesimal sign of things to come! That only 8% indicated they are often curious about why things in nature are the way they are (64% said they are sometimes curious) is perhaps the most disappointing and alarming result released. Preschoolers are extremely curious and investigative. Is the educational and socialization process so stifling and inhibiting that curiosity about nature diminishes? Or could it be that young adolescents interpreted the term nature too narrowly and excluded themselves from nature at an age when self-awareness is a major concern? In any event, an adequate science program encourages and increases curiosity through exciting experiences in inquiry. Curricula and teaching methods must be improved.

Seventeen-year-olds responded that if they learned about a special television program dealing with a scientific topic, they would watch it often (17%); sometimes (64%) are not, in my judgment, cause for concern. Eighty-one percent would be sometimes viewers, which may indicate an ability to judge between and among many excellent programs. Well-rounded people, including scientists, watch different programs to meet personal needs that vary constantly. Winston Churchill read mystery stories to relax when the going was really rough during World War II. Let's upgrade television watching tastes in all areas.

Twenty-nine percent of the Adults said they would watch a science program often, 56% said sometimes, for a total of 85%. Apparently scientific telecasts at least have a fair chance to capture the viewing public.

Purely arbitrarily, I elected to discuss selected exercises under each of the four objectives, state some reactions to the exercises, hypothesize about reasons why some of the responses were given, and indicate some areas in which

improvement seems to be important in science teaching. My major conclusion is that the schools have done a good job with science, but improvement is needed. Exciting curriculum changes and changes in teaching techniques are well under way. I believe that the lay public can view the prospect for tremendous improvement in science education with optimism.

Dr. Mildred Ballou is professor of elementary education at Ball State University, Muncie, Indiana. She received her B. A. and M. A. degrees from Drake University, her doctorate from Northern Colorado University. She has taught nursery school, all elementary grades, special classes for gifted students, undergraduate and graduate classes. She has been a demonstration teacher at Drake, has taught science on KDPS-TV in Des Moines, Iowa, and conducted a summer-long elementary science workshop in LaPaz, Bolivia. She is a past president of the Iowa Science Teachers Association and past secretary of the National Science Teachers Association. She has published numerous articles on science.

SCIENCE ASSESSMENT COMMENTARY

Wilmer Cooksey

Society today is asking some very important questions of educators concerning education in America. Parents are concerned about the reading ability of children, their ability to score on achievement tests, and the high drop out rate. The increasing disorder and vandalism in our schools are indicative that some of our goals are not being reached. The large, complex central administrative offices are constantly being challenged for change to meet the individual needs of pupils in a particular community. Community control of schools is being advocated in many larger cities as a means of improving instruction and classroom performance. Some cities have piloted reading programs using parents as para-professionals in an effort to improve reading. The Federal government has funded various curriculum studies through NSF to improve and revise the teaching of chemistry, physics, biology, earth science, and elementary science. Aside from standardized tests that have ranked students on percentiles, there is little or nothing known as to how much these curricula have contributed to the overall knowledge of our youth. With so much input by scientists and educators and so many dollars from federal funds, educators feel that the youth of today should have a very high degree of scientific literacy. As yet, there is no document that either supports or condemns this assumption.

The National Assessment of Educational Progress, with its census-like results, is the first effort to assess what a student knows, what he can do and what his attitudes are. This commentary is being prepared with these considerations in mind.

In attempting to review this report, I read carefully, analyzed and tried to find an appropriate way to intelligently comment on the results as a classroom teacher. There are many ways to comment on the statistical results obtained in the Science report. I did not want to give data obtainable by reading each exercise, rather I wanted to give the interpretation I got as I studied each age level. I finally decided to comment on each age level and give implications that I see pertinent to science education.

The responses of 9-year-olds in the areas of biology, physical science and earth science indicate that they are equally knowledgeable in each subject. The exercises contain items of general knowledge of the environment. Some exercises could be answered by knowledge obtained from observation of the environment. While the exercises are of general knowledge of the environment, there is science content that could only be learned in a classroom, from actual experiences.

Some explanations for the success of the 9-year-olds may be due to the use of some of the elementary curriculum projects available. Among these, "Science - A Process Approach," is perhaps the most familiar.

From the classroom teacher's point of view, there are several implications for further study and implementation:

1. The primary school pupil is living in a society highly developed in technology. He is constantly using the benefits of scientific knowledge and skills through research and development. If we expect him to have knowledge of facts and principles of science, we must set our objectives and then teach for them. At the age of nine, most elementary pupils are curious about their environment. The inner city, rural, suburban and small town pupil can be taught these facts and principles using the native environment and simple scientific equipment. Some kits are available commercially, or pupil-made apparatus may be used. All 9-year-olds will not have the same motivation. Some will want to pursue various interests toward more detailed experiments. Encouragement and additional stimulus should be given to those with little curiosity.

2. The resources of each community should be utilized in the teaching of science to the 9-year-old. Field trips and community resource personnel should be used extensively. Even though the environment may be essentially manufacturing, service, or agricultural, each community should use its resources to assist in the development of science concepts that are so essential in enabling the child to develop the behavioral objectives set for science instruction.

3. Many elementary school pupils will depend almost wholly upon the school for worthwhile science experiences in

developing acceptable attitudes and appreciations about science.

The performance of 13-year-olds on exercises administered to assess knowledge is higher than I had expected. The exercises they did poorly on may be explained in terms of the amount of experience they had in using tools and interpreting data.

The curricula for elementary science today differ from the traditional curricula. The newly developed programs contain kits for experiments, literature for individual study and objectives stated in terms of behavior. Many of the exercises administered to 13-year-olds required knowledge obtained from experience in or outside the classroom. It is the opinion of this commentator that youth must be taught science and not taught about science. Some of the new curriculum projects do this through experiments and developmental progressions of increasing competence in the process of science.

It is logical to assume that as more elementary schools adopt the newer curriculum programs, the youth completing his elementary education will be more competent in all phases of science information. Elementary teachers will feel more confident in teaching science that is more meaningful to the student.

Approximately 50 percent of the exercises administered to the 17-year-olds were physical science. If we consider the traditional curricula in high schools today and the courses selected by high school students, it is possible for a student to graduate with only one science course. A typical high school graduate may have taken only one science course, usually biology. Other possibilities are biology and chemistry, biology, chemistry and physics, and finally, biology, chemistry and physics, and advanced chemistry. Most of the exercises assessing knowledge required some formal background gained in classroom study. Most of the exercises could have been answered by a student with a biology, chemistry and physics background.

Another factor affecting the responses of 17-year-olds not evident in the report is the type of program being taken. It is possible for a 17-year-old to complete a trade course and take none of the academic sciences. In some high schools, there is a terminal science course that is interdisciplinary in

nature - - an Earth science or physical science course. With these factors in mind, the responses point to a question that has risen frequently - - "How much science do we expect the high school graduate to know?" If we are to answer that question, the implications that can be derived from this report by teachers are:

1. Define the objectives for science in behavioral terms.

2. Select a curriculum providing evidence that the objectives can be met.

3. Select a curriculum that meets the defined needs of the students.

The task of the educator today is to educate all citizens. The person most capable of selecting relevant curricula, writing and defining objectives, and selecting activities to aid the student in reaching these objectives is the classroom teacher. Students terminating their education at the high school level would benefit more from a terminal science course rather than from one of traditional college preparatory courses.

There is a close relationship between the results of the 17-year-olds and the young adults. The 17-year-olds scored higher on exercises requiring knowledge acquired in school while the Adults scored higher in areas of general knowledge. It is reasonable to expect that there are college graduates as well as high school dropouts in this group. It is possible for a college graduate to complete his education without additional science courses, thus not increasing his scientific knowledge.

The fact that Adults answered many exercises I-don't-know indicates the level of maturity and honesty expected of Adults. It also indicates the impact that the era of curriculum revision has had on scientific information. These individuals may have left school before the curriculum revisions began in 1959-1960. Most of the programs were implemented in the schools in the early '60s. A 26-year-old would not have had an opportunity to acquire the new knowledge except through science in college or intensive self study.

In the area of general scientific information obtainable by routine activities as an active citizen, it is logical to expect that the Adults would have a higher percentage of correct responses.

The National Assessment of Educational Progress in its National Science Report has shown how much 9s, 13s, 17s, and young adults know about the facts and principles of science, how much they understand, their ability to interpret data and their attitudes toward science and scientific knowledge. The task before the teachers of science is to interpret this data in a manner such that learning of scientific knowledge by youth will be more rewarding.

Mr. Cooksey in 1969-70 was a graduate student and Chemistry Teaching Associate at the University of Maryland in College Park, Maryland, on leave from Washington, D. C., schools. Prior to his leave he taught in Washington's Douglas Junior High School.

NATIONAL ASSESSMENT OF SCIENCE EDUCATION - A BEGINNING

Richard J. Merrill

This commentary is based upon the preliminary draft of National Assessment of Educational Progress Report I, Science National Results, which was released to the panel of interpreters on June 7, 1970. In addition to that document and the more detailed report which is to follow within the next year, the reader will wish to familiarize himself with goals, procedures, and plans of NAEP and with the Science objectives upon which the assessment was based. These have been published separately by the project.[1]

It should be stated at the outset that this commentator believes that the kind of national assessment being attempted is desirable, that the information it produces will be useful, and that its leading to the development of a "national curriculum" is as unlikely as it is undesirable. NAEP is a well-thought-out plan which is being executed with integrity and skill. Whatever value or interpretation one places on the information the project has gathered about science literacy, one feels that the information is reliable. Sampling procedures have been rational, and the project has made a commendable effort to minimize the effects of reading difficulty and other problems of "test-taking" that always beset educational measurement. The project also seems to be conscious of and open about its limitations. It seems eager to do its best, learn from its mistakes, and do better next time. All criticisms embodied in the following commentary have the dual intent of helping the reader understand the limitations of the study and helping the project in its future attempts to overcome those limitations.

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1 Womer, Frank B., What is National Assessment? Ann Arbor, Michigan, National Assessment of Educational Progress, 1969.
Committee on Assessing the Progress of Education, National Assessment of Educational Progress Science Objectives, Ann Arbor, 1969.

THE OBJECTIVES

The statement of science education objectives that served as a basis for assessment was developed by the Educational Testing Service, with the assistance and guidance of a panel of 12 scientists and science educators. The statement of objectives was reviewed by the Exploratory Committee on Assessing the Progress of Education (ECAPE) and by 11 lay review panels prior to acceptance late in 1965. Sub-objectives and representative behaviors for the various age levels were organized under four major objectives:

I. Know the fundamental facts and principles of science. Twenty-nine content categories are suggested. They need not be listed here. Most of the subject matter commonly dealt with in science in grades K-12 could be listed under one or another of the categories. No major omissions are evident, nor do any of the categories seem inappropriate.

II. Possess the abilities and skills needed to engage in the processes of science.

A. Ability to identify and define a scientific problem.

B. Ability to suggest or recognize a scientific hypothesis.

C. Ability to propose or select validating procedures (both logical and empirical).

D. Ability to obtain requisite data.

E. Ability to interpret data; i.e., to comprehend the meaning of data and recognize, formulate, and evaluate conclusions and generalizations on the basis of information known or given.

F. Ability to check the logical consistency of hypotheses with relevant laws, facts, observations, or experiments.

G. Ability to reason quantitatively and symbolically.

H. Ability to distinguish among fact, hypothesis, and opinion; the relevant from the irrelevant; and the model from the observations the model was derived to describe.

I. Ability to read scientific materials critically.

J. Ability to employ scientific principles and laws in familiar or unfamiliar situations.

III. Understand the investigative nature of science.

A. Scientific knowledge develops from observations and experiments and the interpretation of the observations and the experimental results; such observations and experiments are subject to critical examination and to repetition.

B. Observations are generalized in laws.

C. Laws are generalized in terms of theories.

D. Some questions are amenable to scientific inquiry and others are not.

E. Measurement is an important feature of science because the formulation as well as the establishment of laws are facilitated through the development of quantitative distinctions. Measurements are inherently and only approximate and are progressively inclusive and precise.

F. Science is not, and will probably never be, a finished enterprise.

While all of the statements under objectives II and III are reasonable there seems to be considerable redundancy. II A is quite similar to III D, and II B, C, D and E overlap III A. At least two important objectives, development of classification systems and communication of scientific information, were overlooked or at least not addressed directly. NAEP may in the future wish to consider combining objectives II and III, or dividing them differently.

IV. Have attitudes about and appreciation of scientists, science, and the consequences of science that stem from adequate understandings.

A. Recognize the distinction between science and its implications.

B. Have accurate attitudes about scientists.

C. Understand the relationship between science and misconceptions or superstitions.

D. Be ready and willing knowingly to apply and utilize basic scientific principles and approaches, where appropriate, in everyday living.

E. Be independently curious about and participate in scientific activities.

The writer of attitude objectives is always faced with a dilemma. If he decides, somehow, what the "desirable" attitudes and behaviors are and states them, they will nearly always be controversial. If, on the other hand, he decides that any attitude is acceptable as long as it is based on (or held in light of) accurate information, then he is really only measuring knowledge, not attitudes. This conflict is evident in the set of objectives used. There is a little of each approach, and "Have accurate attitudes about scientists" can't make up its mind. This goal area needs to be reworked. Such recent statements as the Educational Policies Commission's Education and the Spirit of Science,[2] NSSA's Behavioral Objectives in the Affective Domain[3] and the Science Framework for California Public Schools[4] should be very useful. Of the present set, objectives D and E come closest to the mark, but their measurement was far from adequate in the assessment.

On the whole, the objectives upon which the Science assessment was based are valid, well-stated, and deserving of careful attention by school people and interested citizens.

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[2] Educational Policies Commission, Education and the Spirit of Science, Washington, D.C., National Education Association, 1966.

[3] Eiss, Albert F. and Harbeck, Mary B., Behavioral Objectives in the Affective Domain, Washington, D.C., National Education Association, 1969.

[4] California State Department of Education, Science Framework for California Public Schools (Preliminary Edition), Sacramento, 1969.

THE EXERCISES IN RELATION TO THE OBJECTIVES

In general the exercises released are clear, concise, unambiguous, and related to the major objectives they purport to measure. The overwhelming majority of exercises are quite conventional multiple-choice items with I-don't-know as an extra alternative. I-don't-know turned out to be a very attractive alternative to many Adults on many items. It is possible that a disproportionate number of correct answers went down the "don't know" sink. This hypothesis might be worth checking on another round by administering some persons an alternative form in which a choice is forced but the person can indicate his degree of confidence in his answer, e.g., "sure, probably, or wild guess."

The distribution of numbers of exercises by objective and age level is given in the following table. Numbers of exercises released are in parentheses. (Twenty-two exercises not yet scored at the time this commentary was prepared are not included.)

AGE	OBJECTIVE I KNOWLEDGE		OBJECTIVE II PROCESS SKILLS		OBJECTIVE III INVESTIGATIVE NATURE OF SCIENCE		OBJECTIVE IV ATTITUDES	
9	97	(41)	28	(13)	11	(5)	11	(3)
13	74	(28)	30	(12)	8	(4)	10	(3)
17	87	(37)	24	(9)	5	(3)	5	(3)
Adult	86	(35)	23	(11)	5	(2)	5	(1)
Total	344	(141)	105	(45)	29	(14)	31	(10)

The most striking feature is that almost twice as many exercises were administered to measure Objective I as were used for all the other objectives combined! No rationale has been offered to explain this. Perhaps the designers of the items felt that Objective I was most important. Perhaps knowledge items were easier to write. Perhaps it was felt that objectives II, III and IV were adequately covered with fewer exercises. On the other hand, perhaps the designers found that some of the objectives they defined in areas II, III and IV were not measurable within the real or imagined constraints of the study. Possibly time or resources were inadequate for full development of exercises in these areas.

Whatever the reason, the result, in this reviewer's opinion, is that released information for objectives II and III is rather scant, and for Objective IV is so meager as to be almost worthless. With Objective IV the situation is worsened by the unresolved problem of objectives already referred to, and by the questionable validity of some of the exercises released. For instance, Exercise 354 (age 17) and 450 (Adult) asks, "If you learn about a special television program dealing with a scientific topic, do you watch it?" (often, sometimes, never). There are simply too many variables unrelated to interest in science that could affect one's response to this item to put much stock in the pattern of response.

Measurement of attitudes in a "testing" situation is, in any case, extraordinarily subject to interference of the subject's attitudes toward the test, toward the administrator, toward the "image" he seeks to create, and so forth. Perhaps, in addition to experimenting with other kinds of test items such as forced choice, semantic differential and free response, NAEP should in the future seek out and report other kinds of data that might shed light on attitudes about science. For instance, television rating surveys might provide data about how many 17-year-olds watched certain specific science television specials as compared with competing programs.

Another thing to watch for in evaluating the exercises is whether more than one objective is involved in a given exercise. If, for instance, both factual information <u>and</u> process skills are needed to answer an item correctly, then one knows that the successful assessees had both, but one doesn't know where the unsuccessful assessees were deficient. An extreme example is Exercise 21 for 13-year-olds, 17-year-olds and Adults. The exercise calls for using a balance and a ruler to measure the density of a rectangular wood block. This task is directly related to objectives II C, D, E and G, and I F (which would include the concept of density). It is meaningful that only 4% of 13s, 12% of 17s and 12% of Adults were successful on this exercise, but one does not know what kept the great majority from succeeding. Some clues would come from analysis of the other items that were clustered with this one, but those items have not been released. While this is an extreme example, most of the Objective II items for 17s and Adults involve two or three components of Objective II, and many of them require Objective I-type information as well.

Another source of possible confusion is the item which purports to measure process but can be successfully answered on the basis of content knowledge alone. Exercises 152/435 (why few people in the U.S. get smallpox today) and 230/436 (deterioration of paint by wind and sun) seem to fit this category, but this trap has generally been avoided.

Since over half of the exercises have not been released, it is not possible to generalize about how well the sub-objectives were covered. Among the released exercises, this commentator finds little evidence of assessment of objectives II A (ability to identify and define a scientific problem), II I (ability to read scientific materials critically), III B (observations are generalized in laws), III F (science is not, and will probably never be, a finished enterprise), IV A (recognize the distinction between science and its applications), IV D (be ready and willing knowingly to apply and utilize basic scientific principles and approaches, where appropriate, in everyday living) and IV E (be independently curious about and participate in scientific activities).

THE RESULTS

There are a number of things that can be done with the kind of raw data that NAEP has gathered. One is to look for common characteristics among the items on which a given age level is generally successful or generally unsuccessful. This has been done in Report I, Science National Results. The only thing that might be added here is the opinion that perhaps half of the Objective I (knowledge) items which were answered successfully by 66% or more of the 9s and 13s seem to be information that would be as likely to be learned out of school as in school. This would seem to be true of such items as 101/201 (a human baby comes from its mother's body), 102 (a stick needs to be dry in order to burn), 103/202 (you brush your teeth to keep them from decaying), and 106 (thick dark clouds generally bring rain). This is not to imply that the items are trivial, or that it matters whether one learns something in or out of school. It does suggest the possibility that NAEP may here be measuring something that is not primarily a school product. Most of the other exercises in all objective categories for all four age levels seem to measure learning that would probably result from school.

Another way to treat the data is to draw comparisons, wherever possible. Only a small sample of what is to come by way of comparison by region, sex, race, urban-rural, etc., is included in Report I, and this will not be discussed here. Longitudinal comparisons will also be available in three or four years. The comparisons that are not yet available will probably constitute the most interesting and useful information to come out of the assessment.

Comparisons of performance by different age levels on similar exercises (including unreleased ones) are presented and discussed in Report I. Lots of lively dinner table conversations should arise from the implication that 17s have more correct information than Adults, but they don't as often know when they don't know. Some of the comparisons on specific items could lead to worthwhile research.

Another thing that might be done is systematically to place a value on each exercise, decide whether performance was as good as should be expected, and suggest what should be done to improve future performance. That sort of analysis is well beyond the scope of this commentary. A less rigorous approach will be taken - - that of identifying items that come as pleasant or unpleasant surprises to the reviewer.

PLEASANT SURPRISES

101/201 - 92% of 9s and 98% of 13s know that a human baby comes from its mother's body.

108 - 85% of 9s knew that protein is important to building of muscle.

156 - 78% of 9s felt there must be a reason why a rubbed balloon sticks to the wall.

204 - 89% of 13s and 95% of 17s selected the best balanced meal from five alternatives.

UNPLEASANT SURPRISES

228/425 - 53% of 13s and 41% of Adults believed that an ocean fish fossil found in a mountain rock was carried there by a great flood. Only 26% and 39%, respectively, chose "the mountain was raised up after the fish died."

237/441 - Only 38% of 9s and 49% of Adults could time 10 swings of a pendulum.

417 - Only 55% of Adults selected "outlawing the use of insecticides" as not helping to increase food supply.

241/349 - 79% of 13s and 92% of 17s selected mathematics as being useful in scientific research.

304 - 89% of 17s knew that living dinosaurs have never been seen by men. (THE FLINTSTONES notwithstanding!)

306 - 70% of 17s selected "outlawing the use of insecticides" as not helping to increase food supply.

350/446 - 72% of 17s and 57% of Adults understood that repeated measurements are likely to produce results that are "close but not exactly the same."

325/420 - Only 41% of 17s and 45% of Adults knew the function of the placenta.

330/416 - Only 29% of 17s and 55% of Adults knew when, during the menstrual cycle, ovulation generally occurs.

333 - Only 18% of 17s knew that nuclei are more dense than the rest of the atom.

337 - 93% of 17s thought that metal cans for food are made chiefly of tin.

346/444 - Only 33% of 17s and 25% of Adults knew that doubling the linear dimensions of a cube increases its volume eightfold.

348/445 - Only 12% of 17s and 12% of Adults could measure and calculate the density of a rectangular wood block.

332/433 - Only 21% of 17s and 15% of Adults knew that rocks can be dated by the amounts of uranium and lead they contain.

These are by no means the only results that may be considered "good" or "bad"; nor are they all equally important. Each reader should look for his own "surprises," apply his own values and decide for himself what the results mean.

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REVIEW OF REPORT I - SCIENCE NATIONAL RESULTS

Elizabeth A. Wood

The difficulties and hazards of this project must be emphasized before any consideration of the results. Specific questions test specific knowledge in individuals. Reviewers and news media will want generalizations, preferably spectacular and unexpected ones. To make broad generalizations from the limited results available at this stage of the project would be to do a disservice to the project and everyone associated with it, and might result in unwise directives to the educational community. The statement of goals of the National Assessment specifically recognizes this. For example, "One goal of the National Assessment is to report to the American public examples of knowledges, skills, and understandings that are common to almost all American youth." Note that it is examples that are reported, not generalizations.

In Report I of the Science National Results, the writers have, for the most part, been scrupulously honest in detail and laudably cautious in their statements, but even they have erred in some cases. For example, 9-year-olds were told that "Big leaves usually give off more water than little leaves" and were asked to choose the picture of the leaf that gives off most water. Eighty-nine percent performed the simple task of choosing the big leaf, but this was reported as "89% knew that big leaves give off more water than small ones."

The present results are intended as a bench-mark for purposes of future comparisons. Only 40 percent of the results are being released at this time and a repeat survey three years from now will give interesting comparative information. However, each exercise has been administered to approximately 2,000 individuals. Is there not some useful information to be derived from some of the examples available at this time? I think there is.

It is of interest to know that the superstition about number 13 is not widely held by 9-year-olds: only 20% of them thought it unlucky; 45% did not associate bad luck with breaking a mirror, walking under a ladder, or letting a black cat cross your path.

Knowledge about health care is widespread: 91% of 9-year-olds and 98% of 13-year-olds chose the reason for brushing teeth to be to keep them from decaying; 85% of 9-year-olds chose protein as the most effective muscle-builder; 89% of 13-year-olds and 95% of 17-year-olds could select the best balanced meal from five choices. We must remember that we are assessing total learning, not just what respondents have learned in school. Their health habits may come from television and other outside influences as well as from school, and we may be at the mercy of the advertisers in this area.

The fact that 67% of the 17-year-olds and 75% of the Adults could not answer correctly that doubling the length of the edges of a cube multiplies the volume by eight should be taken into account by those designing mathematics and science courses at the freshman college level. It might also be of interest to the packaging industry.

Those planning sophisticated laboratory experiments in physics should be aware of the result that 4% of the 13-year-olds, 12% of the 17-year-olds and 12% of the Adults were able to determine the density of a cube-shaped block of wood when led step-by-step through the processes of determining its volume and mass.

Before attempting to alert the public to the more subtle aspects of environmental interaction, we must consider the fact that 20% of the 17-year-olds and 30% of the Adults thought that the decrease of a rabbit population which fed on grass and was in turn food for hawks would have no effect on either the grass or the hawks.

Those teaching 13-year-olds about the structure of matter should be concerned about the fact that they have given 41% of them the idea that atoms can be seen with a microscope (2% with a magnifying glass and 1% with the unaided eye). The whole laborious effort to determine the arrangement of atoms in such substances as penicillin and DNA by X-ray diffraction would be nonsense if they could be seen with visible light. In view of such grave misconceptions, the fact that 61% of the 13-year-olds said that in hot water the molecules are moving faster than in cold water (12% I-don't-know) while only 49% of the Adults gave this answer (and 32% I-don't-know) may not represent educational progress.

In the opinion of this reviewer, it is not a cause for concern when school children do not know those results of science which are relatively remote from their own experience and which they have probably been asked to accept on the authority of the teacher. Nor is it a cause for satisfaction when they have memorized them. However, it may be a cause for concern when, among 17-year-olds who probably know that iron rusts and who probably have seen rusty cans, 93% said that cans commonly used for containing food were made of tin - - probably because they are called "tin cans" rather widely, for historical reasons. This should alert educators to increase their efforts to encourage students to question labels <u>of all sorts</u> (including labels for groups of people) which are at variance with their own experience.

Although the staff exercised extreme care to try to ensure understanding of the questions by every assessee, there are indications that carelessness and inattention may have affected the results. When 9-year-olds were asked to choose the one item which could NOT have caused the failure of the water supply from a household faucet, 64% chose items which could have caused it. They might have expected that the question would be asked in the positive way. The 17% of 17-year-olds who chose X-rays as detectable with unaided human eyes may have been using the abbreviation "X-rays" for "X-ray photographs." One commonly hears, "Has the doctor seen the X-rays yet?"

The Science exercises were to have been designed to assess achievement of four broad Science objectives. These objectives seem to have been well chosen, in consonance with the thinking of some of our wisest present-day teachers of science. Objective I (Know the Fundamental Facts and Principles of Science) is, in the opinion of this reviewer, less vital to the intellectual well-being of our population and to its scientific literacy than the remaining objectives; namely, II, Possess the Abilities and Skills Needed to Engage in the Processes of Science; III, Understand the Investigative Nature of Science; IV, Have Attitudes about and Appreciation of Scientists, Science, and the Consequences of Science that Stem from Adequate Understandings. The importance of these objectives seems to increase with their designating roman numerals.

Unfortunately the first objective is the easiest to test and by far the greatest number of exercises is directed to testing for it. Hopefully, this imbalance will be corrected in

the next assessment. Ralph W. Tyler, Chairman of the Exploratory Committee and still actively associated with the project, has said, "Learning is a process of acquiring ways of thinking, feeling and acting, that is, of acquiring patterns of behavior." We need more exercises on the National Assessment directed toward assessing learning as defined by Ralph Tyler.

In spite of the inevitable difficulties and disappointments, the first round of the Science National Assessment has produced results which demand attention. Comparison with the second round will be even more fruitful.

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NATIONAL ASSESSMENT PROGRAM IN SCIENCE

Stanley E. Williamson

Since the founding of the American system of public education in the mid-seventeenth century and through its gradual evolution to its present position of importance in today's society, citizens, administrators and teachers of each independent school unit have raised these questions: How well is our school doing toward meeting the needs of the pupils and of this society? In the sciences? The humanities? In citizenship? As educational costs have skyrocketed, school boards and administrators have been hard pressed for definitive answers to these questions. It has not been easy to find direct evidence that our schools have, in fact, been doing a good job of meeting the needs of pupils or of society, as expressed in recognized and stated educational objectives. Even extensive new curriculum programs supported by the Federal government, in English, mathematics, science and social science have not produced indisputable evidence that modern curriculum materials and procedures are more effective than conventional programs.

That a need exists for such information is self-evident. How this evidence can be most effectively and efficiently obtained may be debated for years to come. That some kind of assessment is necessary, that it must come, that in fact it is taking place all the time, is a truism we must accept. The National Assessment Program is one plan that may be used for a systematic, census-like survey of the knowledges, skills, understandings and attitudes held by different age levels in the educational system and by young adults. Only by obtaining some form of objective evidence regarding the achievements of children, youth and young adults in accepted educational objectives can improvements be made in the educational process, its objectives, content and methodology.

It is not only difficult, but dangerous, to draw general conclusions from very limited data such as revealed by this phase of the Assessment program. However, there is evidence to give some tentative answers to the following questions of importance in American education today. In this paper this evaluator will attempt to identify tentative answers to the following questions:

1) What does the National Assessment of Educational Progress in the sciences mean to American education?

2) What does the National Assessment Program mean to science education?
   a) To curriculum design and development?
   b) To strategies and techniques of teaching?

No attempt will be made to critically evaluate the concept of National Assessment, the selection of test items, the sampling techniques or statistics used.

1) What does the National Assessment of Educational Progress in the sciences mean to American education?

   That we live in a science-oriented society, one that is greatly influenced by science and the products of science, and a society which greatly influences the direction and thrust of science, is without question. Science then must be an integral part of general education and is recognized as one of the 10 major areas selected for study and analysis in the first phase of the National Assessment program. This recognition is important, for it reveals the importance and need for science in the educational program K-12. Specifically, the National Assessment of Education in Science has

   a. ...identified the four major general objectives for the 10 selected areas of the curriculum.

      For the first time in many years (possibly ever) the objectives of education and, in general, the specific objectives of each area of the curriculum were developed using the same criteria by scholars in the field, by school staff and administration, and by lay citizens. While it may be impossible to identify educational objectives that satisfy everyone, the objectives selected for the Assessment program are realistic, practical and attainable.

      The objectives are in keeping with current trends in science education and give these trends proper recognition on a national basis. The achievement

of the four objectives in the science program would assure the development of scientifically literate citizens to cope with the many science-related problems in society.

b. ...made a major contribution toward providing a quality science education program for all. As data is collected and analyzed, it will be possible to identify geographical regions, community types or society groups where educational opportunities in the sciences are limited or lacking. Once this Assessment has been made, steps can be taken on a local, state, regional or national basis to make necessary provisions for improvement. Needed facilities, instructional materials and equipment could be identified, as well as new methods and procedures for financing education development.

c. ...provided much-needed evidence for curriculum reform and development in the sciences.

During the past 10 years local, state and national committees have spent much money and given much time and effort to designing new curriculum materials in the basic sciences K-12. The general use and effectiveness of these new programs is not known, nor do we know whether the new materials are reaching children and youth in all geographical sections or all levels of ability. This Assessment program may provide much-needed evidence to enable science educators to critically evaluate current science programs and the contribution made to general education, and to design and develop more effective programs.

d. ...provided needed information to bring about the evaluation and improvement of teacher education programs for prospective science teachers.

In the past, teacher education programs for the preparation of science teachers have not kept pace with current curriculum developments. This was due to a lack of communication between groups preparing curriculum materials and those responsible for preparing teachers. Prospective teachers must

not only know content and methodology, but must also be aware of, and accept, the major objectives in the area they teach. They must understand the place and role of the sciences in the total educational program of children and youth. The National Assessment Program will assist individuals responsible for preparing science teachers to become familiar with the objectives, content and methodology, and the importance of teaching for scientific literacy.

2) What does the National Assessment Program mean to science education?

Study and analysis of the data in the National Assessment report reveals that it has many implications for science education - both positive and negative. Some of the important general implications are:

a. <u>Implications from the objectives</u>

The objectives selected by the science committee are timely, realistic, psychologically sound, practicable and attainable. They are consistent with current developments in the science curriculum. It is assumed that each objective is of major importance and should be somewhat equally assessed. An analysis of the number of exercises at each age level (9, 13, 17 and young adult) for each objective raises some questions. The number of exercises in each category is as follows.

	Objective							
	I		II		III		IV	
	number	%	number	%	number	%	number	%
9 (62)	41	67	13	19	5	8	3	5
13 (47)	28	60	12	25	4	8	3	6
17 (52)	37	70	9	17	3	6	3	6
Adult (49)	35	70	11	22	2	4	1	2
Total Ave.		67		21		7		5

The relative emphasis on exercises for Objective I, Know the Fundamental Facts and Principles of Science, would lead a reader to believe that the Assessment

program places major emphasis on this objective. Modern science programs on the other hand, place much emphasis on objectives III and IV. One may conclude from this that what is actually being emphasized in science teaching today is not being assessed - - at least not in relative proportions. Students assessed were, in general, not high achievers at all age levels in the facts and principles of science, were average or better in abilities and skills, were average in understanding the investigative nature of science, and were low in attitudes toward science and scientists (this may be due to distribution of exercises over the four objectives). Scientific literacy requires the development of proper attitudes and investigative skills as well as a knowledge of fundamental facts and principles. Efforts should be made for a better distribution of exercises over all four objectives. The small number of exercises related to objectives III and IV make it all but impossible to assess achievement in these important aspects of education. In other words, the exercises selected are not assessing achievement of all accepted objectives.

b. Implications from data by age levels

The Assessment program does reveal the gradual, general development of science concepts by 9s, 13s, 17-year-olds and young adults. In general, there is gradual progression in the understanding of concepts for 9s, 13s and 17-year-olds, but a leveling-off for Adults. This may reveal a major weakness, not only in the science program but possibly in the entire educational program, in that students have not mastered the art of learning or developed the desire for continuous self-education after leaving the school. For many students and adults alike, learning is something that takes place only within the four walls of a classroom--for some reason they do not relate learning with experiencing. Major emphasis on scientific facts and principles may not leave time for the other--something that is viable, permanent and transferable. This area has many implications for future research in science education, i.e., at what age level should certain science concepts be introduced in the curriculum? When are concepts

understood? Which objective, if attained, will contribute to a student's understanding of change, accepting change and being able to adjust to it? How can we teach science to insure survival value of the knowledges, skills and attitudes desired?

c. <u>Implications from an analysis of student answers to exercises</u>

The data gathered from the science exercises show what different age levels know and can do, their information and misinformation. The overlap exercises (ages 9-17) reveal about what one would expect. The general drop between 17-year-olds and young adults reveals from these exercises that the curve of forgetting is quite steep and there exists a low degree of permanence in science taught, especially factual information. This is especially true of exercises in the physical sciences using quantitative measures.

1. 9-year-olds (most 100-67%; many 66-34%; and few 33-0%)

While science at this age level is about equally distributed between the biological and physical sciences, the Assessment exercises are distributed 23 biological and 39 physical. Nine of the 23 biological were answered correctly by a majority of the students in comparison to 14 of those in the physical sciences area. Twenty-five were correctly answered (biological and physical) by most children and only three (all physical) by a few children. Forty-one exercises are identified with Objective I, 13 with Objective II, 5 with Objective III, and 3 with Objective IV.

The Assessment reveals a preponderance of exercises in the physical sciences and reveals that 9-year-olds are not achieving well in this area. This may be interpreted as a need for better distribution of exercises drawn from each science and some investigation on the part of science curriculum makers as to adequacy of concept selection and development in the physical science area. Research is needed to identify concept distribution (biological and physical) at this age level. What are the real needs and interests of pupils in this age bracket?

2. 13-year-olds (most 100-67%; many 66-34%; few 33-0%)

Assessment exercises were distributed as follows: 18 in biological sciences and 29 in the physical sciences. Eight of the biological questions were answered correctly by most of the pupils (approximately half) while only six of the questions in physical sciences were answered correctly by most of the students.

One may conclude (1) that physical science exercises were more difficult, or poorly stated, (2) less emphasis is placed on the physical sciences in the school curriculum, or that (3) physical science concepts are more difficult to understand for a majority of students. Exercises involving experiments, abstractions or quantitative measurement are revealed by this data to be more difficult for most 13-year-old students. Here again research is needed in science education on concept, selection and development (content), and methodology. What contribution does laboratory experience make to concept development? To what extent should science be made quantitative at this age level? Should science be theoretical or descriptive?

3. <u>17-year-olds</u> (most 100-67%; many 66-34%; few 33-0%)

Fifty-two exercises were included in the Assessment at this age level - - 37 for Objective I, 9 for Objective II, 3 for Objective III, and 3 for Objective IV. There were 16 exercises from the biological sciences and 36 from the physical sciences. At this age level two of the biology exercises and six from the physical sciences were correctly answered by most of the students. At the other extreme, five of the biology exercises and 10 of the exercises from the physical sciences were answered correctly by few students.

The exercises at this age level are better than two to one from the physical sciences, while in the actual school situation, almost all students elect biology and less than 30 percent elect chemistry and/or physics. Should the Assessment program select exercises that more nearly reflect what is taught in the secondary school or should the science program be redesigned to include more physical science in the scholastic programs of all students?

Here again, exercises from the physical sciences appear to be more difficult for students, revealing weaknesses in objective, content and methodology of science taught at this level. On the other hand, one may seriously question the exercises selected for the Assessment program. Which science concepts are of greatest importance for all students to live in and adjust to technologically oriented society? What kind of evaluative instruments will best reveal the achievement of these concepts? Much research is needed in these areas in science education.

4. Adults (most 100-67%; many 66-34%; few 33-0%)

Forty-nine exercises were included in the Assessment of this age level -- 35 for Objective I, 11 for Objective II, 2 for Objective III, and 1 for Objective IV. Twenty-five exercises were from the biological sciences and 24 from the physical sciences. Only eight exercises were answered by most of the participants (5 biological, 3 physical). The remainder of the exercises were about equal in difficulty. Adults tended to do poorly on factual information exercises and excelled on those related to experience. An obvious implication here is the need in the science education program to develop a structure of science (science built on an understanding of relationship) rather than have mere contact with or rote memorization of the facts and principles of science. Science should be taught so that the processes of science have "carry-over" value in adult life.

These data reveal a need to examine the science program for relevancy and look at its role in assisting the individual in the identification of and development of solutions to daily environmental problems.

a. Implications for curriculum design and development and methodology

At this point in time and state of development, the Assessment of Educational Progress in the sciences does not provide conclusive evidence for making decisions regarding the direction science curriculum design and development should take.

1. The identification of general science objectives is an important first step in any curriculum development program. It now becomes the task of curriculum writers to provide the kinds of experiences that will enable each student to achieve each objective to the level of his ability. It becomes the responsibility of those who design instruments for assessing educational progress to measure the achievement of each objective in relation to its importance. Assessment at its worst could lead to a national curriculum or teachers teaching for the test; at its best it can provide guidelines for future curriculum improvement.

2. A second major contribution of the National Assessment Program is the identification of areas in science education in which research is needed. For example,
   a. Little is known about concept development -- at what level and for how long should given concepts be studied?
   b. How can laboratory experiences be used to provide maximum effectiveness in the learning process?
   c. What methods contribute most to the realization of accepted objectives?
   d. How can a balance be maintained between cognitive and affective domains?

   This Assessment does not answer these questions but does show that such questions exist.

3. The Assessment clearly reveals that while we believe in the development of the four stated objectives it is still most difficult to measure each objective with equal ease. The cognitive domain, both from the standpoint of curriculum development and student evaluation, commands the greater effort and attention. Research is needed to devise science experiences that place more emphasis on the development of objectives III and IV in the learning process and in producing evaluative instruments that will measure how well these objectives are achieved.

4. Finally, much research is needed in the area of physical science concept development, especially those concepts using quantitative measures. The Assessment shows that in most exercises using laboratory equipment participants were able to answer with a degree of accuracy, but exercises that followed which emphasized an understanding of the concept were poorly answered. Curriculum writers should consider the value of an integrated approach to science -- one that develops "a structure of science" rather than emphasizes isolated facts and principles.

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