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A future-oriented analysis of current directions in secondary science education.

Christopher Dede
University of Massachusetts Amherst

A FUTURE-ORIENTED ANALYSIS OF CURRENT DIRECTIONS IN SECONDARY SCIENCE EDUCATION

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By

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Education

A FUTURE-ORIENTED ANALYSIS OF CURRENT DIRECTIONS IN SECONDARY SCIENCE EDUCATION

A DISSERTATION

BY

CHRISTOPHER J. DEDE

Approved as to style and content by:

(Chairman of Committee)

(Head of Department)

Richard D. Konicek
(Member)

Howard A. Peelle
(Member)

(Member)

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Dedicated to

my wife, Patty

"While the mechanistic, reductionist philosophies of science have been of great utility in the physical sciences, in dealing with social situations where complicated human beings both as individuals and as groups occupy the center stage and where the whole is almost always greater than the sum of its parts, the philosophy of pragmatism with its emphasis upon the analysis of possible consequences provides a promising base."

"Approaches to Science Education Research: Analysis and Criticism"

Willard J. Jacobson pg. 7

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A Future-Oriented Analysis of Current Directions in Secondary Science Education

Christopher J. Dede B.S. California Institute of Technology

Directed by: Dr. Byrd L. Jones

This thesis analyzes the assumptions underlying current directions in secondary science reform to determine if these assumptions are viable given probable world futures in the next forty years. The three secondary science assumptions most carefully examined are:

1) Discipline-oriented inquiry alone is a sufficient vehicle for secondary science education, provided that some material based on the scientific disciplines and "relevent" to society is included to interest students.
2) Standardized tests, grades, and similar standards of achievement are a sufficient means of measuring future excellence in secondary students.
3) "Superior" students, "disadvantaged" students, and "science-oriented" students can be identified, and special courses constructed for their use.

To place this analysis in historical perspective, the major reforms in secondary science education after World War II are classified by common characteristics into

two groups. "First generation" reforms (PSSC, BSCS, CBA, CHEMS) occured in response to pressures for change in science education such as the emergence of the Cold War and the post-war rise in industrial demands for trained scientific manpower. "Second generation" reforms (Harvard Project Physics, Engineering Concepts Curriculum Project, American Chemical Society curriculum project, 1971 AAAS Teacher Education Guidelines) occured in response to the lack of success of the first generation reforms in the schools.

The sets of assumptions underlying the first and second generation reforms are evaluated in the light of five alternative forecasts chosen as representative of the current schools of thought in future studies. These forecasts are The Year 2000 (Kahn and Wiener), The Next Ninety Years (Brown, Bonner, and Weir), The Limits to Growth (Systems Dynamics Group--MIT), "What We Must Do" (Platt), and An Alternative Future for America II (Theobald).

The major conclusions reached in this analysis are:

1) A new secondary science vehicle sufficient for teaching both future-oriented skills and discipline-based skills must be found. This vehicle must be capable of including both discplinary and non-disciplinary knowledge and must be viable beyond the traditional constraints and assumptions of the school.

2) New curricula created using this vehicle should be of three types:

   a) Young persons (ages fourteen to eighteen) would be given secondary science courses focusing both on the disciplinary aspects of science and on the long-term (forty years) future-oriented aspects of science and technology.

   b) All persons within the society would be encouraged to participate in semi-formal group experiences oriented around the short-term (ten years) future-oriented aspects of science and technology.

   c) A small group would act to diffuse information through the media about the impacts of science and technology on the future of our society.

3) Specialists in fields other than science should be consulted to help in creating curricula which incorporate materials relevent to science/society issues from these other fields and to aid in ensuring that the science curriculum and other curricula at the same grade level form an integrated whole. At the same time, all three types of curricula at all grade levels should be designed to be an integrated progression of knowledge.

4) IQ tests, achievement tests, and similar instruments which purport to measure ability should be de-emphasized in favor of a broader variety of instruments which measure a wider range of skills and which reflect more adequately the richness and complexity of the challenges students will face in the next fifty years.

5) The use of tracking systems with different basic courses for each track should be discontinued. All science materials should be designed to combat sexual, racial, and social class biases.

TABLE OF CONTENTS

TABLE OF CONTENTS (cont.)

TABLE OF CONTENTS (cont.)

INTRODUCTION

The Intent of This Thesis

As a result of post-war reforms in the science curriculum, science education has moved from a past to a present orientation, both in terms of its content and its strategies for innovation. This thesis attempts a philosophical analysis of the assumptions underlying current directions in secondary science reform to determine if these assumptions are viable for future-oriented education. The thesis concludes with a projection of probable futures for secondary science education in the next ten years.

The three secondary science assumptions which will be most carefully examined are:

- discipline-oriented inquiry alone is a sufficient vehicle for secondary science education, provided that some material based on the scientific disciplines and "relevant" to society is included to interest students.
- standardized tests, grades, and similar standards of achievement are a sufficient means of measuring future excellence in secondary students.
- "superior" students, "disadvantaged" students, and "science-oriented" students can be identified, and special courses constructed for their use.

These assumptions have been cornerstones in recent developments in secondary science reform, and any future-oriented curricula must decide whether to continue building on these assumptions.

A Synopsis of the Early Part of the Reform Movement in Science Education

In the two or three year period following the end of World War II, a crisis in American science education was brewing. The emergence of a Cold War forced an emphasis on science and mathematics for national security; industrial demands for trained scientific manpower began to exceed the supply available at current wages; and the war-time proliferation of technological areas made efforts to update factual curricula extremely difficult. The "establishment" in education seemed unable to make reforms to meet this growing crisis.

In response, critics began a sweeping set of attacks on conventional science education. These critics included opponents of the Progressive movement in the schools, parents desiring upward mobility for their children, and college instructors wanting better prepared college entrants. These attacks prompted several curriculum reform projects: the University of Illinois Committee on School Mathematics in 1951, the Physical Sciences Study Committee in 1956, and the Chemical Bond Approach Project in mid-1957. Not until the Russians launched Sputnik in late 1957, however, did a public reaction against professional educators occur for allowing America to "fall behind" in science. That charge provided the final impetus for launching full scale reforms in science education.

In 1958, the Rockefeller Report on education called for a national effort to develop an ample supply of high calibre scientists, mathematicians, and engineers. Also, the National Defense Education Act was passed, which, in its first three years, disbursed $116 million in federal funds and a matching amount from state and local sources to upgrade educational facilities for science education. In 1959, the Biological Sciences Curriculum Study and the Science Curriculum Improvement Study were begun. In 1960, the Chemical Education Materials Study and the Elementary Science Study initiated work. After 1960, Science--A Process Approach, Interaction of Matter and Energy, and numerous other programs came into existence.

This early stage in the curriculum reform movement had many of the characteristics of a revolution. The movement was largely not an evolutionary outgrowth of pre-war trends in the schools; on the contrary, leadership of the movement came from professional scientists in the universities rather than from professional educators, and financial support came from foundations and federal grants rather than from the usual state and local agencies. Nor did the reform movement rely on a series of controlled experiments to test and refine a set of empirical-inductive changes. Rather, these early reforms were the implementation of hypothetical assumptions by the university scholars who provided leadership for the movement. From the final products produced, the shared assumptions underlying these first generation reforms can be deduced.

Assumptions About Science

- The discrete scientific disciplines provide the sole content base needed for teaching secondary science. The needs of the learner or of society need not be considered.
- The most crucial aspects to learn about a scientific discipline are its key concepts, its principles, and its modes of inquiry. By learning these things, a student gains the crucial skill of perceiving reality as a scientist perceives it.
- The topics in science courses should be extensively interrelated, just as scientific theories are interrelated and interdependent. Understanding a few concepts in depth is preferable to learning many superficially.
- Knowledge is an end in itself, so non-rigorous or outdated scientific knowledge is worse than useless. The science curriculum must be updated periodically to ensure that obsolete knowledge is removed, new knowledge added.
- The interactions of science and technology are not a

part of the science curriculum.

- Those sciences which have traditionally been taught in the schools are those most important to teach.

Assumptions About Education

- Preparing courses to be taught in schools to persons of the appropriate ages is a sufficient step to solve the national problems which have led to pressures for science education reform.
- An adequate science curriculum can be designed within the traditional organizational constraints of the schools (grading, single teacher, discrete subjects at discrete times, etc.).
- Instructional materials packages coupled with teacher training programs are sufficient to ensure that schools adopting the new science curricula will use them correctly.
- Instructional materials packages are best prepared by groups predominantly composed of scientists and led by prominant scientists.
- Students learn science best through textbooks coupled with inductive exercises; the laboratory and audio-visual materials are valuable aids when coordinated with textual materials.
- The schools will use the new science curricula when they are developed.
- Standardized tests, grades, and similar standards of

achievement are a sufficient means of measuring future scientific excellence in secondary students. "Superior" students, "disadvantaged" students, and "science-oriented" students can be identified, and special courses constructed for their use.

Synopsis of Current Directions in Secondary Science Reform

In the last eight years, several changes in these initial assumptions about the nature of the "new science" have taken place. Less than twenty percent of American classrooms have been using the early reform curriculum materials, and a still smaller percentage have been using these materials in an integrated and coherent fashion. Public misunderstanding and mistrust of science, which these new curricula were designed to alleviate, has remained untouched or has increased.

In response to this lack of success of the early materials, more recent developments in science education (such as Harvard Project Physics; the Engineering Concepts Curriculum Project; and the American Association for the Advancement of Science and, independently, American Chemical Society Reports of 1970 and 1971) have made empirical-inductive revisions in the "new science" assumptions in order to create more viable curricula. Primarily, these new materials place greater emphasis than the earlier reforms on the needs of the learner and of society, on the interactions of science with society, and on the role of the teacher as a mediator of learning. For example, the purpose of the second American

Chemical Society Conference in 1970 was "to lay plans to develop 1) a new humanistic chemistry program for high school and two year college students who do not contemplate a career in science, and 2) a mass-media campaign to increase appreciation by the public of the chemical world in which we live."[1]

The intent of this thesis is to suggest new assumptions to replace those which have been the cornerstones of these recent reforms without discarding the contributions to science education that these new curricula have made. The process envisioned is similar to that described in Thomas Kuhn's The Structure of Scientific Revolutions, which delineates the manner in which radically new scientific perspectives emerge from and build upon existing theories, yet change the fundamental ways in which science approaches reality.

This thesis attempts a new approach to discussing science education which allows non-scientists to participate with scientists in evolving curricula. By describing the shared characteristics and deducing the underlying assumptions of a set of reforms in science education, the thesis shifts discussions about the science curriculum from decisions by scientists about whether gravitational force should be taught before or after electromagnetism to dialogues among scientists and non-scientists on the fundamental individual and societal goals served by particular formulations of science education.

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[1]American Chemical Society, Division of Chemical Education, "National Conference on the Public Understanding of Chemistry," Fort Collins, Colorado, Dec. 12-14, 1970, pg. 1. (offset.)

CHAPTER I

THE EARLY PART OF THE REFORM MOVEMENT IN SCIENCE EDUCATION

A Factual Summary of Events: World War II to Sputnik

Science in the Schools

The goals of science teaching on the elementary level as stated by the National Society for the Study of Education (NSSE) in its forty-sixth yearbook (1947) were:

1) developing an understanding of science principles and generalizations and an ability to apply them for interpreting the immediate environment;
2) acquiring and using scientific skills and attitudes in problem solving;
3) developing an interest in and an appreciation of the environment; and
4) acquiring favorable social attitudes.[2,3]

The areas of study which the NSSE (1947) suggested be used in fulfilling these goals were:

- Life Sciences: Plant Life
  Animal Life
  Human Beings and Health

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[2]In fact, the general NSSE goals for science education had been fairly constant for thirty years. This can easily be seen by comparing the four statements of goals for science education cited in Robert H. Carleton, et al., "Improving Secondary Science," Rethinking Science Education, Fifty-ninth Yearbook of the National Society for the Study of Education, Part I (Chicago, Ill.: University of Chicago Press, 1960), pg. 152

[3]As quoted in Paul DeHart Hurd and James Joseph Gallagher, New Directions in Elementary Science Teaching (Belmont, Calif.: Wadsworth Publishing Company, Inc., 1968), pg. 28.

- Earth Sciences: Rocks, Soils, Geological Processes Weather and Climate, Earth in Space, Solar System and Beyond

- Other Physical Sciences: Machines and Engines, Forces, Matter, Energy, Heat, Sound, Light, Other Radiant Energy, Magnetism and Electricity, Structure of Matter, Chemical Change.[4]

These vague statements were generally actualized in classrooms in the following manner. Readings in a textbook and activity-oriented experiments were the primary means used by elementary teachers to cover the three areas of study. Reading a thermometer or a compass, making a telegraph key, collapsing an oil can, "exploding" a volcano, or using a magnet were typical elementary science experiments.[5] As a figure typical of the amount of time spent on science in the elementary school, the average number of hours per week spent on science instruction in Illinois (1958) were 1.9 hours per week in the primary grades and 2.4 hours per week in the upper elementary grades.[6] In the years immediately after World War II only two-thirds of the junior high school population took general science in the ninth grade;[7] so this elementary

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[4]Robert Stollberg, _et al._, "The Status of Science Teaching in Elementary and Secondary Schools," _Rethinking Science Education_, Fifty-ninth Yearbook of the _National Society for the Study_ of Education, Part I (Chicago, Ill.: University of Chicago Press, 1960), pg. 84.

[5]Hurd and Gallagher, _Elementary Science Teaching_, pg. 29.

[6]Stollberg, "Status of Science Teaching," pg. 95.

[7]As quoted in M. F. Vessel, _Elementary School Science Teaching_, (Washington, D.C.: Center for Applied Research in Education, Inc., 1963), pg. 33.

school exposure to science, coupled with perhaps some seventh and eighth grade science, was their only education in science for many pupils (other than those who skipped general science, but took high school biology).

Junior high school science provided a gradual transition from the elementary school's integration of the sciences to the high school's specialized courses in a particular area of science. All three years of junior high science frequently were taught using a textbook series; the content of these series usually resembled that suggested in the 1947 NSSE guidelines:

> Grade 7 - Science experiences having to do with the immediately personal problems of the learner and with simple understandings
> Grade 8 - Science experiences dealing with the physical and community environment
> Grade 9 - Science experiences dealing with the wider social significance of science and the use of science for the control of environment.[8]

One difference between elementary school and junior high science was that relatively few experiments were conducted at the junior high level; the teacher's primary resource was the textbook.

At the high school level, the assumptions underlying science teaching were:

> 1) Science teaching should contribute to the broader purposes of general education and must include content of wide personal and social significance...

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[8]As quoted in Stollberg, "Status of Science Teaching," pg. 86.

2) Science is best learned as an association of facts culminating in a concept expressed as a principle or generalization of science...
3) The skills, attitudes, and methods usually associated with the "problem-solving" aspect of scientific methodology are worthy objectives of science teaching...
4) The curriculum content is best defined in terms of the principles and generalizations of the subject field...
5) There should not be a distinction between class and laboratory procedures; both should contribute to the solution of problems...
6) Testing and evaluation should be in terms of all the objectives of the course...
7) There is a need for a balanced program of science with some opportunity for all students to build a background in both the biological and physical sciences...
8) The program of science instruction should be continuous from the kindergarten through high school.[9]

The three major subjects offered at the high school level were biology, chemistry, and physics; but at many schools a wide variety of other subjects were available, including courses in physical science, earth science, physiology, applied science, applied chemistry, applied physics, aeronautics, and household science.[10] The biology textbook usually contained little information that the student had not already encountered in junior high or elementary school; laboratory work was infrequent. Work in the chemistry laboratory usually occupied up to one-half the students' time; much of the text concentrated

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[9]Paul DeHart Hurd, Biological Education in American Secondary Schools, 1890-1960, BSCS Bulletin No. 1 (Washington, D.C.: American Institute of Biological Sciences, 1961), pg. 71.

[10]Stollberg, "Status of Science Teaching,"pg. 88 and Melvin Ronald Karpas and Leo E. Klopfer, "General Problems of Science Education in American High Schools," The Challenge of Science Education, ed. by Joseph S. Roucek (New York, N.Y.: Philosophical Library, 1959), pg. 134.

on the practical applications of chemical discoveries. Physics was generally taught as six distinct and "unrelated" subjects: mechanics, heat, light, sound, electricity/magnetism, and atomic physics; laboratory work occupied perhaps one-quarter of the students' time.[11]

In 1956, 74 percent of all tenth grade students took a course in biology, 34 percent of all eleventh grade students took chemistry, and 24 percent of all twelfth grade students took physics.[12] Both the number of students in the schools and the percentage of students taking science courses increased steadily during the years between World War II and Sputnik. Enrollment in the elementary schools climbed from twenty million in 1945 to twenty-eight million in 1955,[13] and high school enrollment increased 29 percent from 1948 to 1956. From 1948 to 1956, enrollment in general science courses increased 41 percent, in biology increased 44 percent, in chemistry 26 percent, and in physics 6 percent.[14] Eighty percent of the students in first grade went on to enter ninth grade, 60 percent continued to graduate from high school, 20 percent

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[11] H. Seymour Fowler, Secondary Science Teaching Practices (New York, N.Y.: Center for Applied Research in Education, Inc., 1964), pp. 26, 43, 58.

[12] Stollberg, "Status of Science Teaching," pg. 95.

[13] Frank G. Jennings, "Tomorrow's Curriculum: Future Imperfect," The Curriculum: Retrospect and Prospect, Seventieth Yearbook of the National Society for the Study of Education, Part I (Chicago, Ill.: University of Chicago Press, 1971). pg. 79.

[14] Stollberg, "Status of Science Teaching," pg. 95.

entered college, and 13 percent graduated from college (3 percent in engineering and science).[15] These increases in enrollment necessitated the hiring of 50 percent more staff and a six-fold increase in the building and equipment program over a twelve-year period.[16] (In 1957, the public schools were short 142,000 classrooms for 1,943,000 pupils).[17]

These increased enrollments in science courses were paralleled by a decrease in the number of new science teachers. From a high point in 1950, the number of new college graduates certified as science teachers declined to 41 percent of the 1950 figure in 1954. This drop-off was certainly not due to lack of jobs; of the 7900 jobs available in 1954 for science and mathematics teachers, only 2100 were filled (3800 graduated certified to fill these positions). The better starting salaries and higher long-term wages that industry was offering these graduates helps to explain this situation.[18]

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[15]Harrison Brown, James Bonner, and John Weir, The Next Hundred Years (New York, N.Y.: The Viking Press, 1957), pg. 123.

[16]Robert M. McClure, "The Reforms of the Fifties and Sixties," The Curriculum: Retrospect and Prospect, Seventieth Yearbook of the National Society for the Study of Education, Part I (Chicago, Ill.: University of Chicago Press, 1971), pg. 46.

[17]Rockefeller Bros. Fund, Panel Report V. of the Special Studies Project, The Pursuit of Excellence (New York, N.Y.: Doubleday and Co., Inc., 1958), pg. 21.

[18]Brown, Bonner, and Weir, Hundred Years, pg. 131.

Secondary science teachers also were often overburdened with duties and responsibilities as a result of these manpower shortages and the science curricula then in use. In addition to all the usual duties of a teacher, science laboratory materials (often improvised for lack of funds) required extensive preparation, clean-up, and inventory. New materials and equipment needed to be purchased, new textbooks evaluated; the science teacher had the responsibility of keeping current on the latest scientific developments and incorporating them into his teaching. Small wonder than science teaching was not a popular profession.

The Report of the Conference on Nation-Wide Problems of Science Teaching in the Secondary Schools (1953) drew the following generalizations:

a) a considerable minority of science teachers (particularly in smaller schools) are not certified in science
b) a significant proportion of teachers who are certified in science have relatively meager backgrounds in this area[19]
c) a fairly large number of science teachers have their training concentrated in one area, to the near exclusion of other areas
d) many teachers certified in science spend all or part of their time teaching non-science classes or engaging in other types of educational activity
e) teachers of general science tend to have less thorough backgrounds than those who teach special science subjects

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[19]Less than one-half of secondary science teachers had had a methods course in the subject they were teaching. See Paul DeHart Hurd, New Directions in Teaching Secondary School Science (Chicago, Ill.: Rand McNally and Co., 1969), pg. 28.

f) there is a tremendous range in both the scientific and the professional educational backgrounds of the nation's science teachers
g) a considerable percentage of science teachers have graduate degrees, or have done graduate work in science and education
h) in general, the science teachers in larger schools tend to be better prepared than those in smaller schools.[20]

Forces Pushing for Change

Although the science curriculum in American schools remained relatively unchanged in the years from the end of World War II to Sputnik, many societal forces were pushing towards a massive revision:

- The war-time search for trained manpower had revealed a widespread lack of knowledge in science and mathematics.
- The war-time proliferation of technological areas made efforts to update factual curricula extremely difficult.[21]
- The federal government's investment in scientific research and development increased from 96 million dollars in 1940 to 1606 million in 1945 to 2020 million

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[20]As quoted in Karpas and Klopfer, "General Problems of Science Education," pg. 143.

[21]For a discussion of this point, see John I. Goodlad, "The Curriculum," The Changing American School, the Sixty-fifth Yearbook of the National Society for the Study of Education, Part I (Chicago, Ill.: University of Chicago Press, 1966), pp. 34-38 and John I. Goodlad, The Changing School Curriculum (New York, N.Y.: The Fund for the Advancement of Education, 1966), pp. 11-19.

in 1955.[22]

- The emergence of a Cold War forced an emphasis on science and mathematics for national security.
- Industrial demands for trained scientific manpower began to exceed by far the supply available at current wages, and manpower forecasts indicated that by 1982 twice as much technical manpower would be needed as would be available if present rates of technical manpower production were continued.[23]

These forces for change were indicative of the larger fact that America was rapidly being transformed by technology. Science and government had formed an alliance solidified by the creation of the National Science Foundation in 1950--science received funds, the country received new tools to gain power over its environment. Rapid urbanization, the automobile and the airplane, telephones and radios and televisions, the growth of the aerospace and electronics industries, and a population boom combined to change the societal structure of America in a few short years, Technological complexity bred societal complexity which necessitated trained and specialized manpower to create new technologies to solve the problems generated by societal complexity. The new affluence created by technology resulted in new responsibilities and

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[22] William W. Cooley, "National Welfare and Science Education," The Challenge of Science Education, ed. by Joseph S. Roucek (New York, N.Y.: Philosophical Library, 1959), pg. 42.

[23] Brown, Bonner, and Weir, Hundred Years, pg. 119.

expectations; the Supreme Court decision in "Brown vs. the Board of Education of Topeka" (1954) was an early indication of the demands to be made on the schools because of these new expectations.

In response, critics began a sweeping set of attacks on conventional science education. These critics included opponents of the Progressive movement in the schools, parents desiring upward mobility for their children, and college instructors wanting better prepared college entrants. A detailed account of these attacks is presented in Lawrence Cremin's <u>The Transformation of the School</u>, Chapter Nine. The ill-fated reports of the first and second Commissions on Life Adjustment Education were favorite targets in these attacks; the ill-chosen title of the Commisson and its assertion that no more than twenty percent of the student population could benefit from an intellectually-oriented education were particularly unfortunate for the Progressive movement.

Of all these critics, Arthur Bestor was the most influential. In <u>Educational Wastelands</u> (1953) and The <u>Restoration of Learning</u> (1955), he set forth the theses that the purpose of education is intellectual training through the academic disciplines, the function of the public school is to give such a training to all citizens, the great subversion of education has been the separation of the schools from scholarship, and the reform needed for education is to remove schools from the control of educators.[24] Bestor's ideas prefigured the main thrust of the curriculum reforms to come in science education.

Although many educational remedies were suggested in the twelve years from World War II to Sputnik, no clear directions for educational change emerged. Everyone from President Eisenhower and the federal government to the General Electric Company and the Carnegie Corporation provided funds for the public schools. In 1957, private foundations granted a total of $319,000,000 dollars to education (including higher education); less than one percent of these funds, however, went into any aspect of the secondary school science program.[25]

In the early 1950's, several science curriculum reform projects began, foreshadowing the proliferation of such projects following Sputnik. The University of Illinois Committee on School Mathematics was created in 1951, the Physical Sciences Study Committee (PSSC) in 1956, and the Chemical Bond Approach Project (CBA) in mid-1957. All of these projects were attempts by professional scientists and mathematicians to change curriculum on a national level in response to perceived deficiencies in the schools. PSSC, under the sponsorship of Jerrold Zacharias at MIT, received (in 1957 alone) $500,000 from the

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[24]The influence on education of Bestor and other critics of the Progressive Movement is discussed in Lawrence A. Cremin, The Transformation of the School (New York, N.Y.: Vintage Books, 1964), pp. 328-346.

[25]Helen B. Hale, et al., "Auxiliary Attempts to Improve the Secondary School Science Program," Rethinking Science Education, the Fifty-ninth Yearbook of the National Society for the Study of Education, Part I. (Chicago, Ill.: University of Chicago Press, 1960), pg. 190.

Ford Foundation, $250,000 from the Alfred P. Sloan Foundation, and $200,000 from the Fund for the Advancement of Education.[26] The conspicuous success that PSSC enjoyed in obtaining funds and publicity may have contributed to the rash of national science curriculum reform projects modeled on PSSC after Sputnik.

A Factual Summary of Events: Sputnik Through 1963

Forces Shaping the Reforms

On October 5, 1957, the U.S.S.R. launched the first man-made satellite ever put aloft--Sputnik. In 1958, the Russians announced that they had built and were operating the world's largest atomic power plant. Also in that year, three Russian physicists became the first Soviet scientists to win a Nobel prize. On January 3, 1959, Russia launched the first vehicle towards the moon--Lunik. These clear demonstrations of growing scientific competence in a Communist country unleashed great fear in America--fear that through another country's scientific breakthroughs we could lose World War III in the same manner that we crushed Japan at the end of World War II. This fear, coupled with the forces for educational change discussed in the previous section, led to massive pressures for curriculum reform in science education.

In 1958, the Rockefeller Report on Education called for a special effort to develop "an ample supply of high

[26]Ibid., pg. 187.

calibre scientists, mathematicians, and engineers."[27] Also in 1958, after eight weeks of hearings which produced over 3600 pages of testimony and after seven days of heated debate in the House, Congress passed the National Defense Education Act. This provided money for public schools to improve their services by purchasing laboratory equipment and consulting assistance (the section of the bill on federal scholarship-fellowship-loan money for students to stimulate the country's brainpower development died on the House floor). Each federal dollar had to be matched by an equal amount from state and local funds--in 1958-59, the Act disbursed $36.2 million in federal funds; in 1959-60, $46.3 million; and in 1960-61, $43.6 million. Approximately seventy-five percent of this money was spent on the science curriculum.[28]

The collapse of the Progressive movement and the availability of funds for innovation provided the opportunity for numerous revisionary ideas about the nature of education to emerge. In 1958, the National Academy of Sciences--National Research Council charged that schools could teach pupils more effectively if they revised teaching practices to include the latest research on learning.[29] In 1959, thirty-five noted

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[27]Rockefeller, Pursuit of Excellence, pg. 28.

[28]Paul E. Marsh and Ross A. Gortner, Federal Aid to Science Education: Two Programs (Syracuse, N.Y.: Syracuse University Press, 1963), pp. 27-28, 51.

[29]Hurd, New Directions in Teaching Secondary School Science, pg. 27.

scientists, educators, and scholars met at Woods Hole, Massachusetts, to discuss how science teaching could be improved. Dr. Jerome Bruner of Harvard chaired the ten-day conference, which was co-sponsored by the American Association for the Advancement of Science, the National Science Foundation, the Carnegie Corporation, the United States Office of Education, the Air Force, and the RAND Corporation. Representatives of the major schools in the psychology of learning, in motivational psychology, and in the nature of intelligence were present, as were members of the curriculum reform projects which originated in the early 1950's.

The conferees based their discussion around the themes of structure, readiness, intuition, and motivation. With regard to curriculum structure, they agreed that knowledge acquired in the absence of a comprehensive framework to integrate it would likely be forgotten. The work of Piaget and other developmentalists on readiness prompted concern for the creation of a curriculum which would increase in intellectual difficulty as the child increased in learning potential. Intuition was discussed as a learnable skill which could be acquired through proper use of the "discovery" method of teaching, and motivation was examined in terms of the impact of television on the school and in terms of the relationship between teaching skill and pupil interest.[30]

The most influential ideas to emerge from the Woods Hole conference were those of its chairman, Jerome Bruner.

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[30]McClure, "The Reforms of the Fifties and Sixties," pg. 54.

His report of the conference, The Process of Education (1960), emphasized "that any subject may be taught effectively in some intellectually honest form to any child at any stage of development."[31] Unfortunately, Bruner did not place his ideas in historical perspective by contrasting them with the ideas of John Dewey, Charles H. Judd, or Franklin Bobbitt; rather, he and the other Woods Hole conferees chose to ignore the past and to proceed as if the subject of curriculum reform had never been explored before.[32] This insistence on "re-inventing the wheel" precluded the new reform movement from learning from the mistakes of the Progressive movement in the 1920's.

Another influential figure in developing a theoretical base for science education reform was Jerrold Zacharias, the MIT physicist who initiated the PSSC physics project. Zacharias proposed a four component model for curriculum revision:

a) determine the precise boundaries of the educational unit,

b) identify the subject matter which will be considered within the educational unit,

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[31] Jerome S. Bruner, The Process of Education (Cambridge, Mass.: Harvard University Press, 1960), pg. 33.

[32] John I. Goodlad, "Curriculum: A Janus Look," Teachers College Record, Vol. 70, No. 2 (Nov. 1968), pg. 97.

c) embody that subject matter in material form (texts, laboratory manual, learning aids), and

d) give teachers an understanding of the new subject matter and train them to use the new materials.[33]

Zacharias recognized that having each curriculum project individually determine the precise boundaries of its educational unit would inevitably result in an incoherent overall curriculum; but perceived no solution to this problem, which loomed ever larger as subsequent curriculum projects (such as the Biological Sciences Curriculum Study (1959) and the Chemical Education Materials Study (1960)) followed the PSSC model.

In general, the curriculum reform movement drew heavily on the ideas of disciplinary scholars, who naturally were quite critical of the non-rigorous, pseudo-disciplinary materials being used by the schools. In 1961, the National Education Association Project on Instruction sponsored a Disciplines Seminar to "facilitate study and effective use of the disciplines by a) focusing upon those fundamental ideas and methods of inquiry from selected fields of study which should be in the mainstream of the instructional program of the public schools, and b) exploring frontier thinking and research in the nature of knowledge and ways of knowing."[34]

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[33]Jerrold R. Zacharias and Stephen White, "The Requirements for Major Curriculum Revision," New Curricula, ed. by Robert W. Heath (New York, N.Y.: Harper and Row, 1964), pg. 69.

[34]Project on Instruction, The Scholars Look at the Schools: A Report of the Disciplines Seminar (Washington, D.C.: National Education Association, 1962) pp. 1-2.

The First Wave of Science Curriculum Reform Projects

The post-war wave of science curriculum reform projects was unique in two ways:

1) the reform movement aimed at a revolutionary change in curriculum rather than at an evolutionary revision of current curriculum materials, and
2) the reform movement drew its leadership and financial support from outside professional education.[35]

The major science curriculum projects in this first wave of reforms were SAPA, SCIS, and ESS on the elementary level, and BSCS, CHEMS, CBA, and PSSC on the secondary level. PSSC and CBA began in 1956 and 1957, respectively. In 1959, the Education Committee of the American Institute of Biological Sciences organized the Biological Sciences Curriculum Study (BSCS). That same year, the University of California--Berkeley began its Science Curriculum Improvement Study (SCIS). In 1960, the Chemical Education Materials Study (CHEMS) was organized by the American Chemical Society, and Educational Services Incorporated began the Elementary Science Study (ESS). The last of the major projects in the first wave of reform was Science--A Process Approach (SAPA), which was sponsored by the Commission on Science Education of the American Association for the Advancement of Science (AAAS) beginning in 1963 (after a series of AAAS conferences on science education which began in 1961).

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[35]Goodlad, "The Curriculum," pp. 32-34.

Many smaller projects also came into existence during this period, especially on the elementary level. In addition to ESS, SCIS, and SAPA, elementary schools could consider the Conceptually Oriented Program in Elementary Science (COPES); the Elementary School Science Projects (ESSP) at Berkeley, the University of Illinois, and Utah State University; the Inquiry Development Program (IDP); the Minnesota Mathematics and Science Teaching Project (MinneMAST); the School Science Curriculum Project (SSCP); the Study of a Quantitative Approach in Elementary School Science (SQAIESS); and the Webster Institute for Mathematics, Science, and the Arts Program (WIMSA).

Reform of science curricula in response to social pressures has not been unusual in American education; science curricula have often been responsive to the social needs of their particular period in American history. In the 1900's, the poor health conditions of that time inspired civic biology courses. Chemistry courses and physics courses changed in the 1920's and 1930's to include a great deal of information about the technological advances (smelting ores, the telephone) that these two fields had fostered. The Depression led to courses in "consumer science" to encourage wise purchasing, and the war years of the early forties prompted courses in "air-age" biology, chemistry, and physics. Thus, the post-Sputnik production of new courses to train more scientists to meet the manpower needs of an increasingly technological society was an extension of this trend to orient science curricula toward societal problems.[36]

However, the reforms were unique in that they did not attempt to revise and update the materials used in the schools; on the contrary, current curricula were to be replaced by new curricula based on entirely different assumptions. Further, the assumptions underlying these new curricula were not to be derived by a series of controlled experiments to define and test a set of empirical-inductive changes; that is, no attempt was made to learn from the early mistakes of the Progressive movement, nor were the successes of current curricula noted. Rather, the reforms were based, for the most part, on "the implementation and refinement of some assumptions deduced hypothetically,"[37] by the scholars who provided leadership for the movement. These assumptions will be discussed in more detail in the next section of this chapter.

The reform movement also rejected traditional sources of educational leadership and funding. Leadership of the science curriculum reforms came from professional scientists in the universities rather than from professional educators. Financial support for the curriculum projects came from foundations and federal grants (especially from the National Science Foundation) rather than from the usual state and local

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[36]Hurd, <u>New Directions in Teaching Secondary School Science</u>, pg. 12.

[37]Goodlad, "Precollege Reform," pg. 9.

agencies. Thus, the science curriculum reform projects attempted a revolutionary transition from traditional goals and traditional processes of curriculum change.

Descriptions of the histories, goals, and products of the major science curriculum projects are numerous;[38] the PSSC project (secondary level) and the SAPA project (elementary level) are typical examples of the other reforms. Early in 1956, Dr. Jerrold Zacharias at MIT approached other prominent physicists with the idea of a project to revise the high school physics curriculum. By September, Dr. Zacharias had received indications of interest from a number of prominent physicists and financial support from the National Science Foundation, the Ford Foundation, and the Sloan Foundation. In December, 1956, fifty physicists and educators met at a three-day conference and laid the foundations of the revisions by tentatively selecting and ordering the course materials.

Between December and June of the next year, the participants at the conference drafted portions of the text; at an eight-week workshop in the summer of 1957, one-quarter of the text was finished, the remainder begun, films and laboratory experiments produced, and a teacher's guide started. In the fall of 1957, the materials were classroom

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[38]Good references in this area are Heath, New Curricula; Goodlad, The Changing School Curriculum; Hurd and Gallagher, Elementary School Science; Hurd, Secondary School Science; and J. Stanley Marshall and Ernest Burkman, Current Trends in Science Education (New York, N.Y.: Center for Applied Research in Education, 1966).

tested in eight secondary schools; in the spring of 1958, a motion picture studio was initiated. Another eight-week workshop and five summer institutes for teachers filled the summer of 1958. Two hundred and fifty schools experimented with the materials in 1958-59; more summer workshops for teachers were held in the summer of 1959; five hundred schools used the materials experimentally in 1959-60; final editing took place in the summer of 1960; and in the fall of 1960 the course began commercial production.

Over its four-year developmental period, PSSC was tested in eight hundred schools by over one thousand teachers (approximately eight percent of the secondary physics teachers in the United States). The project cost six million dollars, plus an equal amount in teacher retraining costs, in the period 1956-61; in the years after 1961, costs per year of keeping the materials up-to-date averaged $300,000.[39] The other secondary science curriculum reform projects were roughly equivalent in time used, money spent, and methods used to prepare the materials.

One major difference between the elementary level and secondary level reform projects was that the secondary level projects were originated by practitioners of a single branch of science (physics, chemistry, biology) while the elementary level projects, being interdisciplinary, had no discipline-oriented professional societies (such as the American Chemical

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[39]Zacharias, "Requirements for Revision," pp. 78-80.

Society or the American Institute of Biological Sciences) to champion them. SAPA began as the result of two years of conferences on elementary science education sponsored by the American Association for the Advancement of Science by request of the National Science Foundation. Three regional three-day conferences were held, each attended by fifty participants including scientists, administrators, psychologists, elementary teachers, and science educators. The participants agreed that:

> 1) science should be a basic part of general education for students at the elementary and junior high levels,
> 2) instruction at the elementary level should deal in an organized way with science as a whole,
> 3) there must be a clear progression in the study of science from grade to grade,
> 4) there should be no single, national curriculum in science, and
> 5) science teaching should stress the spirit of discovery characteristic of science itself. 40

Following these conferences, the AAAS appointed a Commission on Science Education in 1962 which in turn began SAPA in 1963. Thus, elementary level curriculum reform projects were often initiated through more tortuous paths than secondary projects for lack of ready sponsorship.

Once initiated, SAPA focused on "reducing content to the smallest possible discrete steps so the learner is led in a systematic way to a predetermined end which is the sum of the steps taught"--a form for instruction used extensively by the Navy in World War II and promoted by Bruner's ideas in The Process of Education. SAPA was designed to teach

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[40] As quoted in Vessel, Elementary School Science Teaching, pp. 73-74.

science as a process rather than scientific facts or principles, and was founded on the premise that complex scientific inquiry can be reduced to a hierarchical sequence of simple steps. A set of behavioral hierarchies which were based on Robert Gagne's theories of learning were devised; these were intended to "a) provide a rationale for selecting and ordering the sequence of objectives; b) tell the teacher what should have preceded the exercise, where to start, and what will come after; c) assess student achievement; d) provide program evaluation; and e) indicate when 'terminal' behavior has been achieved." In testing the curriculum, it was found that ninety percent of the students could master at least seventy percent of the desired competencies in the exercises.[41]

Differences Between the New Secondary Projects and Traditinal Science Curricula

The major secondary level reform projects (PSSC, CHEMS, CBA, BSCS) were vastly different than the traditional courses that they were intended to replace. The PSSC materials had the following characteristics in comparison with traditional high school courses:

> 1) The PSSC course covers less topical material than is usually presented in high school physics while penetrating more deeply into selected areas which contribute most heavily to an understanding of the universe.
> 2) Physical models are developed and used as they are by scientists in attempting to explain phenomena.

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[41]McClure, "The Reforms of the Fifties and Sixties," pp. 67, 69, 70.

3) Physics is treated as a unified, interconnected story, and as a human activity set within our society and carried on as a part of the historical development of mankind.
4) Less emphasis is placed on technological applications of physics, and more on an understanding of fundamental principles.
5) The laboratory is integrated more closely with the rest of the materials than is customary.
6) The materials provided for the student and teacher--text, laboratory guide, teacher's guide, films, and monographs--make a more complete kit of materials for learning than have been available in any course previously. 42

Trowbridge, in a study of PSSC materials (1961) deduced seventeen objectives unique to PSSC, seventeen unique to traditional courses, and thirty common to both.[43]

In chemistry, the CHEMS and CBA materials both ignored almost entirely the history of chemistry, modern technological applications of chemistry, "complete coverage" of the field of chemistry, and other subjects stressed in traditional courses. Rather, CHEMS and CBA were based around the beauty and order in chemistry as chemists see it, the fundamental ideas of chemistry as a discipline, and the conceptual schema of chemistry as a challenge to man's intellect. Unlike traditional chemistry courses, both CHEMS and CBA were highly structured, with each idea and each experiment building on those learned previously.[44]

All three versions of BSCS (the Blue version organized around molecular level biology, the Green version organized

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[42]Marshall and Burkman, Current Trends, pg. 28.

[43]Paul DeHart Hurd and Mary Budd Rowe, "Science in the Secondary School," Review of Educational Research Vol. 34, No. 3 (June, 1964), pg. 288.

[44]Marshall and Burkman, Current Trends, pg. 65.

around ecological biology, and the Yellow version organized around the concept of the cell) differed greatly from traditional biology courses, which stressed the biology of the individual (organismic biology). Morphological concepts (gross structure of organisms) and taxonomic concepts (classification of organisms) were de-emphasized in the BSCS materials, to be replaced in part by "controversial" topics such as evolution and human reproduction, and in part by more emphasis on the chemistry of life and the ecological biology of communities and societies.[45]

Basic Assumptions Underlying the First Generation Reforms

Common Characteristics of the First Generation Reforms

By describing the shared characteristics and deducing the underlying assumptions of a set of reforms in science education, a basis is formed for allowing non-scientists to participate with scientists in evolving curricula. Discussions about the science curriculum are shifted from decisions by scientists about whether gravitational force should be taught before or after electromagnetism to dialogues among non-scientists and scientists on the individual and societal goals served by particular formulations of science education. This change away from a specialized elitism to a generalized participation in decisions seems an important step in improving current forms of science education.

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[45]*Ibid.*, pp. 38-39.

One of the major characteristics of the first generation secondary level curriculum reforms was their deliberate development of courses centered on a single scientific discipline, rather than on the learner, the needs of society, or interdisciplinary problems. Traditional secondary curricula separated physics, chemistry, and biology, but treated these fields as accumulations of facts and technological achievements rather than as disciplines. With the reforms, each of the new courses in these areas was organized only around the primary structural elements of its particular discipline and around representative activities within that field. In this way, the scientists designing these secondary level reforms attempted to mirror within secondary courses the conceptual structures and patterns of inquiry of their disciplines. Because this disciplinary emphasis required that each concept considered be taught in depth, a great many concepts taught in traditional courses had to be eliminated from the new courses for lack of classroom time.

A second major characteristic of these secondary reform courses was their emphasis on inductive methods of learning which were designed to direct students along lines of thought inevitably leading to a particular conclusion which the student "discovers." Two psychological assumptions bolstered this emphasis: the idea of "massive general transfer" refers to the hypothesis that students taught by the "discovery" method will become able to grasp intuitively the relationship between new phenomena and phenomena they had learned to understand, new problems and problems they had been taught to solve. Learning theorists also argued that "puzzle fascination"--the lure of finding solutions to problems posed as puzzles--was a stronger motivating force for student involvement than relating the utility of a student's learning to his everyday life.[46]

Focus on a discipline and discovery learning led to a third characteristic of the new curricula. Usually, a curriculum reform had begun by stating new goals; a new course would then be constructed using these goals as criteria for content selection. The science curriculum reform projects, however, began with the scientific disciplines and their modes of inquiry as content; the new courses were constructed intuitively around this content; and only then did the reformers examine the finished product to see what goals had, in fact, been incorporated.[47] Not surprisingly, the primary goal which emerged when the new courses were finished was to teach each student to think and behave as if he were a scientist. To facilitate this goal, the content of each course was intuitively chosen from the concepts, key ideas, principles, and modes of inquiry of the particular scientific disciplines on the basis of the following criteria:

a) authenticity and importance within the discipline at present,
b) linkage value with other components of the course,

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[46]*Ibid.*, pg. 6.

[47]Hurd, *Secondary School Science*, pg. 30.

c) potential for involving the student, and
d) adaptability to the inquiry approach. 48

Two further characteristics of the reform courses were that the technological applications of science were dropped from the secondary curriculum, and that the laboratory became an integral part of course work. The reformers argued that the sciences are creative endeavors concerned with knowledge for its own sake, while technologies are crafts oriented around the practical uses of scientific information. Hence, technology was allowed no place in the first generation science courses; understanding the relationship of technology and science was not even listed as a goal.[49]

The laboratory, which in traditional courses was often unrelated to the text, in the reform courses became a key component of the instructional materials. The heart of the inductive method of learning was the laboratory, and experiments changed from the "cookbook" orientation of traditional courses to an approach based on carefully structured, open-ended inquiry. Text and laboratory in the new courses were designed to treat course topics simultaneously, each expanding on the insights learned from the other (except in courses like CBA, in which text and laboratory could be used independently if desired).[50]

A sixth common characteristic of the reform courses was their end product--a comprehensive instructional materials

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[48]Goodlad,"The Curriculum," pg. 40.

[49]Hurd, Secondary School Science, pg. 22.

[50]Goodlad, Changing School Curriculum, pg. 95.

package. Previously the schools had purchased science materials in fragmentary fashion; now each project generated its own instructional package, usually containing texts, laboratory equipment, teacher's guide, films, and supplementary materials. Some of these collections of materials were designed only for use as an integrated unit; others could be utilized as separate parts if desired.

Extensive teacher training programs were another characteristic of the reform courses. In fact, several curriculum reform projects would not allow school systems to use their products if their teachers had not attended training workshops.[51] These workshops were sometimes sponsored by NSF through the project, other times by the local school district. To illustrate the importance that some reform projects placed on this area, PSSC spent half its funding on teacher training workshops.

An eighth major characteristic common to the new secondary courses was their emphasis on scientific knowledge as ever changing. Traditional courses implied that science was a body of invariant facts; the reform curricula emphasized that scientists constantly revise their theories on the basis of new evidence. The new courses attempted to give students both a knowledge of science at present and the tools to acquire new scientific knowledge as present ideas become outdated and obsolete.

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[51] Goodlad, "The Curriculum," pg. 41.

An extensive interrelatedness of topics within a single course was a ninth characteristic of the new secondary science courses. In traditional science courses, each chapter in the text could be grasped independently of understanding any of the other chapters; the topics considered in these courses were discussed fragmentarily and as if they were unrelated. In the new courses, each successive concept depended on an understanding of those examined previously; each problem required the student to understand all the information, concepts, principles, and thought processes the course had considered to date.[52] This necessitated careful sequencing of the course materials so that the student did not become hopelessly confused.

A list summarizing the differences between traditional secondary science courses and the curricula produced by the reform projects is reproduced below from Hurd's New Directions in Teaching Secondary School Science:[53]

From	To
1. goals defined in personal-social terms	1. goals defined in intellectual competency terms
2. problem solving as a specified procedure	2. modes of inquiry suitable to exploring a discipline
3. student-centered curriculum	3. discipline-centered curriculum

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[52] Hurd, Secondary School Science, pg. 43.

[53] Ibid., pp. 52-54.

From	To
4. local responsibility for curriculum development guided by high school teachers	4. national responsibility for curriculum development guided by scientists working with high school teachers
5. major emphasis on informational aspects of science and minimal attention to the processes of science	5. an emphasis on science"as a way of knowing" emphasizing the processes of science as they relate to what is known
6. a survey of many science topics to acquaint students with the range of knowledge in a subject	6. a few topics explored in depth and taught to the point of understanding
7. descriptive and applied science	7. interpretive and theoretical science
8. "established" knowledge with emphasis on "basic" facts	8. knowledge in the mainstream of modern scientific thinking, with emphasis on models and theories
9. rote learning and memorization	9. concept formation and systematic thinking
10. group learning, teacher directed 'telling', and drill	10. individual learning, student centered guided 'discovery', and contemplation
11. the opinion that learning has occurred if information can be repeated	11. the opinion that learning has occurred if the pupil can use his knowledge in an explanatory and interpretive manner
12. subject matter chosen by teachers or textbook authors	12. subject matter chosen by research or professional scientists
13. personal-social needs of pupils as criterion base for choosing course content	13. the conceptual schemes of science as the criterion base for choosing course content
14. testing mostly on factual information with a 'right' answer	14. testing mostly on use of concepts to interpret observations or provide explanations

From		To	
15.	laboratory exercises to demonstrate, visualize, or verify known information	15.	laboratory exercises to raise problems, test inquiry skills, and provide 'discovery' opportunities
16.	laboratory follows class discussion of topics and is largely divorced from classroom learning	16.	laboratory work as an integral part of classwork with pre- and post-laboratory discussion
17.	learning capability depends almost entirely on student effort and teacher 'telling'; a passive process	17.	learning capability depends upon organization of curriculum and ability of teacher to match a teaching style with stated goals; an active process
18.	education focused on the world as it is today	18.	education for change and the future
19.	sequence of learning materials as teacher's arbitrary choice	19.	sequence of learning materials dependent on logical structure of discipline
20.	curriculum improvement through revision and refinement	20.	curriculum improvement through reform and innovation
21.	supervision by a curriculum generalist	21.	supervision by a science specialist
22.	courses built of instructional units representing a logical organization of information	22.	courses built around conceptual schemes in a coherent sequence stressing logical unity of discipline
23.	instruction as information giving	23.	instruction as information processing
24.	courses written at a uniform level of conceptualization	24.	courses written at increasing meaning, building upward on previously learned concepts

The first generation curriculum reform projects on the elementary level had many of the same common characteristics as the secondary level projects; both produced instructional materials packages, sponsored teacher training workshops, and emphasized "discovery" learning. Two fundamental differences between the secondary and elementary reforms arose from problems that the elementary projects encountered in trying to design discipline-oriented curricula. First, since no disciplines had traditionally been stressed at the elementary level (as physics, chemistry, and biology were in high school), the reformers had to decide which of the many scientific disciplines should be taught in the elementary school. Second, since the secondary school reforms were based upon the major concepts underlying the disciplines of physics, chemistry, and biology, the reformers felt that they had to find a way to teach these concepts on a simple scale to young children so that they would be prepared for their new high school science courses.[54]

At least four different patterns of response to these two problems emerged in the new elementary science curricula. Some reforms, such as the University of Illinois Elementary School Science Project, based their elementary curricula on a single discipline not usually taught in the high school (astronomy). Other projects, such as the Elementary School Science Project at the University of California--Berkeley, developed alternating, interchangeable mini-courses in several scientific disciplines (physics, physiology, botany, chemistry, paleontology, and zoology). A third group of projects, such

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[54]Goodlad, "The Curriculum," pg. 42.

as SAPA, based their curricula on developing general skills and competencies (observation, classification, measurement, prediction) claimed to be essential to learning any science. A fourth group of programs, such as SCIS, developed elementary curricula based around essential concepts from a host of scientific disciplines without attempting to match each concept with its particular disciplinary base.[55]

The elementary reforms differed from their secondary counterparts in one other respect; perhaps because of the difficulties inherent in planning the elementary curriculum downward from the already finished "new science" at the secondary level, the elementary reformers were more willing than their secondary counterparts to consider radical changes in time allotments, grade placement of courses, and traditional subjects within the schools. Individual differences, team teaching, non-grading, programmed instruction--even limited synthesis of disciplines and attention to developmental needs of the learner--were all components in various elementary reform projects. Basically, however, the elementary reforms were predicated on the same assumptions of disciplinary content and "discovery" process that characterized the new secondary level curricula.[56]

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[55] Ibid., pg. 43.

[56] Ibid., pg. 44.

Basic Assumptions Underlying the First Generation Reforms

As discussed earlier, the first generation curriculum reforms were not an empirical-inductive evolution of current practices, but rather were a revolution based on "the implementation and refinement of some assumptions deduced hypothetically"[57] by the university scholars that provided leadership for the reform projects. These assumptions can be deduced both from the common characteristics of the first generation reforms and from the reactions of the reformers to the Progressive movement in education. The Progressive movement reached its height between the years 1918 and 1938; its basic philosophy was to stress the processes of education rather than the content.

When Progressivism became influential in the early 1920's, the high school curriculum placed heavy emphasis on teaching certain subject matters: algebra, plane and solid geometry, European and American History, English and American literature, biology or chemistry and physics, and a foreign language. The texts for these courses were usually written by college professors and stressed the scholarly aspects of these fields. The Progressives attempted to replace this subject matter by an experience-oriented curriculum. In the elementary schools, children were to be taught reading, writing, and spelling as the by-product of child-centered, group-process-

[57]Goodlad, "Precollege Reform," pg. 9.

oriented activities. At the junior high and secondary levels, discrete courses in a particular subject were to be replaced by a core curriculum which cut across disciplinary lines. The traditional scholarly texts, which were not suited to these new programs and which seemed too difficult for the increasing number of "lower talent" students entering high school, were replaced by more informal, less disciplinary texts written by teams consisting of a subject matter specialist, a curriculum specialist, and a professional writer with a strong background in education.[58] The subject matter in these texts tended to be only partially concerned with the disciplinary aspects of the particular field in question, and often was out-of-date and non-rigorous by disciplinary standards.

These Progressive programs were somewhat anti-scholarly, and provoked the wrath of college professors who felt that the schools did not sufficiently prepare students for college. When the reforms came in the late 1950's, the scholars critical of Progressivism advocated a return to the type of secondary education that the Progressives attempted to eliminate. The new curricula were not to be based on the needs of the child, but on the disciplines as discrete subjects. All curricula were to be geared to the needs of the "gifted" child, not the "slow" learner. Teachers were to be given first a strong grounding in a discipline, and only then a

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[58]Paul Woodring, "Introduction," New Curricula, ed. by Robert W. Heath (New York, N.Y.: Harper and Row, 1964), pp. 3-4.

background in professional education. All of these efforts were to be focused on the formal curriculum; the informal activities of the student outside of his courses were to be ignored. Texts and instructional materials were to be prepared by university scholars rather than professional educators, and were to be updated periodically by experts in that subject area.[59]

Some educators did play an important part in the reforms. O. K. Moore's work at the University of Pittsburgh on responsive environments, Patrick Suppes' research at Stanford on learning strategies in mathematics, and Joseph Schwab's ideas at the University of Chicago on the structure of knowledge were very influential in shaping the new curricula.[60]

One of Schwab's colleagues at the University of Chicago, Benjamin Bloom, published a book in 1964 entitled Stability and Change in Human Characteristics which greatly influenced later reform projects. He reported that early childhood was an especially significant period of life, for his research indicated that between the ages of three and eight from fifty to eighty percent of ultimate attainment in many aspects of human development is reached. Bloom went on to say that this did not imply that children should be taught to behave like

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[59] Ibid., pg. 5.

[60] John I. Goodlad, "Where Precollege Reform Stands Today," The Challenge of Curricular Change (New York, N.Y.: College Entrance Examination Board, 1966), pp. 2-4.

adults--but his work was widely misinterpreted to mean this, to the detriment of the curriculum in the early primary grades.[61]

Because the educational research these four educators conducted was relatively "hard-edge", they were able to capture the interest of the reformers. Most educators, still caught up in the Progressive movement and unable to offer concrete results to prove their ideas, were ignored by the reformers. Because of this reluctance to accept well-established "intuitions", the disciplinary scholars leading the reforms discarded many educational theories which could have saved them costly mistakes.

From these reactions to the Progressive movement and from the common characteristics of the first generation curriculum reforms, the basic assumptions underlying these reforms can be deduced. These assumptions fall into two categories:

<u>Assumptions About Science</u>

1. The discrete scientific disciplines provide the sole content base needed for teaching secondary science. The needs of the learner or of society need not be considered.
2. The most crucial aspects to learn about a scientific discipline are its key concepts, its principles, and its modes of inquiry. By learning

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[61] *Ibid.*, pp. 4-5.

these, a student gains the crucial skill of perceiving reality as a scientist perceives it.

3. The topics in science courses should be extensively interrelated, just as scientific theories are interrelated and interdependent. Understanding a few concepts in depth is preferable to learning many superficially.
4. Knowledge is an end in itself, so non-rigorous or out-dated scientific knowledge is worse than useless. The science curriculum must be updated periodically to ensure that obsolete knowledge is removed, new knowledge added.
5. The interactions of science and technology are not a part of the science curriculum.
6. Those sciences which have traditionally been taught in the schools are those most important to teach.

<u>Assumptions About Education</u>

1. Preparing courses to be taught in schools to persons of the appropriate ages is a sufficient step to solve the national problems which led to pressures for science education reform.
2. An adequate science curriculum can be designed within the traditional organizational constraints of the schools (grading, single teacher, discrete

courses at discrete times, etc.).

3. Instructional materials packages coupled with teacher training programs are sufficient to ensure that schools adopting the new science curricula will use them correctly.
4. Instructional materials packages are best prepared by groups predominantly composed of scientists and led by prominent scientists.
5. Students learn science best through textbooks coupled with inductive exercises; the laboratory and audio-visual materials are valuable aids when coordinated with textual materials.
6. The schools will use the new science curricula when they are developed.
7. Standardized tests, grades, and similar standards of achievement are a sufficient means of measuring future scientific excellence in secondary students.
8. "Superior" students, "disadvantaged students," and "science-oriented" students can be identified, and special courses constructed for their use.

All the first generation secondary reform curricula were predicated on these assumptions. Most of the elementary reform curricula, while following the lead of the secondary reforms, modified at least one of these assumptions.

The Strengths of the First Generation Reform Curricula

One of the major strengths of the first generation curriculum reforms was that scholars in the scientific disciplines again became involved with the pre-college curriculum. This infusion of expertise resulted in an updating of the subject matter taught in science texts, an inclusion of a stronger disciplinary background in teacher workshops, and a surge in efforts to devise curricula and modes of teaching well-suited to the various sciences. Psychologists joined scientists in these efforts by adding a concern for the complex processes of human inquiry to learning theories preoccupied almost exclusively with rote processes in animals.[62]

A second major strength of the reforms was their development of curricula providing alternative methods of learning the same material. Teachers were often compelled to use audio-visual media in teaching the reform curricula, and found to their surprise that, properly designed, these media could be a useful alternative to lectures. A few "slow" students did quite well in the new science courses; the provision of a different mode of learning (media, "discovery" method) than the traditional accidentally demonstrated that a student's academic ability is at least partially related to the type of instruction he is given.[63,64]

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[62] Goodlad, "The Curriculum," pg. 46.

[63] <u>Ibid</u>., pg. 46.

[64] Unless this was due to a Hawthorne effect.

The reform curricula also contributed greatly to American education by focusing more attention on the plight of teachers in the schools. The in-service teacher workshops sponsored by the new science courses helped teachers to gain needed skills their pre-service training had failed to include, and fostered widespread acceptance of the idea that teachers should be given periodic opportunities to attend experiences oriented towards self-directed improvement in teaching. The response to the infusion of funds accompanying these workshops dramatized the extent to which reform in the schools was limited by a simple lack of time and resources.[65]

A fourth strength of the reform movement was that the new courses offered an intellectual challenge to students. "Gifted" students and "slow" students alike were presented with curricula that assumed a higher standard of excellence that traditional science courses and that were designed to make intellectual effort interesting. Some students responded by demonstrating greater ability to cope with these new courses than educators had thought possible.[66]

The more accurate picture of the scientific disciplines that the reform materials presented was a fifth major strength

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[65] Ibid., pg. 48.

[66] James R. Killian, "The Return to Learning," New Curricula, ed. by Robert W. Heath (New York, N.Y.: Harper and Row, 1964), pg. 261.

of the new science. By stressing concepts and modes of inquiry rather than facts, the new curricula gave a better model for understanding the growth of a scientific discipline. The emphasis in the new science on the ever-changing, never certain nature of the scientific disciplines helped establish in students a truer perception of science as a human endeavor.[67]

Of course, attempts were made to prove that, given these strengths, reform courses were better than the traditional. At least four means of evaluating the reform projects emerged:

> 1) observation of whether or not the students for whom the material is intended appear to be progressing satisfactorily,
> 2) both casual and systematic questioning of students involved in the programs,
> 3) periodic examination of students by tests designed to cover the new materials, and
> 4) comparative testing of students in the old and new programs with traditional and specially designed tests. 68

Unfortunately, none of the evaluations conducted were particularly systematic; most were studies of a particular facet of the new courses (such as student motivation) rather than studies of the courses as wholes. Further, the student population of the reform courses tended to be in the top half of the "ability distribution," and the teachers using

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[67] Hurd, Secondary School Science, pg. 95.

[68] Goodlad, Changing School Curriculum, pg. 98.

the new materials were often closely associated with the curriculum reform projects. For these reasons, the results of these limited evaluations were by no means generalizable.

Testimonials from students and teachers testing the reform curricula were relatively favorable, stressing that the new courses were challenging and flexible. Attempts to quantify these reactions through systematic testing resulted in the generalizations that 1) students in conventional programs did well on conventional tests, 2) students in the reform courses did well on tests especially prepared for these courses, 3) attempts to determine how well reform students did on conventional tests and *vice versa* were so marred by poor research design as to be useless, and 4) some "low ability" students did remarkably well in the new programs relative to "high ability" students.

Prominent scientists generally agreed that the content of the new courses was a more valid representation of the scientific disciplines than traditional course content. However, attempts to assess the pedagogical validity of the new courses were hampered by the unreliabilities of using teacher and student feedback as a source of data--teachers and students tended either to be uncritically enthusiastic or to judge the new programs by the standards of traditional curricula. The social and philosophical validity of the new courses was not evaluated at all, for lack of a set of overall educational goals to measure these projects against.[69]

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[69] Hurd, *Secondary School Science*, pp. 127-137.

In general, attempts to evaluate the worth of the reforms failed for the reforms drew their criteria for validity solely from within the structure of the scientific disciplines. The unwillingness of the reformers to set forward broader, more socially based goals (other than vague and implicit goals of attainment of intellectual-scientific skills and appreciation of the _geist_ of science) resulted in a lack of standards by which to judge the overall worth of the reforms. Schools attempting to decide which of alternative reform curricula to use, or whether to use the reform curricula at all, were forced to choose without meaningful data for decision-making.

CHAPTER II

RECENT DEVELOPMENTS IN THE REFORM MOVEMENT IN SECONDARY SCIENCE EDUCATION

Some Problems of the First Generation Reform Curricula in the Secondary Schools

The Context: American Education in the 1960's

The first generation science curriculum reforms were a response to pressures for educational change which had culminated with the launching of Sputnik; these forces for change were based on the premise that America needed more scientists, and resulted in curriculum reforms centered on the "gifted" student. In the 1960's, a new set of forces for educational change developed; these new pressures were predicated on the assumption that America needed to assimilate the "disadvantaged," and demanded curriculum reforms centered on the "slow" learner. The first portent of this shift in social priorities came with the Supreme Court decision on school desegregation in 1954; in the 1960's, the Civil Rights Movement and the Detroit and Watts riots underscored this new emphasis on education for the "culturally deprived."

The federal government under the Johnson administration provided impetus for educational change in this area by massive infusions of federal funds; twenty-four major pieces of educational legislation were passed in the five years from 1963-1968. These included the Manpower Development and Training Act, the Vocational Education Act, the Economic Opportunity Act, Head Start, Upward Bound, the Job Corps, and VISTA--all of which were designed to supplement the U.S. formal educational system with special provisions for the "disadvantaged." In addition to these special programs, Title I of the Elementary and Secondary Education Act provided a billion dollars of funds to reduce inequalities in the schools themselves by providing additional money to school districts with a high percentage of low income families. These programs to counter "cultural deprivation" through education were quite expensive, and accounted for much of the huge increases in federal expenditures on education from $1.4 billion in 1955 to $3.6 billion in 1965 to $8.8 billion in 1968.[70]

Despite this new preoccupation with the "disadvantaged," strong pressures still existed to continue focusing education on the "gifted" student. Manpower demand projections, for example, continued to stress that far too few scientists and engineers were being trained. In 1967, a book published by the California Institute of Technology entitled The Next Ninety Years stated that technical manpower shortages in 1967

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[70]McClure, "The Reforms of the Fifties and Sixties," pp. 59-61.

were greater than those in 1957; that the needs of our society for technical manpower would continue to grow at an increasing rate; and that, despite present educational efforts (the first generation reforms) to meet these shortages, our society's supply of scientists and engineers would continue to fall farther behind its needs.[71] The authors went on to predict immediate and crucial shortages of technical manpower unless the present emphasis on training scientists was not only continued, but intensified. Despite these pressures to focus education on the "gifted" student, the new awareness in the 1960's of the problems of the "disadvantaged" did have a negative effect on the use of the first generation reforms in the schools.

A second major force for educational change in the 1960's were the teachers' professional organizations: the National Education Association (NEA) and the American Federation of Teachers (AFT). In particular, the NEA Project on the Instructional Program in the Public Schools had a major impact on curriculum innovation. Its four-volume report in 1963[72] raised important questions about sequence and con-

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[71]Office for Industrial Associates-California Institute of Technology, The Next Ninety Years (Pasadena, Calif.: Calif. Institute of Technology, 1967), pp. 53-70.

[72]National Education Association, Deciding What to Teach; Education in a Changing Society; and Planning and Organizing for Teaching (Washington, D.C.: National Education Association, 1963); and Schools for the Sixties: A Report of the Project on Instruction (New York, N.Y.: McGraw-Hill Book Co., 1963).

tinuity, educational priorities, and comprehensive instructional programs--questions that highlighted some of the weaknesses of the first generation science curriculum reforms.

Four other forces had a major impact on what the schools taught in the 1960's: national corporations marketing curriculum packages, state legislatures and local school boards, school administrators moving towards different organizational structures, and schools of education.[73] Spurred by the increased funds schools had to use, corporations such as Westinghouse; G.E.; Time, Inc.; IBM; and Xerox developed subsidiaries concerned with marketing educational materials. These education-oriented commercial ventures marketed both reform and traditional curricula, using Madison Avenue techniques to outsell competitors. "Truth in advertising" thus became a problem in deciding which curricula to use, reform or traditional.

The restrictions state legislatures and local school boards put on curriculum also influenced use of the reform curricula. The new secondary curricula, which were designed to fit into traditional patterns of instruction, suffered less than the more innovative elementary school reforms from state and local regulations governing class size, number of minutes a subject had to be taught per day, and specific curricular topics which had to be included. Simultaneously,

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[73]McClure, "The Reforms of the Fifties and Sixties," pp. 62-66.

however, many schools in more progressive areas were experimenting radically with new forms of school organization. Rural areas tended to centralize their schools to conserve resources; urban areas decentralized their largest school districts for greater ease in administration. Team teaching, non-graded classes, differentiated staffing, flexible scheduling, and individualized instruction were some of the new internal organizational patterns used by more innovative schools; patterns which prejudiced these schools towards non-traditional curricula.

Another factor which influenced curriculum usage in the 1960's was the teacher training programs sponsored by schools of education. In-service training was very limited in most school districts; the pre-service training a student received strongly determined how that person would teach in the schools. Students whose teacher training programs stressed traditional curricula did not adapt well to using the reform curricula, and <u>vice versa</u>. The ROSES study, which will be discussed in the next section, indicated some ways in which teacher training programs may have contributed to the lack of success of the first generation reform curricula in the schools by ignoring the new science courses.

School enrollments and the percentage of students going on to college continued to climb in the 1960's. In 1970, elementary education was nearly universal--93 percent of those eligible had completed eight years of schooling.

Sixty-six percent had completed high school, and 12 percent college. For every 100 students in elementary school, twenty-five entered college and thirteen graduated--four in engineering and science.[74] In 1970, more than 40 percent of those who graduated from high school went on to some form of higher education, as opposed to 20 percent before World War II. However, the proportion of baccalaureate degrees in the physical sciences began to decline in 1961, as a greater percentage of high school students entered college, and this drop in the percentage of science majors has continued for the last ten years.[75]

The Lack of Success of the First Generation Secondary Level Reforms in the Schools

In the absence of shared criteria for success, it is difficult to discuss the lack of success of a science curriculum. Three generally accepted criteria for the success of a new curriculum are:

1) that it be used in the schools;
2) that, when used, it be used properly and coherently; and
3) that formal and informal evaluations reveal that use of the new curriculum results in significant

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[74]Industrial Associates, Next Ninety Years, pg. 59.

[75]Division of Chemical Education, American Chemical Society, Preliminary Report: International Conference on Education in Chemistry (Washington, D.C.: the Society, 1970), pg. 90.

improvements in student interest and performance over use of traditional curricula.

By all three of these criteria, the first generation secondary level curriculum reforms did not succeed in the schools.

The new secondary science curricula did not replace traditional science curricula in the schools. Almost the entire eligible student population--2,694,000 pupils--took a biology course in high school in 1964-65; but only 328,400 took a BSCS course (12.2 percent of those who took biology). Two-fifths of the eligible high school population--1,084,000 students--took a chemistry course in 1964-65; but only 128,100 took CHEMS (11.8 percent of those who took chemistry) and only 23,800 took CBA (2.2 percent of those who took chemistry). One-fifth of the eligible student population--526,000 pupils--took a secondary level physics course in 1964-65; but only 99,900 took PSSC (19 percent of those who took physics).[76]

More recent statistics from an Educational Testing Service survey reveal the same low percentages of use. In data taken in 1965-66, only twelve percent of the seniors taking the College Board Biology Achievement Test and twenty-six percent of the juniors taking the same test had taken BSCS as their biology course.[77] Less than three percent of

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[76]Fletcher G. Watson, "Why Do We Need More Physics Courses?" Physics Teacher Vol. 5, No. 5 (May, 1967), pg. 210.

[77]William Kastrinos, A Survey of the Teaching of Biology in Secondary Schools (Princeton, N.J.: Educational Testing Service, 1969), pg. 43.

the students taking the College Board Chemistry Achievement Test in 1965-66 had taken CBA as their chemistry course, and less than nineteen percent had taken CHEMS.[78] Only forty percent of the students who took the College Board Achievement Test in Physics in 1965-66 had taken PSSC physics.[79] When comparing these figures with those in the preceding paragraph, it must be remembered that the students who take College Board Achievement Tests are usually "bright" students, hence more likely to have taken a first generation reform course that a typical student. The percentage of typical classroom use, then, was probably lower than the College Board Test figures indicate.

These low figures of reform course usage indicate that, publicity campaigns and teacher training programs notwithstanding, most schools chose not to teach the first generation secondary level reform courses to most of their students. This situation has not appreciably changed today; if anything, enrollments in the first generation reform courses have dropped off from the figures cited. The fact that in 1965-66 only twenty percent of the students taking physics and only four percent of the total secondary school population eligible were taught PSSC physics when a full eight percent of the secondary school physics teachers in

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[78]Frank J. Fornoff, A Survey of the Teaching of Chemistry in Secondary Schools (Princeton, N.J.: Educational Testing Service, 1969), pg. 43.

[79]Raymond E. Thompson, A Survey of the Teaching of Physics in Secondary Schools (Princeton, N.J.: Educational Testing Service, 1969), pg. 42.

the United States pretested the PSSC materials can only be construed as a lack of success of the PSSC materials. BSCS, CBA, and CHEMS fared no better.

Even when the new science curricula were used in the classroom, there is indirect evidence to suggest that often these curricula were used improperly and incoherently. One observer, in 1969, estimated that up to fifty percent of the teachers using the new courses were doing so improperly.[80] As early as 1966, two researchers studying trends in science education wrote:

> Naturally, one would expect the students in such different types of programs (traditional and reform) to perform quite differently; yet surprisingly, such differences in student performance have proved very difficult to detect with the tests now in use....One factor...is the problem of who teaches the science and how it is taught. Although new kinds of textbooks, carefully contrived educational films, and unique laboratory experiences are important elements in the science program, the science teacher still serves as the interpreter of these things to the student and is at the center of the teaching-learning situation. Only if his interpretation reflects the philosophy of the course developers is it reasonable to say that the student has 'taken' the new course. If it differs sharply from the philosophy which guided the developers, one can say only that the student has enrolled for a given course--and perhaps received credit for it. He may well not have learned what the textbook and other aids to learning were intended to help him learn.... Thus, one hypothesis put forth to explain the unexpectedly small differences which have been detected in students in the new courses in science and students in traditional courses is that some of those who purport to teach the new courses actually do not do so at all. Much of the difficulty which some teachers

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[80] Hurd, Secondary School Science, pg. 49.

> experience in translating the new programs into effective classroom instruction can be traced directly to the kinds of teacher training programs they have undergone. 81

In "The Schools Vs. Education" (1969), John Goodlad agreed that the new curricula, even when used, were often not used well. Speaking of the overall curriculum, he wrote:

> We were unable to discern much attention to pupil needs, attainments, or problems as a basis for beginning instruction, nor widespread individual opportunities to learn. Most classes were taught as a group, covering essentially the same ground for all students at the same rate of speed. Teaching was predominantly telling and questioning by the teacher, with children responding one by one or occasionally in chorus. In all of this, the textbook was the most highly visible means of learning and teaching. If records, tapes, films, film strips, supplementary materials, and other aids to learning were in the schools we visited, we rarely saw them. When small groups of students worked together, the activities engaged in by each group member were similar, and bore the mark of the teacher's assignment and expectations. Rarely did we find small groups intensively engaged in pursuit of knowledge; rarely did we find individual pupils at work in self-sustaining inquiry. Popular innovations of the decade--non-grading, team teaching, 'discovery' learning, and programmed instruction--were talked about by teachers and principals alike, but were rarely in evidence....As far as our sample of schools is concerned, we are forced to conclude that much of the so-called educational reform movement has been blunted on the classroom door. 82

Silberman, in Crisis in the Classroom, concurred that a major reason for the lack of success of the reform curricula was that they were misused in the schools. He states:

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[81] Marshall and Burkman, Current Trends, pp. 82-83.

[82] John I. Goodlad, "The Schools Vs. Education," Saturday Review (April 19, 1969), pg. 60.

> Without changing the ways in which schools operate and teachers teach, changing the curriculum alone does not have much effect....The reformers' goal, sometimes stated, sometimes implicit, was to construct 'teacher proof' materials that would 'work' whether the teachers liked the materials or not, or taught them well or badly....The effort was doomed to failure. For one thing, the classroom teacher is in an almost perfect position to sabotage a curriculum he finds offensive--and teachers are not likely to have a high regard for courses designed to bypass them. For another, many of the 'teacher proof' curricula have turned out to be more difficult to teach than the courses they replaced. 83

As Silberman notes, the reform courses often were harder to teach than traditional courses, and the Research on Science Education Survey (ROSES) conducted by the Harvard School of Education from 1965-1967 offered factual evidence that pre-service teachers were not trained to teach the first generation science reform courses. Only one-half of the science methods courses surveyed gave pre-service teachers any instruction in using the reform curricula, and only fifteen percent of class time was devoted to the new science courses in those methods courses that did consider them. In secondary level science methods courses, 68 percent paid "some" attention to BSCS, 47 percent "some" attention to PSSC, 40 percent "some" attention to CBA, and 50 percent "some" attention to CHEMS. Only 21 percent paid "intensive" attention to BSCS, only 8 percent "intensive" attention to PSSC, only 4 percent "intensive" attention to CBA, and only 10 percent "intensive" attention to CHEMS. As the report

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[83] Charles E. Silberman, Crisis in the Classroom (New York, N.Y.: Vintage Books, 1971), pp. 181-182.

itself notes:

> Both instructors and students reflect some concern about the implementation of the new courses in actual school classrooms. Some instructors referred to the practical difficulties and limited success they had seen in introducing these courses into schools in their own areas. Students themselves gave little evidence of being enthused about teaching the new courses. Many of them expressed the feeling that the courses could not be practical in "real" schools because of the administrative problems, lack of time, or lack of the "right" kind of student. 84

Given this preparation, small wonder that teachers using the first generation reform curricula often used them improperly and incoherently.

A third criterion for measuring the success of a new curriculum is that formal and informal evaluations reveal that use of the new curriculum results in significant improvements in student performance over use of traditional curricula. The evidence from the ROSES study indicates that pre-service agencies had a low opinion of the first generation reform courses in their informal evaluation of science education curricula. Formal evaluations of the new science curricula did not produce evidence to refute such opinions. As an article in the Review of Educational Research (October, 1969) stated: "Many comparative studies of achievement in new and traditional science programs have been made. Perhaps the most pervasive impression is the relatively small

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[84] David E. Newton and Fletcher G. Watson, The Research on Science Education Survey: 1965-67 (Cambridge, Mass.: Harvard Graduate School of Education, 1968), pp. viii, 78, ix.

difference in performance on a wide range of measures."[85] Early research studies[86,87] comparing secondary level reform and traditional science curricula concluded that students in traditional courses scored higher on traditional tests, students in reform courses higher on reform course tests. Later, more sophisticated efforts[88,89] compared students completing a secondary level first generation reform course with students completing a traditional secondary science course on scales designed to measure general intellectual ability (such as Bloom's taxonomy). The gains in measured intellectual ability of both groups in these evaluations were very similar, undercutting the claims by reformers that new science was superior to traditional courses, and reinforcing teachers' opinions that the reform courses did not justify the extra work involved in teaching them.

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[85] Herbert A. Smith, "Curriculum Development and Instructional Materials," Review of Educational Research Vol. 39, No. 4 (October, 1969), pg. 406.

[86] Wimburn Wallace, "The BSCS 1961-62 Evaluation Program--A Statistical Report," BSCS Newsletter 19 (September, 1963), pp. 22-24.

[87] Robert W. Heath and David W. Stickell, "CHEM and CBA Effects on Achievement in Chemistry," Science Teacher 30 (September, 1963), pp. 45-46.

[88] J. Dudley Herron, "Evaluation and the New Curricula," Journal of Research in Science Teaching 4 (1966), pp. 159-170.

[89] Earl Brakken, "Intellectual Factors in PSSC and Conventional High School Physics," Journal of Research in Science Teaching 3 (1965), pp. 19-25.

By all three of the criteria previously discussed, the first generation secondary level science courses did not succeed in the schools. A brief case history of the CBA reform course provides a dischronic illustration of this conclusion. The CBA project began in June, 1957. A trial version of the CBA course was tested on 800 students in 1959-60, and a revised version by 15,000 students in 1960-61.[90] The final version of the CBA course was marketed in late 1961. Despite the fact that 15,000 students pre-tested the CBA course, only 23,800 students used the course in 1964-65.[91] Evaluations of the CBA course were not encouraging: in a survey of college professors asking for their preference in high school chemistry preparation, 50.5 percent supported traditional courses, with only 17.5 percent opting for the CBA course. In the same survey, high school teachers described the course as having an overly difficult text and as needing more "everyday" chemistry, as being inflexible and as suitable only for the "above average" student.[92] In another study, students in conventional courses outperformed students in the CBA course in a"difficult, competitive"

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[90] Hurd, Secondary School Science, pg. 183.

[91] Watson, "More Physics Teachers?", pg. 210.

[92] John J. Monteau, Ruth C. Cope, and Royce Williams, "An Evaluation of CBA Chemistry for High School Students," Science Education 47 (Feb., 1963), pp. 37, 42.

examination in chemistry.[93] In 1965-66, less than 3 percent of the students taking the College Board Achievement Test in chemistry had taken CBA;[94] and in 1965-67, only 4 percent of the secondary science methods courses offered "intensive" preparation in CBA.[95] The developers of CBA had hoped to reform the teaching of chemistry in the secondary schools; clearly, they did not succeed. None of the first generation reform courses had the major impact on science education that the reformers had argued must occur.

One unexpected by-product of the first generation reforms was that some of their ideas for presenting material were adopted by traditional courses. PSSC, for example, made extensive use in its text of ripple tank photographs to illustrate wave motion. Traditional texts, such as Dull, Metcalf, and Williams,[96] had never incorporated this approach to explaining waves; after PSSC, such photographs and explanations were common in most traditional materials. Similarly, the use of a stroboscopic flash to produce photographs "freezing" the motion of an object to indicate its path and

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[93]Earl L. Pye and Kenneth H. Anderson, "Test Achievements of Chemistry Students," Science Teacher 34 (Feb., 1967), pp. 30-32.

[94]Fornoff, Survey Chemistry, pg. 43.

[95]Newton and Watson, Research Survey, pg. 78.

[96]Charles E. Dull, H. Clark Metcalfe, and John E. Williams, Modern Physics (New York, N.Y.: Holt, Rinehart, and Winston, 1955, 1960, 1963, 1964).

acceleration was pioneered by PSSC and then adopted by most traditional texts. However, while traditional texts did freely borrow some of the modes of explanation pioneered by the first generation reforms, the assumptions about science and education underlying these explanations were ignored. Overall, traditional texts were affected by the reforms only on a superficial level.

Perceived Problems and Weaknesses of the First Generation Secondary Level Reforms

Whether or not the weaknesses of the first generation secondary level reforms were a major cause of their lack of success is an open question. The reformers were not oblivious to the weaknesses of the science curricula they created; many of the books which enthusiastically praised the new science devoted many pages to an analysis of its faults. One of the major criticisms that emerged was that the new secondary level curricula were so oriented to single disciplines as to omit from consideration significant interdisciplinary and transdisciplinary problems. This focus on the disciplines also led to a preoccupation with the traditional and well-established sciences (biology, chemistry, physics) to the neglect of "newer," more "frontier" sciences (astronomy, geology). As a result, students learned to think like chemists, biologists, and physicists--with little ability to apply that knowledge to other-disciplinary or non-disciplinary problems.

A second major criticism of the new science was that the reformers ignored the past--the lessons to be learned from the failures of Progressive education, the child development skills of many teachers in the schools--to plan from the college level downward. This resulted in a neglect of resources within the schools, resources which could have been used to combine a concern for subject matter with a concern for the learner. The new secondary level curricula, by concentrating solely on subject matter, created a classroom situation as unbalanced as that which characterized the excesses of the Progressive movement.

A third concern of those critiquing the reform movement was that designing comprehensive instructional packages left little room for teacher and pupil spontaneity. To the teacher, each day's work was carefully mapped out, regardless of whether the particular classroom situation that day was conducive to that particular lesson--and the lessons could not be interchanged because each built on those preceding it. Students, too, were often constrained to a particular sequence of learning regardless of their backgrounds and interests.

The difficulties which school districts experienced in choosing which secondary reform curricula to use (if any) were a fourth major criticism of the new science courses. Competing curricula (such as CHEMS and CBA) offered no guidelines as to which to choose, and the vague educational objectives and sweeping claims of each made the decision of which to use quite difficult. If a district chose to use one of the new secondary science courses (e.g. PSSC), it had to decide whether to use the others (CHEMS or CBA, BSCS) so as not to vitiate the potential of the first. Then these decision-makers had to consider how well the reform courses chosen would tie in with the traditional non-science curriculum. Time and scheduling problems also became a factor, as each science subject tended to absorb a large portion of the school day (and school resources). Small wonder that many schools preferred, in the absence of an integrated new curriculum, not to make any changes at all.

The lack of specific educational objectives in the new secondary science courses posed problems not only for decision-makers, but also for evaluators and those revising the curriculum. Evaluators faced questions such as: how does one determine whether a student has successfully been taught to think "as a scientist does?" These difficulties in evaluation created problems for those attempting to revise and improve the new curricula: when performance cannot easily be measured, how can a new curriculum be revised to be more effective? Further, by using mastery of subject matter as the only goal of the new science, its designers precluded the possibility of relating its immediate objectives to the long term goals and problems of society. Hence, the secondary reform courses became static, unquestionable entities from the moment of their design. The assumptions underlying the reforms remained hypothetical, for no experimental evidence could be brought to bear on these assumptions in the absence of criteria to measure by. Now that a concern for subject matter had again become a part of the curriculum, the issue of the "ends of education" became crucial--and the reform courses had nothing to offer in this regard.

A seventh major criticism of the secondary level reform courses was that they proved too difficult for the majority of students. The emphasis in the new science courses was on the abstract, discipline-oriented dimensions of a particular science; in effect, the course presupposed that each student enrolled planned to become a scientist. For the majority of students (who were not so interested in science to consider it as a profession), the reform curricula inevitably were unmotivating and overly demanding.

The reformers argued that if these students had not become accustomed to traditional science courses (with their emphasis on everyday applications and on the memorization of facts) the new courses (emphasizing abstractions and inquiry) would be more attractive, even to non-science majors. The reformers argued that as the reform courses penetrate to lower grade levels in the curriculum, the students who encounter the secondary reform courses will come properly prepared to handle them. However, a major criticism of the secondary level reform courses was that their single-discipline focus made efforts to design lower level preparatory courses extremely difficult. Thus, the reform courses have had to interest a student population trained to respond to a completely different kind of subject matter.

Recent Developments in Secondary Science--The Second Generation Reform Projects

Two Secondary Level Second Generation Reform Curricula--Harvard Project Physics and the ECCP Course

Those new science courses which were developed after the initial wave of post-Sputnik reform curricula had entered the schools can legitimately be defined as "second generation" reforms, as the developers of these courses had observed the lack of impact PSSC, CHEMS, CBA, and BSCS had on the schools. Some of the new reform projects, such as Harvard Project Physics, were designed primarily because the PSSC course had failed to attract more than a narrow segment of the student population. Others, such as the Engineering Concepts Curriculum Project (ECCP) broght a completely new subject matter focus to the secondary school curriculum.

Unlike the first generation reform projects, those second generation projects which have emerged did not at all adopt a single model for curriculum development (as PSSC provided for CHEMS and BSCS). Nor was there a second "wave" of curriculum reforms to parallel the rapid emergence of new science courses in the period immediately following Sputnik. The major distinguishing characteristic of the second generation reforms was that they were developed primarily in response to the lack of impact that the first generation curricula had on the schools, rather than primarily in response to the inadequacies of traditional science curricula. Beginning in 1964 with the initial work on Harvard Project Physics and continuing to the present with the 1971 set of AAAS Guidelines and Standards for the Education of Secondary School Teachers of Science and Mathematics, the second generation reforms represent the latest developments in secondary science education.

In this section, two major second generation reforms--Harvard Project Physics and the ECCP curriculum--will be explored. In the next section, the 1971 AAAS Guidelines for Pre-Service Secondary Science Teachers and the 1970 American Chemical Society (ACS) Conferences on Chemical Education will be discussed--for the second generation reforms attempted to influence science education through more general means than simple curriculum development.

The Harvard Project Physics group began work in 1963, supported by the Carnegie Corporation, the Alfred P. Sloan Foundation, the U.S. Office of Education, and the National Science Foundation. The developers intended to create a secondary level physics course that would "1) be sound physics; 2) have close connections with other sciences, such as astronomy and chemistry; 3) illustrate the methodological and historical development of the sciences; and 4) include the social and cultural consequences of the progress of science."[97] The leadership of the project exemplifies its difference from the first generation reforms: the three co-directors were a physicist and philosopher of science, a science educator, and a high school physics teacher. Its twelve-man Advisory Committee included scientists, science teachers, a specialist in publishing, a specialist in scientific manpower problems, science educators, and historians and philosophers of science.

The first draft of the course was written and taught experimentally in two high school during 1963-64. During the following three years, the course was revised each year and taught to sample groups of 550, 2500, and 4000 students.[98] In 1968-69, an "interval" edition was published; the final version of the course was ready to be used in the 1970-71 school year. This long development time (by the standards of the first generation reforms)was used to ensure that the materials would be as acceptable to teachers as possible.

Harvard Project Physics produced a set of Student Guides, a set of supplementary units, a set of Physics Readers, a set of self-instruction booklets, a set of Project Physics Handbooks, a Laboratory Guide, a uniquely designed set of laboratory equipment, film loops, sound films, overhead transparencies, and a Teacher Guide. The six Student Guides

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[97]Hurd, Secondary School Science, pg. 193.

[98]Ibid., pg. 194.

were equivalent to six units of a textbook complete with prepared tests (they now are produced as a single text) and are entitled: Concepts of Motion, Motion in the Heavens, Energy, Waves and Fields, Models of the Atom, and The Nucleus. The Physics Readers supplement the six Student Guides by providing a more detailed look at aspects of the particular part of physics being taught, and the Physics Handbooks act as the equivalent of a teacher's guide for the student. The supplementary units and self-instruction booklets are designed to provide additional topics for the course beyond the six units at the discretion of the teacher. The laboratory equipment is expensive: $1800 for a "starter" set, $3000 for a "recommended" set, and $5200 for a "complete" set for a single classroom.[99] As the multiplicity of materials suggests, the developers made every effort to give students and teachers great autonomy in interacting with the course.

The educational objectives delineated by the developers of Harvard Project Physics were to give students an understanding and appreciation of:

1) how the basic facts, principles, and ideas of modern physics developed;
2) who made the key contributions, and something of the lives of the men and women who did;
3) scientific methodology as illustrated by physics;
4) how physics relates to the cultural and economic aspects of contemporary society;

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[99] Holt, Rinehart, and Winston, Complete Order Form for the Project Physics Course Materials (New York, N.Y.: Holt, Rinehart, and Winston, 1970), pg. 3.

5) the effects of physics on other sciences, especially chemistry and astronomy; and
6) the relationship and interaction between physics and contemporary technology. 100

In designing the curriculum to accomplish these objectives, the project leaders attempted to validate all materials in terms of five areas: the discipline of physics, a normative philosophy of physics, learning effectiveness and differentiation, instructional effectiveness, and an integration of physics with the total curriculum. A major goal of the project, above and beyond its educational objectives, was to increase enrollments in secondary physics courses.

Harvard Project Physics was designed primarily to be an alternative (and, perhaps, a successor) to PSSC; the Engineering Concepts Curriculum Project (ECCP) was intended to provide a completely different subject matter focus in the high school curriculum. The basic conception underlying the ECCP was to "give students some understanding of the characteristics, capabilities, and limitations of modern technology;"[101] again, a major spur to developing the course was diminishing enrollments in high school physics. The developers intended that the course be cultural with technical and scientific content; that it not be vocational nor act as a replacement for biology, chemistry, or physics; and that it be aimed at the large majority of high school

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[100]Hurd, Secondary School Science, pg. 195.

[101]Engineering Concepts Curriculum Project, Teachers Manual, pg. xv.

graduates who do not take physics.[102]

The ECCP project began in the summer of 1965 when twenty-five engineers, scientists, and high school teachers developed a first draft of the course. This ECCP curriculum was then revised and tested each year over a three-year period with sample groups of five, twenty-eight, and sixty-five schools. A preliminary final version was published in 1968, and a final version in 1970. The student population used in testing the course was somewhat biased towards the "above average," science-oriented student: ninety-six percent of the sample student population planned to enter college, twenty-seven percent in science or mathematics.[103]

The ECCP project produced a textbook (The Man-Made World), a set of thirty laboratory experiments, and a Teacher's Manual. The textbook has fifteen chapters and is centered around the theme of "the extension of man's natural abilities to cope with nature," as elaborated through:

1) the extension of man's mental powers through information handling and processing,
2) the extension of man's sensory powers through information that can be used to formulate effective strategies of mobility and communication, and
3) the extension of man's muscular powers through the control of energy to specific ends.

As in Harvard Project Physics, the laboratory equipment is expensive: $3000 for a minimum package and $5000 for a complete package for a single classroom.[104]

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[102] Hurd, Secondary School Science, pg. 204.

[103] Ibid., pg. 205.

[104] Ibid., pp. 205-207.

The educational objectives of the ECCP course were:

1) to contribute to the technical literacy of all students;
2) to understand the impact of technology on today's world well enough to think rationally about technically based problems affecting society;
3) to appreciate technological-individual-societal interactions;
4) to provide insights into and understanding of the devices, processes, systems, and structures man creates to help him cope with nature;
5) to use beneficially the fruits of technology as they increasingly influence science and shape the quality of life in our society;
6) to appreciate the precision of thought and language gained through mathematics by manipulating symbols, and using models;
7) to acquire some of the basic engineering concepts and principles by means of which the world may be viewed rationally; and
8) to correct misconceptions and oversimplifications about the nature of science and of engineering. 105

Two Other Second Generation Reform Projects--the 1970 ACS Conferences on Chemical Education and the 1971 AAAS Pre-Service Guidelines

In 1970, the American Chemical Society (ACS) held two conferences on chemical education for the 1970's. The first of these conferences, the International Conference on Education in Chemistry, developed five reports: Chemistry for Citizens, Graduate Education in Chemistry and Beyond, Preparing Chemists to Meet Society's Future Needs, The Structure of Chemistry, and International Aspects of Chemical Education. All of these reports mentioned pre-college education tangentially; the Chemistry for Citizens group (of which I was a member) directly discussed the issue of elemen-

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105 Ibid., pg. 204.

tary and secondary science education.

The ACS reports produced the following recommendations for secondary education in chemistry:

> The educational community must make major efforts in curriculum development and in teacher training for the teaching of science and chemistry in the schools of the world so that education in both primary and secondary schools may reflect the broader view required today. Every analysis of the teaching of science has concluded that the most important single aspect of effective teaching is the capability and quality of the teacher. In the present instance, this implies the need for teachers who not only are trained in a broadened vision of science's capabilities and responsibilities, but are themselves imbued with a philosophy which gives high priority to society's needs. 106
>
> For secondary schools, a program for producing materials for the study of chemistry from a humanistic approach should be developed. This flexible approach would utilize newly developed, varied materials such as readers, laboratory exercises and equipment, programmed instruction books, films, texts, and teacher's guides. A diversity of new learning aids will enable teachers and students to emphasize those aspects of the materials which interest them the most and need not impress upon them a specific list of subjects. These materials would stress the humanistic development of chemistry as a creative product of the disciplined imagination and beyond this emphasize the interrelations between chemistry and the other natural sciences.... Full advantage should be taken of the relationship between pure and applied chemistry. An example would be the story of DDT: the basic chemical research which led to its synthesis, a consideration of its use by the agricultural industry, and finally an evaluation of the conflicts resulting from its wider ecological effects. The ethical and social dimensions of science and technology would be further developed in these materials through topics such as the potential manipulative power of the genetic code. The results of this curriculum development would function as a teacher training program of the first magnitude. The resultant evolution in teachers' attitudes and the availability of new materials should increase the numbers of involved students and their appreciation of science. 107

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[106] Division of Chemical Education, Preliminary Report, pg. 40.

[107] Ibid., pg. 58.

> The American Chemical Society should make special provisions to increase significantly the contact between college and university teachers of chemistry and all teachers of chemistry in the lower schools. To this end, changes should be made in the membership requirements for the Division of Chemical Education to enable all teachers of chemistry to become full and active members of the Division, and appropriate programs of participation should be developed. The American Chemical Society should establish a study group, composed of teaching chemists and competent specialists in educational theory, to develop up-to-date guidelines for teacher training and related areas. 108

In response to these recommendations, a second conference, the National Conference on the Public Understanding of Chemistry, was held by the ACS in late 1970. The purpose of this conference was "to lay plans which could be the basis for proposals to develop 1) a new, humanistic chemistry program for high school and two-year college students who do not contemplate a career in science, and 2) a mass media campaign to increase appreciation by the public of the chemical world in which we live."[109]

At this conference, the planning group concerned with mass media produced a set of recommendations which will be considered in Chapter V. The group concerned with developing a humanistic secondary level chemistry course evolved the following essential criteria for building such a course:

- [the meeting of the student at the level of his own experience, interest, concerns, and problems while providing him with an awareness of the chemical world in which he lives]
- [flexibility to the needs and environment of the student]

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[108] Ibid., pg. 60.

[109] American Chemical Society, Public Understanding of Chemistry, pg. 1.

- full student involvement and participation in the formulation of concepts before their verbalization
- a multidisciplinary base
- emphasis on chemistry as a human endeavor and a humane enterprise, not as a disembodied discipline enhancement of the curiosity, sensitivity, and self-fulfillment of the individual student
- strong, positive motivation of students
- continued testing of all materials in real-life situations with free and valid feedback
- approval and support by professional societies such as the American Chemical Society
- recognition of the classroom teacher as the strong, independent variable in the program, who must be totally involved at each step in the development and testing of the program [110]

To implement these criteria, the planning group conceptualized a course consisting of "project-oriented motivational modules" and accompanying "basic conceptual modules." By organizing the course in this manner, the group hoped that students would first become motivated by interest in a topic of current concern (motivational modules) and then would explore the intellectual undergirdings of the topic they had become interested in (conceptual modules).

These two ACS conferences may well result in the development of a second generation secondary level chemistry course to supplement and replace CHEMS and CBA. The American Association for the Advancement of Science (AAAS) also held a series of conferences in the period 1969-71; these conferences were not directed towards curriculum development *per se*, but towards revising the preparation of science teachers to produce teachers more effective in and more receptive to the new science materials.

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[110] *Ibid.*, pp. 8-9.

A major failing of the first generation secondary science projects was their preoccupation with changing the curriculum to the point of ignoring the teacher; even those first generation projects which did attempt to change teacher attitudes confined their efforts to holding in-service workshops, and ignored pre-service teaching. The lack of success of the first generation materials in the schools and the results of the ROSES study convinced the second generation reformers that if change was to occur in science education, attention must be given to the pre-service education of teachers. To this end, the AAAS and the National Association of State Directors of Teacher Education and Certification (NASDTEC) collaborated to produce the document "Guidelines and Standards for the Education of Secondary School Teachers of Science and Mathematics" (1971).[111] A similar document of guidelines for elementary level pre-service science education was published by the AAAS in 1970.[112]

To prepare the secondary guidelines, two preliminary conferences were held to review existing practices, consider

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[111] American Association for the Advancement of Science and National Association of State Directors of Teacher Education and Certification, Guidelines and Standards for the Education of Secondary School Teachers of Science and Mathematics (Washington, D.C.: American Association for the Advancement of Science, 1971).

[112] American Association for the Advancement of Science, Pre-Service Science Education of Elementary School Teachers (Washington, D.C.: American Association for the Advancement of Science, 1970).

present trends, and discuss future needs in pre-service secondary science preparation. As a result of these conferences, four committees were formed to prepare preliminary reports on:

1) the nature of science and mathematics and implications for the teaching of science and mathematics,
2) the necessary preparation of the mathematics teacher in mathematics and other areas,
3) the necessary preparation of the science teacher in areas of science and mathematics, and
4) the strategies for the teaching of science and mathematics. 113

Three regional conferences were then held to discuss these reports; from the results of these conferences, the final set of Guidelines and Standards was prepared.

The Guidelines concerned with secondary science teachers read as follows:

Guideline I: Teacher education programs should provide experiences that foster continuous growth in those human qualities of the teacher that will enhance learning by his students.

Guideline II: Teacher education programs should provide teachers with the knowledge and experience to illustrate the cultural significance of science, to relate science and mathematics through technology to social conditions, and to apply the analytical methods of science in multidisciplinary approaches to studying and solving societal problems.

Guideline III: Teacher education programs should provide opportunities for prospective teachers to gain insight into the intellectual and philosophical nature of science and mathematics.

Guideline IV: The teacher education program should require the prospective science teacher to attain broad minimum competencies in several fields of science and technology, and high levels of competence in an appropriate teaching speciality.

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[113] American Association for the Advancement of Science, Guidelines for Secondary Teachers, Forward.

Guideline V: Teacher education programs should equip the science teacher with at least minimal mathematical competencies

Guideline IX: The teacher education program should provide the prospective science or mathematics teacher with experiences which require him to seek out and study concepts which are new to him, and then to synthesize written and especially oral expositions of them designed for others for whom the ideas are also new.

Guideline X: Teacher education programs should provide experiences that will enable the prospective teacher to learn about the nature of learning, conditions that help young people learn, and how to maintain a proper learning environment.

Guideline XI: Teacher education programs should develop the ability of the future teacher to select, adopt, evaluate, and use strategies and materials for the teaching of science and mathematics so that teaching-learning situations for which he is responsible will be consistent with general knowledge about teaching and learning and will be appropriate both to the special needs of the learners and to the special characteristics of the science disciplines or the interdisciplinary problem.

Guideline XII: An undergraduate program for the secondary school mathematics and science teachers should develop the capacity and the disposition for continued learning in mathematics and science and the teaching of these subjects. 114

The Basic Assumptions Underlying These Second Generation Materials

Common Characteristics of the Second Generation Reforms

Because the second generation secondary level reforms did not utilize a common model for curriculum development and did not come in a single "wave" of revision (as did the first generation reforms), they exhibit less uniformity in goals

[114] *Ibid.*, pp. 5-41.

and methods than did the first generation reforms. For example, of the four second generation reform projects I have cited, one (Harvard Project Physics) represents a "reform" of a first generation course (PSSC), one (ECCP) represents a new subject matter focus, one (the ACS conferences) represents an incipient "reform" of the CHEMS and CBA courses, and one (the AAAS Guidelines) attempts to affect the secondary science curriculum by changing pre-service teacher education. This diversity is in sharp contrast to the first generation secondary level reforms; for PSSC, CBA, CHEMS, and BSCS were all very similar attempts to change the curriculum materials for a single scientific discipline.

Despite this diversity, the second generation reform projects have a number of common characteristics. First, each project emphasizes the interrelatedness of the scientific disciplines. Those projects which are grounded in a single discipline (Harvard Project Physics, the ACS course) focus on that discipline's close connections with the other sciences, its methodological and historical emergence as a distinct entity, and its applications to multidisciplinary scientific problems. Moreover, curriculum projects have emerged to develop secondary level science courses (such as the ECCP materials) which do not concentrate on a single scientific discipline.

Second, the social and cultural consequences of science are considered in the second generation reform materials.

The AAAS Guidelines discuss the need for teachers to acquire knowledge in the cultural implications of science and technology as well as in its disciplinary foundations. The interactions of science, technology, and society are utilized in Harvard Project Physics, the ECCP materials, and the incipient ACS course to motivate the student to undertake intellectual explorations into the disciplinary underpinnings of science.

Third, the second generation projects focus on the role of the teacher as interpreter and mediator of learning. Teachers and professional educators have been heavily involved in all stages of the four second generation reforms cited. The materials produced by these projects are designed primarily as a supplement to the teacher's knowledge and skills. They deliberately include many alternative pathways for learning to allow for flexibility in deciding what content students should learn at what time.

The increased flexibility in the second generation materials extends to the student as well as to the teacher. Since these materials were prepared to attract and hold the interest of pupils not especially interested in science, the content of these courses is heavily oriented to current societal concerns, and provides many opportunities for self-directed exploration and learning. To facilitate student interest, teachers of these courses have been encouraged by the reformers to increase their skills in creating an interesting classroom environment and in understanding and using the latest developments in learning theory.

A fifth common characteristic of the second generation reforms is their concentration on behavioral objectives and performance criteria. For example, one of the four standards in the AAAS Guidelines and Standards requires that "teacher education institutions should develop performance criteria as guides in planning teacher education experiences, in evaluating teacher education programs, and in assessing the ability of prospective teachers to contribute to effective learning."[115] While the Harvard Project Physics and ECCP courses are not explicitly oriented to behavioral objectives, these materials spell out in much greater detail what is desired of the student than did the first generation reform courses.

Differences Between Traditional, First Generation, and Second Generation Science Courses

In Chapter I, the differences between traditional secondary science courses and the first generation reform courses were considered, and the basic assumptions underlying the first generation reforms were delineated. The second generation reform curricula seem to represent, because of the many similarities between the two, a return to the traditional pre-Sputnik science course. In fact, however, the second generation courses are a fusion of these traditional courses and the first generation reforms, a compromise which takes for

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[115] Ibid., pg. 46.

its substance something from each extreme.

For example, traditional science courses, especially those from the Progressive era, focused only on how the needs of the pupils and society could be fulfilled by the teacher, to the neglect of scholarship and the disciplines. The first generation reforms emphasized only these latter concerns, while ignoring the needs of the pupils and society and the influence of the teacher on the curriculum. The second generation reforms, co-sponsored by both scientists and professional educators, combined these sets of emphases by attempting to orient discipline-based materials somewhat towards the needs of the pupils, the teacher, and society.

Traditional secondary science courses emphasized the role of the teacher to the virtual exclusion of disciplinary content; the first generation reforms attempted to create "teacher-proof" materials, and developed course content so interdependent that daily lesson plans became completely predetermined. The needs and interests of students were a dominant factor in the selection of content for traditional science courses; the first generation reforms were predicated on the assumption that any content would interest students if packaged in a "puzzle-solving" format. In the second generation reforms, flexibility for the teacher and provision of student interests has been ensured by providing many alternatives in subject matter for a given course, but a disciplinary orientation has been retained by using a sub-structural scientific framework around which all materials are based.

In the second generation reforms, the rigor and scholarship of the first generation materials has been de-emphasized in favor of attracting more pupils to science and creating a generalized "scientific literacy." The content of the second generation materials, however, is far more up-to-date, accurate, and discipline-oriented than was the content of traditional secondary science courses. The focus on the single scientific disciplines in the first generation reforms has shifted to more of a concentration on multi-disciplinary scientific problems in the second generation materials; and the interactions of science and technology, which were completely omitted from the first generation reforms, have again become a part of the science curriculum.

Mindful of the fact that the lack of success of the first generation reforms may have been due to the way that they were diffused as well as to their substance, the second generation reforms have included much more input from professional educators and have paid more attention to factors affecting the curriculum such as pre-service education. Because of the difficulties inherent in evaluating the first generation reforms, the second generation materials have tried to specify carefully what is desired of students and what the educational objectives of the courses are.

Overall, the second generation reforms are predicated on the following basic assumptions.

Assumptions About Science

1. The scientific disciplines (plus engineering) provide the sole content base needed for teaching secondary science. Some discipline-based materials dealing with the needs of the pupil, the teacher, and society should be included as motivational, subsidiary content.
2. The most crucial aspects to learn about a scientific discipline are its key concepts, its principles, its modes of inquiry, and its relevance to contemporary society. By learning these, a student gains the two skills secondary science provides: understanding society as seen through the scientific disciplines, and perceiving reality as a scientist perceives it.
3. The topics in science courses should be arranged so that student and teacher have a wide variety of alternatives to choose among; concepts should be covered in as great a depth as possible without sacrificing student involvement.
4. Non-rigorous or outdated scientific knowledge is worse than useless. The science curriculum must be updated periodically to ensure that out-of-date

knowledge is removed, new knowledge added.

5. The interactions of science and technology are a part of the science curriculum.
6. Those sciences which have traditionally been taught in the schools are those most important to teach, but courses corresponding to an inter-disciplinary scientific approach are permissible as supplements to the traditional sciences.

Assumptions About Education

1. Preparing courses to be taught in schools to persons of the appropriate ages is a sufficient step to solve the national problems which have led to pressures for science education reform.
2. A good science curriculum can be designed within the traditional organizing constraints of the schools (grading, single teacher, discrete courses at discrete times, etc.).
3. Instructional materials packages coupled with teacher training programs and support from educators are sufficient to ensure that schools adopting the new science curricula will use them correctly.
4. Instructional materials packages are best prepared by groups consisting of scientists, teachers, and professional educators.

5. Students learn science best through textbooks coupled with inductive exercises--both of these should contain some discipline-based materials oriented to their interests. Students should have several alternatives open to them at any one time.
6. The schools will use the new science curricula when they are developed.
7. Standardized tests, grades, and similar standards of achievement are a sufficient means of measuring future scientific excellence in secondary students.
8. "Superior" students, "disadvantaged" students, and "science-oriented" students can be identified, and special courses constructed for their use.

By comparing these second generation assumptions with the assumptions governing the first generation reform materials (pages 45-47), it can be seen that, although many revisions have taken place, the second generation reforms overall are closer to the first generation materials than to traditional science curricula.

Analyzing the Strengths and Weaknesses of the Second Generation Reforms

The second generation reform materials have not been in use long enough to determine whether or not they are successful according to the three criteria cited in Chapter II:

1) that the new materials be used;

2) that, when used, they be used correctly and coherently; and

3) that, on the basis of formal and informal evaluations, use of the new materials results in substantially more pupil interest and better student performance than the materials which the new are intended to replace.

By a judicious system of compromises, the second generation reform materials have managed to retain many of the strengths of the first generation reforms while eliminating many of their acknowledged weaknesses.

For example, unlike the first generation reforms, the second generation projects have tried to keep their materials from being too sophisticated or too abstract for the average high school student. They have attempted to design materials which are constructed for the non-science major, and have tried to motivate more students to take science courses by designing materials with some social and personal applications. More attention has been paid to preparing the teacher for the new courses, and to specifying what pupil behaviors the new materials hope to elicit. Great care has been taken in the diffusion of the second generation courses to ensure, as much as possible, that they will be used.

However, two major and oft-noted weaknesses of the first generation secondary materials remain. First the second generation materials are designed to fit the existing organization of the school curriculum (grading, single teacher, etc.), and have made no effort to change these arrangements to a structure more suited to the teaching of science. At the time, this was a necessary strategic move to give the reform curricula viability in being adopted. Now, however, changing the schools to fit science education seems a more important issue than changing science education to increase leverage for implementation in the schools. Chapter III discusses the reasons behind this shift in educational priorities.

Second, the second generation reforms have created only isolated components to fit within the present curriculum rather than working to produce a curriculum integrated either horizontally or vertically. That is, no effort has been made to produce a joint set of science materials and materials from other subjects which together present a unified whole. Nor has any effort been made to produce an integrated set of science materials extending from K-12, or even from 9-12.

Two major unperceived weaknesses of the first generation reforms have also been perpetuated in the second generation materials. First, to prepare young people for future roles in shaping and responding to society's future needs is one of the primary responsibilities delegated to the formal educational system.[116] Certainly one great strength of the Progressive movement was its focus on this responsibility (although the ways with which it attempted to fulfill this responsibility ultimately failed). Today, the educational system's responsibility for future-oriented training falls especially on science education, as science takes an ever greater role in shaping the world's future. Yet, a major weakness of the secondary science reforms must be that no systematic effort has been made to determine what science-based problems and concerns our society may have ten to forty years in the future,[117] for this is the amount of time that will pass before students now in high school are making the major decisions in our society. The whole issue of defining a future-oriented set of objectives for science education--an issue central to defining "ends" for education--has been bypassed by both the first and second generation reforms (although the second generation reforms at least have developed some present-oriented objectives). As a result of this weakness, the objectives now in use in secondary science education risk producing students unprepared to face the crucial challenges from its scientific prowess that mankind may encounter in the next twenty to forty years.

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[116]This point is well discussed in Hurd, Secondary School Science, pp. 104-107.

[117]Other than fairly naive manpower extrapolations.

Second, both the first and second generation secondary reforms have accepted our country's entire system of formal education as satisfactory in its present form. The assumptions underlying our present educational system that education should use the disciplines as its sole content, that certain limited kinds of achievement connote future excellence, and that students can meaningfully be screened according to future ability have all been unquestioningly accepted by the second generation reforms. The failure of the second generation reforms to analyze these assumptions and to determine if they are suitable for secondary science education constitutes a second major weakness.

These four major weaknesses, two oft-noted and two largely unperceived, ultimately stem from flaws in the basic assumptions underlying the second generation reforms. The next three chapters will examine certain of these assumptions in order to determine what changes need to be made to eliminate these four weaknesses. In Chapter III, a rudimentary set of future-oriented objectives for secondary science education will be constructed, and these objectives used to analyze whether the scientific disciplines taught via textbooks and inquiry constitute a solely sufficient vehicle for teaching secondary science, given the additional science-based skills that preparing students for the future may require. In Chapter IV, the assumption that standardized tests, grading, and similar standards of achievement are a sufficient means of measuring future science-based excellence in secondary students will be examined. In Chapter V, the assumption that "superior" students, "disadvantaged" students, and "science-oriented" students can be identified and special courses constructed for their use will be discussed. The thesis will conclude with a summary of the implications of these examinations for current directions in secondary science education, and a brief projection of probable futures for secondary science education in the next ten years.

CHAPTER III

EXAMINING DISCIPLINE-ORIENTED INQUIRY AS A VEHICLE FOR TEACHING SECONDARY SCIENCE

A Brief History of Discipline-Oriented Inquiry in Secondary Science Education

After the Progressive movement's emphasis on the needs of the student had created a science curriculum out of touch with the scientific disciplines, the first generation reforms produced secondary science curricula based solely on discipline-oriented content taught through a process of inquiry. When these first generation materials did not succeed in the schools, the second generation reformers, fearful that this lack of success was due to an overly disciplinary focus, created science curricula which still--with one exception--were based upon the disciplines; but which also attempted to take into account the needs of the pupil, the teacher, and society (as perceived by the reformers).

For example, Harvard Project Physics and the incipient ACS secondary chemistry course are both designed around the subject matters and conceptual schemes of their disciplines, but attempt to interest students by discussing contemporary social-technological aspects of our society which are related to the accomplishments of these disciplines. For instance, after an explanation of the concept of electromagnetic induction, the Harvard Project Physics text takes fifteen pages to discuss the electric motor, the electric light bulb, the Niagara Falls Power Plant, and the effects of electricity on society.[118] Similarly, the ACS course has tentatively been structured around "motivational" modules (on such topics as body chemistry, population control, air and water pollution, and psychedelic drugs) followed by "conceptual" modules based on current chemical theories relevant to these phenomena.[119]

In contrast to these two discipline-oriented courses, the ECCP course, The Man-Made World, is a second generation secondary reform which is not based on any scientific discipline (although much of it is oriented around engineering). The ECCP course uses practically-oriented technological inquiry rather than discipline-oriented scientific inquiry as its vehicle for discussing the nature of physical reality. That is, rather than attempting to convey the conceptual structures and processes of inquiry of a scientific discipline, the ECCP course attempts to give its students technical

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[118] F. James Rutherford, Gerald Holton, and Fletcher G. Watson, The Project Physics Course (New York, N.Y.: Holt, Rinehart, and Winston, Inc., 1970), pp. 84-99.

[119] American Chemical Society, Public Understanding of Chemistry, pg. 9.

literacy, an understanding of the impact of technology on today's world, and a conception of some basic engineering principles by which the world may be viewed rationally. In fact, the scientific disciplines are seldom mentioned in the ECCP text, and the few discussions of the nature of science which do occur are relatively simplistic.[120]

The ECCP course is an exception to recent thought in secondary science education; much of the work in science education since Sputnik has been centered on the idea of discipline-based instruction. In the last ten years, for example, the National Education Association's Disciplines Seminar (1961),[121] J.J. Schwab's Inglis Lecture at Harvard (1961),[122] the curriculum conferences at the University of Illinois and San Jose State (1963, 1964),[123,124] the National Science Teachers Association's Theory into Action recommendations

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[120] Such as the discussion on "Nature's Laws" in Engineering Concepts Curriculum Project, The Man-Made World (New York, N.Y.: McGraw-Hill Book Company, 1971), pg. 621.

[121] Project on Instruction, Scholars Look At Schools.

[122] Joseph J. Schwab, "The Teaching of Science as Inquiry," The Teaching of Science (Cambridge, Mass.: Harvard University Press, 1966).

[123] Fifth Annual Phi Delta Kappa Symposium on Educational Research, Education and the Structure of Knowledge (Chicago, Ill.: Rand McNally, 1964).

[124] G. W. Ford and Lawrence Pugno, eds., The Structure of Knowledge and the Curriculum (Chicago, Ill.: Rand McNally, 1964).

(1964),[125] the NEA Educational Policies Commission's Education and the Spirit of Science recommendations (1966),[126] and J. T. Robinson's work on the philosophical bases of science teaching (1968, 1969)[127,128] have produced major ideas for the secondary science curriculum which are based on the concept of discipline-centered courses (although some of these ideas do deal with the disciplinary attributes of science as a whole rather than with the particular scientific disciplines). The basic rationale underlying all of these discipline-focused ideas is that:

1) the knowledge that comprises a discipline is the only organized knowledge of the culture;[129]
2) therefore, the teaching of science in high school should reflect the nature of science as it is known to scientists (the conceptual schemes,

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[125] National Science Teachers Association Conference of Scientists, "Conceptual Schemes and the Process of Science," Science Teacher (October, 1964), pp. 11-13.

[126] Educational Policies Commission, Education and the Spirit of Science (Washington, D.C.: National Education Association, 1966).

[127] James T. Robinson, The Nature of Science and Science Teaching (Belmont, Calif.: Wadsworth Publishing Company, 1968).

[128] James T. Robinson, "Philosophical and Historical Bases of Science Teaching," Review of Educational Research Vol. 39, No. 4 (October, 1969),pp. 459-471.

[129] Hurd, Secondary School Science, pg. 38.

values, and evolutionary organization of scientific thought);

3) by doing this:

a) teaching will be more effective because the elements of knowledge taught will be logically related,

b) what is learned will be better retained because it is tied into a meaningful cognitive structure,[130]

c) what is learned will be more transferable because it is part of a system of knowledge, and

d) students will not be shocked in later life if the "facts" they learned in school are revised.[131]

This recent predominance of discipline-oriented content has been paralleled by preoccupation with inquiry as the best process for teaching secondary science. That is, not only have recent reformers argued that science should be taught as a process of inquiry, but they have also tended to conclude that students learning science should be taught by being allowed to inquire into their science materials. Each student is encouraged to be an "independent investigator" of a

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[130]David P. Ausubel, "Some Psychological Aspects of the Structure of Knowledge," Education and the Structure of Knowledge (Chicago, Ill.: Rand McNally, 1964).

[131]Schwab, "Teaching of Science," pp. 37-52.

scientific problem, although the science materials are carefully designed so as to lead him to "discover" the "right" conclusion. For example, the BSCS curriculum has a series of "invitations to inquiry" designed to build cumulatively through the school year; their range and sequence is as follows:

> I. Simple Inquiry: the role and nature of general knowledge data, experiment, control, hypothesis, and problem in scientific investigation.
> II. The Conception of Cause in Biological Inquiry: causal factors, multiple causes, time sequences, negative causation, feedback.
> III. Quantitative Relations in Biology: linear relations, exponential relations, rate, change of rate, units, and constants. 132

As can be seen from this outline, although the student is allowed to inquire freely, he is expected to reach a specified, pre-set goal. The basic rationale underlying the use of inquiry as a process for teaching science is that:

1) students will learn the processes of the scientific disciplines best by doing them,
2) students will learn scientific values such as asking their own questions and doing their own exploring, and
3) students will become more creative and more involved with their science materials.

Inquiry has encountered more opposition among those concerned with science education than has the concept of a discipline-focused curriculum. David Ausubel, for example,

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[132] Hurd, Secondary School Science, pg. 82.

has extensively questioned the philosophical and psychological foundations of inquiry, and has argued that it necessarily prevents the systematic presentation of science as an organized body of knowledge by concentrating too much attention on a deep probing of isolated areas.[133] In general, however, the second generation materials have supplemented their textbooks with carefully led inquiry into concepts; most of the Harvard Project Physics and ECCP laboratory experiments are designed in this manner.

Discipline-oriented inquiry, then, is the central structural focus of modern secondary science education--but it is not the only focus which could be used. Schwab has identified <u>four</u> factors (each having ephemeral and perennial portions) on which a science curriculum could be based:

1) needs, demands, and conditions that our social structure imposes on us;
2) characteristics of the learning individual or the learning process;
3) characteristics of the teaching individual or the teaching process; or
4) characteristics of the subject matter being taught.[134]

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[133] David P. Ausubel, "An Evaluation of the Conceptual Schemes Approach to Science Curriculum Development," <u>Journal of Research in Science Teaching</u> 3(1965), pp. 259.

[134] Schwab, "Teaching of Science," pp. 32-37.

Both the first and second generation reforms have centered their curriculum development on the characteristics of their subject matter (subject to the constraints of the formal educational system in the United States); the second generation reforms have also added some minor concern for the characteristics of the learner, the teacher, and society.[135] No major work is being done in current science education to evolve alternative secondary science courses based on other than a disciplinary subject matter focus; such work falls outside the basic assumptions underlying these reforms.

Schwab, at the NEA Disciplines Seminar in 1961, suggested one way that this central focus of contemporary science courses on subject matter might be modified. He proposed that the demands of the disciplines and the needs of our culture and society, where competitive, could be reconciled by considering the curriculum at each level of school as consisting of two parts:

> One part, to be called the nuclear curriculum, would contain materials from the disciplines selected to fulfill those needs of education which are determined primarily by the needs of the developing child and those aims imposed by our culture and society. Such materials would be taught, wherever possible, within the frame of the discipline from which they were taken. But where the exigencies of time, of learning competence, or other need required it, the materials would be freely removed from their theoretical or disciplinary context and put into the context of

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[135]The ECCP course is not an exception to this overall subject-matter orientation; while it is not structured around a scientific discipline, it still has a predominant focus on engineering.

> unquestioned principles designed for use.[136]
>
> The second, or cortical, component of the curriculum would be chosen by contrary and complementary principles. It would consist of materials chosen specifically because they are representative of major disciplines. Such materials would display the more important conceptual frames of each discipline, its techniques of discovery and verification, and the variety of problems to which it addresses itself....
>
> An overall ratio in the school, probably about sixty percent nuclear--forty percent cortical, was envisioned....In the earlier grades, the cortical, or disciplinary, component might be as small as ten percent. In the last two years of high school, it might well rise as high as eighty to ninety percent. 137

Current directions in curriculum development in secondary science education are aimed primarily at producing cortical materials. This narrow focus has resulted in two weaknesses: a lack of future-oriented objectives, and a non-integrated curriculum. By determining the science-based skills which must be taught to prepare students for the future, the adequacy of a discipline-centered curriculum for teaching these skills can be examined.

A Future-Oriented Analysis of What Skills Secondary Science Education Should Attempt to Convey

The Assumptions underlying Future Studies

Future studies is an emerging field of knowledge which attempts to describe the alternative futures which may result

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[136]Note that in Schwab's conception even nuclear materials would be based solely on disciplinary sources.

[137]Project on Instruction, Scholars Look At Schools, pp. 51-52.

from our actions in the present. A futurist, Robert Bundy, has compiled a short list of the basic assumptions about the future that underlie future studies:

> 1. The future is a mental construct--an idea--it has no existence except in the human mind.
> 2. An array of possible futures are open to mankind; there is no single already determined line of the future, nor was there only one historic past which could have happened.
> 3. The specific social future of mankind that will actually occur cannot be known with certainty. We cannot have a knowledge of the future. We can only have knowledge of the past or present.
> 4. Conjectures about the future are neither true nor false. We can only try to determine which one is more plausible.
> 5. All possible futures cannot be described at any point in time.
> 6. Man by his conscious choices can affect how the future actually occurs; man is part of and agent in directing the historical process.
> 7. Thus, the future is influenced by human choices in the present. There is a causal and chronological connection between past, present, and future even though this connection cannot be perfectly known...
> 8. Without forecasting, there is no freedom of choice. To make better decisions about the future it is necessary to learn to make better conjectures about the future. 138

Future studies, then, is necessarily an inexact field of knowledge. In science education, it may seem paradoxical to base decisions on inexact knowledge from a still-emerging field. But, as long as our formal educational system has responsibility for preparing students in the present for societal roles in the long-term future, decisions about how science education will fulfill this responsibility must be

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[138] Robert Bundy, "Some Basic Assumptions About the Future," Syracuse, New York: Feb., 1971 (offset).

made. Decisions based on organized, systematic knowledge are likely to be more successful than decisions based on intuitive, unexamined beliefs; and future studies is our only source of organized, systematic knowledge about the future.

A future-oriented analysis of what skills secondary science education should attempt to convey--given the needs of our society--must include the following:

1) a normative forecast--a description of what societal future is desired with a statement of what values underlie this choice,
2) a set of alternative primary forecasts--descriptions of what societal futures may occur if present trends and policies continue without intervention,
3) a set of alternative secondary forecasts--descriptions of what interventions will be needed to bring each alternative primary forecast close to the normative forecast, and
4) a discussion of what skills secondary science education should attempt to convey, given these forecasts.

Obviously, within the scope of this thesis any such analysis can only be rudimentary. A rigorous normative forecast for a democracy would require a knowledge of what all those affected by science education desire for the future. Rigorous primary and secondary forecasts would require a description of alternative futures for the world and the United States in all those areas which the science education of United States citizens might affect. The difficulties involved in doing such forecasts would be enormous, and the sophistication required would transcend the state of the art in future studies at this time.

However, a rudimentary analysis is not subject to such extreme difficulties. A set of basic values for the future can be deduced from our societal norms, and a very basic normative forecast for our society can be inferred from these values. Many futurists have attempted to construct alternative futures for the United States and the world in the next thirty to fifty years; the major schools of thought which have emerged can be used to provide very basic primary and secondary societal forecasts. A rudimentary analysis from these very basic forecasts would be worthwhile because:

1. It would derive a set of science-based, future-oriented skills that secondary science education needs to provide.
2. It would give some indication of the viability of our basic societal assumption that we can train and screen students now to assume major responsibility in the long-term future.
3. It would provide a comparison for the implicit assumptions about the future underlying science

education at present.

4. It would give some indication of how fruitful and how difficult a more rigorous future-oriented analysis might be.

The remainder of this section is devoted to such a rudimentary analysis.

A Normative Forecast--What Future is Desired

If any American presidential candidate were to state his goals for the long-term future of the country in such a way as to appeal to the broadest possible segment of the American population, his statement might read:

> We all should have access to the basic necessities of life, including food; clothing, shelter; and a safe, livable environment. We all should be able to accumulate possessions beyond these basic necessities consonant with our achievements. We all should have the opportunity to participate in any societal decision which affects us. Our society should not interfere with the lives of its citizens. We should all be able to feel secure knowing that our children will grow up in a society which has maintained these rights.

The values expressed in this statement are central to our present societal norms and seem likely to remain basic goals for our society for at least the next thirty years.

Of course, some of these values contradict one another; for example:

- maintaining the long-term existence of our society seemingly necessitates less than total participation by citizens in decision making, particularly in wartime when secrecy and quick decision-making are crucial.
- to preserve a safe, livable environment, our society often interferes in the lives of its citizens through traffic laws, restrictions on pollution, and so on.

Our country has resolved these contradictions in its basic values by striving to maximize their sum rather than attempting to maximize each separately.

Also, these societal value statements are very general; if the meanings of these statements were specified by stating them in operational terms, many citizens would disagree about what these values actually mean in practice.

- Should citizens who do not work receive from society "the basic necessities of life"?
- Must school children forcibly be bussed to ensure that each citizen can "accumulate possessions consonant with his achievements"?

Despite such issues of major dissensus concealed by the generalized nature of these value statements, inasmuch as our country has any set of shared, fundamental values which provide a societal matrix of beliefs, they are represented in the above statements. From these values, a basic normative forecast for our society in the next thirty to fifty years can be extrapolated.

A utopian United States in the year 2000 might look like this:

> All of the inhabitants of the United States have adequate food, clothing, shelter, living space, and an environment conducive to health. Each person has access to services which foster self-realization and physical and mental well-being. No one needs to fear either violent crime or dishonesty. Each member of the society has at least two-thirds of his or her time free for personal affairs; each person is free to live during this time in the manner he or she chooses, so long as this does not infringe on the similar rights of others. Sufficient natural resources and technological accomplishments exist so that those who desire to live in a state of wealth and luxury will be able to compete with others through a system of accomplishment-based free enterprise for the privilege of attaining this status. Whether the United States has preserved its status as a nation or joined a world consortium, its inhabitants live in a democracy, secure in the knowledge that they will not be forced to relinquish this form of government.

This normative forecast may seem so basic as to be worthless; but the primary forecasts which follow indicate that, without intervention, the future may deviate from the pattern above in surprising ways.

A Set of Alternative Primary Forecasts-- What Futures Are Expected

In the last five years, many noted figures in future studies have attempted to construct alternative thirty- to fifty-year forecasts for the United States and the world. Given the basic assumptions about the nature of future studies on page 107, the criteria by which these projections can be judged are:

1) plausibility--a forecast should be reasonable, i.e. it should describe a state of affairs which could grow out of the present and be continuous with the present....A forecast could be plausible and yet be judged to have a low probability...
2) specified time frame--a forecase should be built around some time frame which makes clear the speed and direction with which the imagined state of events could occur...
3) internal consistency--a forecast should be coherent in all its parts, i.e. any component part of a forecast should not contradict any other component...
4) clearly articulated assumptions--the forecast should not leave in doubt what assumptions are being made to support the forecast. To state... that if present trends continue the United States will have a population of 300 million by the year 2000 is of little value unless one defines what basic assumptions are being made...no major wars, a continuing rate of population growth, no major changes in family structure, no basic changes in attitudes towards children, etc...
5) realism--a forecast...should be a state of affairs in which it is judged real people can live. A forecast...that contradicts our basic knowledge and understanding of human nature would be unrealistic...

6) justification--a forecast...should be built on as high a level of rational argument as possible....[139]

From these criteria and two additional specifications--that the forecasts should represent the spectrum of major schools of thought in future studies and should discuss those areas delineated in the normative forecast--five alternative primary forecasts have been selected for use in this analysis from the work that has been done in future studies during the last five years. These are:

a) the "surprise-free" projections for American from The Year 2000 (Herman Kahn and Anthony Weiner);[140]

b) the forecast for the world from The Next Ninety Years (Harrison Brown, James Bonner, and John Weir, eds.);[141]

c) the projections for the world from the World 3 Model of the Systems Dynamics Group at MIT (Forrester, Meadows);[142]

d) the forecast for America from An Alternative

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[139] Robert Bundy, "Purpose and Characteristics of Forecasts," Syracuse, New York: Feb., 1971 (offset).

[140] Herman Kahn and Anthony J. Weiner, The Year 2000 (Toronto, Canada: The Macmillan Company, 1967).

[141] Industrial Associates, Next Ninety Years.

[142] Dennis L. Meadows, et al., The Limits to Growth (New York, N.Y.: Universe Books, 1972).

Future For America II (Robert Theobald);[143] and

e) the analysis of the future in "What We Must Do" (John Platt).[144]

Brief descriptions of these forecasts are summarized in Appendix A.

Each of these five alternative primary forecasts for American society contains a radically different view of what challenges the United States will encounter in the next twenty to fifty years. To summarize the ways in which each differs from the normative forecast:

- the "surprise-free" projection for America from The Year 2000 pictures a future for America essentially like that depicted in the normative forecast
- the forecast for the world from The Next Ninety Years describes three major deviations from the normative forecast for America:
  1) United States population will be quite large, and problems of crowding will occur;
  2) the material standard of living in America will be depressed by severe environmental problems and a lack of trained technical manpower; and
  3) the position of the United States in the world community will be very insecure as a result of

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[143] Robert Theobald, An Alternative Future for America II (Chicago, Ill.: Swallow Press, 1970)

[144] John Platt, "What We Must Do," Science 28 (Nov., 1969), pp. 1115-21.

its status as a "have" country in a world of "have-nots."

- the projections for the world from the World 3 Model of the Systems Dynamics Group at MIT forecast a primary future different from the normative future for the United States in that:
    1) America's growth and standard of living will be limited by lack of resources, pollution, or lack of food; and
    2) the world tensions generated by pressures of resource depletion, over-population, and pollution will create an international situation conducive to global warfare.
- the forecast for America from <u>An Alternative Future for America II</u> depicts a primary future which deviates from the normative forecast in predicting that:
    1) America's present economic system, its familial structures, its system of national defense, its educational system, its political dynamics, and its total reliance on technology to solve all societal problems will all become dysfunctional (domestically and internationally) in the next five years; and
    2) As a result of this massive obsolescence of its societal structures, America will enter a profoundly unstable period, become paranoid,

and deteriorate to a fascist police state within the next ten years.

- the analysis of the future in "What We Must Do" differs from the normative forecast for the United States in predicting that:

    1) in the next five years, the United States faces nuclear escalation, racial conflict, problems in severe urban poverty, some difficulties in maintaining a system of participatory democracy, and a collapse of effective techniques for administration;
    2) in the next twenty years, disruption in the ecological balance will add to these problems;
    3) in the next fifty years, overpopulation and drastic problems with reconciling its political theory and its economic structure will also become major difficulties for America; and
    4) as a result, the United States as we know it will probably have ceased to exist by 2020.

A Set of Alternative Secondary Forecasts--What Interventions Are Needed to Change Present Societal Directions

Each of the sources from which these primary forecasts were derived also describes what interventions in present societal directions need to be made to change the unfavorable aspects of the societal futures predicted. From these descriptions, a set of very basic secondary societal forecasts has been derived; as with the primary forecasts, these brief summaries should not be construed as valid representations of the original sources, but as crude condensations made for the purpose of this analysis.

A) the secondary forecast for the "surprise-free" projections from The Year 2000

As these primary projections are very like the normative forecast, no interventions need be made in the predicted course of events to bring the primary societal future close to the normative. Hence, no secondary forecast is needed.

B) the secondary forecast for the projections made in The Next Ninety Years

So that American society can help solve the problems of overpopulation, natural resource depletion, and low standards of living in the "underdeveloped" countries, the authors of The Next Ninety Years propose steps such as:

1) increase American foreign aid expenditures "two, three, five, or even ten times over our present expenditures of about $3 billion;"[145]

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[145] Industrial Associates, Next Ninety Years, pg. 16.

2) initiate a massive effort in developing the necessary technology to generate adequate resources for the world's population to enjoy our standard of living;[146] and

3) develop a long-term (20 years or more) American political agency to implement a continuous development program for the "have-not" nations.[147]

To reduce America's problem of a technical manpower shortage, the authors suggest:

1) a massive research and development program in education to promote early identification, encouragement, and education of future scientists;

2) a campaign to urge more women to go into science; and

3) more efficient utilization of the technical manpower now available.[148]

Finally, to alleviate America's coming environmental problems, the authors propose solutions such as:

1) dump all wastes in the ocean rather than rivers;

2) restore the ecological balance in all fresh water bodies; and

3) pipe water from inland areas to solve the water needs of cities like Los Angeles.[149]

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[146] Ibid., pg. 38.

[147] Ibid., pg. 17.

[148] Ibid., pp. 62-63.

[149] Ibid., pp. 103-110.

C) the secondary forecast for the projections from the World 3 Model

Within the constraints of the World 3 Model, the only solution which yields stable long-term dynamics is to establish a world equilibrium. The MIT group found that the following steps, taken immediately, would bring about a stable equilibrium within the Model by 1990:

- reduce resource consumption to one-quarter present levels by 1975
- reduce pollution generation to one-quarter present levels by 1975
- set birth rate equal to the death rate by 1975
- divert capital to food production sufficient to give the world's population a decent diet by 1975
- divert agricultural capital to increased soil preservation by 1975
- design technology to double the lifetime of industrial capital by 1975
- move societal consumption preferences towards services (health, education) rather than factory goods by 1975
- set the investment rate of industrial capital equal to the depreciation rate by 1990[150]

These interventions would result in a long-term equilibrium with the world population only slightly higher than today, the world average lifetime nearly seventy years, twice

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[150]Meadows, Limits, pg. 165.

as much food per capita as in 1970, and a total average income per capita about one-half present U.S. levels and three times present world levels.

D) the secondary forecast for the projections from <u>An Alternative Future for America II</u>

The basic societal changes which Theobald proposes to prevent America from becoming a fascist police state are:

- changing the present United States socioeconomic system to reflect a Maslovian (self-actualizing) view of man rather than a Skinnerean (stick and carrot) view of man
- orienting societal institutions toward processes rather than goals
- moving to a system of administration in which authority is based on knowledge rather than hierarchical position

Examples of the specific reforms which he argues must take place in the next five years are:

1) the implementation of an economic system with a guaranteed annual income, free basic goods, and the highest wages for the least enjoyable jobs;
2) the rejection of all distinctions between work and leisure and the creation of an educational system based on life-long self-actualization;
3) the giving of major economic aid to the Third World countries, rather than the continuation of

America's present system of international stabilization by military deterrence;

4) the development of new alternative life styles for child raising and for urban living;

5) the initiation of a reliance on inductive rather than deductive thinking:

6) the use of the computer and biomedicine to create new ways for man to be human; and

7) the general acceptance that societal change must be evolutionary rather than revolutionary.

E) the secondary forecast for the analysis of the future in "What We Must Do"

To solve the many crises that Platt foresees in America's future, he proposes:

> something very similar to the mobilization of scientists for solving crisis problems in wartime....We need full-time interdisciplinary teams combining men of different specialties, natural scientists, social scientists, doctors, engineers, teachers, lawyers, and many other trained and inventive minds who can put together our stores of knowledge and powerful new ideas into improved technical methods, organizational designs, or "social inventions" that have a chance of being adopted soon enough and widely enough to be effective. 151

Although Platt envisions a variety of people being involved in these task forces for "social research and development," he visualizes scientists as playing the greatest role. These groups are envisioned as beginning by "the organization of

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[151] Platt, "What We Must Do," pg. 1117.

intense discussion and education groups in every laboratory."[152] The major problem areas such groups might attack include:

1) peace-keeping mechanisms and feedback stabilization;
2) biotechnology for controlling population, ecology;
3) game theory applied to resolving the arms race crisis;
4) new psychological and social theories for improving family life, community and management structures;
5) social indicators--new ways for measuring social parameters; and
6) case studies of the best channels of effectiveness for societal change.

The time span within which Platt feels that these groups must work in order to make a significant contribution is one to five years--three years on the average.

A Sample Set of Skills That Secondary Science Education Should Attempt to Convey

Given these alternative forecasts, a set of future-oriented objectives for secondary science education can be constructed. This section will discuss the derivation of only those educational objectives which are directed towards making all students competent future members of society; the issue of preparing special educational objectives for future

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[152] Ibid., pg. 1120.

scientists, "above-average" students, and "disadvantaged" students will be discussed in Chapter V. Two points need to be made about using these forecasts to construct educational objectives:

First, if all of these forecasts are likely possibilities for America in the next half century, then perhaps the range of long-term future alternatives is so great as to require the implementation of an additional component of the formal educational system which prepares adults for the short-term (ten years) future. The implications of this conclusion will be discussed in Chapters IV and V.

Second, if these forecasts are all likely alternatives, then any set of educational objectives which attempts to prepare students for America's future must be so constructed as to prepare students for any of these alternatives. Further work in future studies will produce more consistent, more complete, and more comprehensive sets of forecasts. The greater detail these provide will be most helpful in formulating educational objectives, and therefore more work in this area is clearly important to education. However, by the very nature of future studies, any further work done will inevitably emerge as a series of alternative futures--the expectation that a single possible future will emerge from further study is false.

To construct a non-redundant set of science-based educational objectives which will prepare students for any of these possible futures, the similarities and differences between these alternative forecasts must be delineated. The forecasts can be divided into two groups: one set of forecasts (The Year 2000, The Next Ninety Years, "What We Must Do") expresses a "conventional" organizing image of the future; the other set of forecasts (the World 3 Model, An Alternative Future for America II) expresses a "transformational" organizing image of the future.[153] "Conventional" forecasts presuppose a different type of educational objectives than "transformational" forecasts.

The "conventional" organizing image may be characterized as follows:

1) present day problems are severe, but amenable to traditionally successful approaches
2) these problems are primarily 'substantive' problems (problems which lie at an applied level and are immediate targets for corrective action: i.e. poverty) and 'process' problems (problems which impede the collective setting of appropriate priorities and strategies regarding substantive problems: i.e. lack of co-ordination in government agencies)
3) political and technological solutions to these problems can be expected through the development of new skills if agreement on societal objectives can be obtained
4) planning for the future is best done by extrapolation from the present and the past
5) the solutions for present day problems are either 'compensatory' (helping recovery from the undesirable consequences of the problem) or 'ameliorative' (reducing or preventing some of the usual impacts of the problem) 154

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[153] O. W. Markley, D.A. Curey, and D. L. Rink, Contemporary Societal Problems (Menlo Park, Calif.: Educational Policy Research Center, Stanford Research Institute, 1971), pp. xi-xiv, 1-27.

[154] Ibid., pp. xi, 9, 26.

In contrast, the "transformational" organizing image emphasizes:

1) present day problems are intrinsic to the present 'industrial state paradigm,' which is made up of premises such as:
   a) the 'technological imperative' that any technology that can be developed and any knowledge that can be applied, should be;
   b) the belief that the summed knowledge of experts constitutes wisdom;
   c) the reductionist view of man;
   d) the belief that men are essentially separate, so that little responsibility need be felt for the effects of present actions on remote individuals or future generations;
   e) the 'economic man' image which leads to an economy based on an ever-increasing GNP, consumption, and expenditure of irreplaceable resources;
   f) the belief that man is separate from nature and that nature is to be exploited and controlled; and
   g) the assumption that the future of the world can safely be left to autonomous nation states operating independently 155
2) these problems are primarily 'normative' (problems which concern the appropriateness and effectiveness of societal values, preferences, and loyalties: i.e. the erosion of institutional legitimacy) and 'conceptual' (problems in ways of thinking and words used: i.e. logical or semantic fallacies)
3) political and technological solutions to these problems are infeasible without a pervasive reordering of priorities and the emergence of new cultural norms
4) planning for the future is best done by normative anticipation and a search for transitional strategies
5) the solutions for present day problems are 'systemic' (changing the overall environment, system functioning, frame of reference, or definition of the problem) 156

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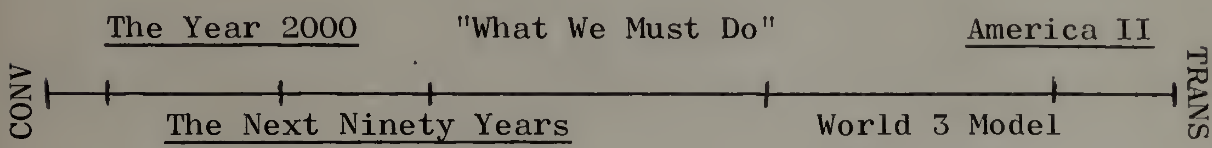
[155] Willis W. Harman, Alternative Futures and Educational Policy (Menlo Park, Calif.: Educational Policy Research Center, Stanford Research Institute, 1970), pp. 9-10.

[156] Markley, Curry, and Rink, Contemporary Societal Problems, pp. xii, 9, 26.

The five alternative forecasts delineated earlier do not fall neatly into this conventional-transformational dichotomy; rather, each forecast may be placed on a continuum bounded by a totally conventional image of the future on one end and a totally transformational image on the other. Thus:



The more a forecast is towards the conventional end of the spectrum, the more the educational objectives derived from it will differ in their fundamental goals from the objectives derived from a forecast towards the transformational end of the spectrum.

A completely conventional forecast assumes that present societal problem-solving skills will be successful in the future. By making this assumption, the forecast also affirms that the essential nature of our present formal educational system is viable for the future, for a society's approaches to problem-solving and its formal educational system are intrinsically interrelated. A great portion of what the schools teach is present societal problem-solving skills; in fact, the reforms in the formal educational system are always based on the substitution of a new societal problem=solving approach for the old approach. For example, the first generation reforms were motivated by the fact that the schools were producing both future scientists and future citizens with an insufficient understanding of the scientific disciplines (the new problem-solving approach) to deal with the impact of these disciplines on society. Further, the approaches which a society evolves to solve problems are determined ultimately by persons (especially "experts") who have been carefully inculcated by the formal educational system with current systems of societal beliefs about the nature of societal problems and solutions. Because of these interrelations, any forecast which is conventional is predicated on the belief that an educational system in touch with a society's present will be basically in tough with its future.

A conventional forecast then necessarily assumes that the three components of our present educational system which combine to produce our present societal approaches to problem-solving are basically viable. That is, the forecast assumes that:

1) the skills conveyed by our present educational system are the viable and functional skills to teach in preparing students for the future;
2) the content and methods presently used to teach these skills (if up-to-date) provide an adequate vehicle for conveying them; and
3) the techniques that are now used to screen students according to future problem-solving ability (if up-to-date) are essentially accurate.

This is not to say that a conventional forecast necessarily assumes that the present formal educational system is perfect; on the contrary, a conventional forecast may very well quarrel with the efficiency with which the schools use these contents, methods, and screening techniques and may well insist that the schools be continually improved with up-to-date developments in educational theory and technology. However, a conventional forecast does assume that the educational objectives it implies can be implemented in a formal educational system similar in its essential nature to that existing at present.

A purely transformational forecast operates from the opposite assumption: that present day problems are intrinsic to the problem-solving approaches used by our society, and that only a thorough conversion to a new set of problem-solving approaches can bring our society through its problems to a desirable future. This assumption implies that the essential nature of our present educational system is not viable for the future--even if it is in touch with the present--and that:

1) our present formal educational system omits skills which must be taught to prepare students for the future (and, perhaps, some skills taught now must be omitted as dysfunctional);
2) the content and methods presently used in our schools must be examined to see if they are suitable vehicles for teaching these new skills, and new

content and new methods possibly added (or old ones dropped) if the old are not suitable; and

3) the techniques that are now used to screen students according to future problem-solving ability may well have to be thoroughly revised so that they screen effectively for these new skills.

Thus, a transformational forecast assumes that the educational objectives it implies must be implemented in an educational system essentially different, at least in part, from that existing now.

If the formal educational system is to prepare students for <u>any</u> of the five alternative futures derived earlier, then it must necessarily implement both conventionally-oriented and transformationally-oriented educational objectives. Some of each person's secondary science education must take place in a context essentially similar to that which exists in the schools today; the rest of each person's secondary science education must occur in a radically different context. The following is a crude list of future-oriented educational objectives pertaining to a curriculum in secondary science and derived from the five basic alternative forecasts. This list is incomplete and lacking in detail because of the rudimentary nature of this analysis; a more extensive analysis will have to be made to generate any list of objectives which could serve as the basis for production of an actual curriculum in secondary science. Given with each educational objective is a very brief description of an appropriate educational context for its implementation.

CONVENTIONAL SCHOOL METHODS, SCREENING; DISCIPLINARY CONTENT

1. students should understand the basic implications for society of predicted increases in our technological prowess in the field of nuclear power; the art of strategic warfare; the areas of electronics, computers, information processing, and automation; the field of holography; the work on lasers; and the biological manipulation of man. Specific objectives for secondary students might be:

   a. be able to demonstrate that every five years there will probably be a complete revolution in the technology of central war[157] (discuss implications for the United States Defense Budget).

   b. discuss the implications for day-to-day life in the year 2000 if the present trend of an increase in computer capacities by a factor of ten every two or three years continues.[158]

   c. demonstrate why automation will probably create as many jobs as it eliminates, at least in

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[157] Kahn and Wiener, Year 2000, pg. 80.

[158] Ibid., pg. 89.

the next ten years.[159]

d. discuss the societal dysfunctions that may occur as present societal norms are threatened by the development of the capability to choose the genetic characteristics of one's children.[160]

CONVENTIONAL SCHOOL METHODS, SCREENING; DISCIPLINARY CONTENT

2. students should understand the implications for America's support of science and technology of bringing the rest of the world's population up to America's material standard of living. Specific objectives for secondary students might be:

   a. discuss what cultural/social factors have been found to bring about decreased population growth, and what this implies for the amount of research and development needed in "underdeveloped" countries to stabilize population.

   b. be able to discuss what level of technology is needed to reduce natural resource depletion sufficiently to allow all the world in the year 2000 to live at our present standard of living indefinitely.

3. students should be able to demonstrate the gross economic effects of a shortage of technical manpower in the United States, and in the world.

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[159] Ibid., pg. 93.

[160] Ibid., pg. 113.

CONVENTIONAL SCHOOL METHODS, SCREENING

4. students should understand the strengths and weaknesses of using a computer simulation to generate predictions. Specific objectives:
   a. discuss and critique the basic assumptions underlying the postulated interrelationships in the World 3 Model.
   b. experiment to determine if minor changes in these basic assumptions result in radically different predictions.

TRANSFORMATIONAL METHODS, SCREENING

5. students should understand the implications for our present technological society of implementing a solution leading to equilibrium such as the MIT group describes in its World 3 Model. Specific objectives:
   a. experience (perhaps via a two-week simulation) the global effects of an immediate implementation of the MIT solution.
   b. experience (perhaps via extended "field trip" projects) the difficulties of 1) attempting to reduce pollution by advancing technology, 2) attempting to reduce pollution by convincing polluters to stop, 3) attempting to cut resource depletion by advancing technology, 4) attempting

to cut resource depletion by reducing capital investment.

c. experience (perhaps via travel to an "under-developed" country) the aspirations and goals of the non-affluent, and discuss the implications of these goals for America's future technological development.

d. study and discuss different designs for a technological-political-economic complex of institutions[161] which could support a civilization of equivalent complexity to ours, and yet could tolerate discontinuities in policy equivalent to the MIT solution.

CONVENTIONAL METHODS, SCREENING

6. students should understand and be able to discuss the arguments underlying the claims
   - that the 'technological imperative' is dysfunctional
   - that the summed knowledge of experts is not necessarily the best determinant of policy
   - that the reductionist view of man is obsolete
   - that the belief that man is separate from nature and that nature is to be exploited and

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[161]Such as the proposed CASCOT model (Citizen's Association for Social Control of Technology) outlined in P. G. Marduke, The CASCOT System (Silver Spring, Md.: CASCOT, 1970).

controlled is dysfunctional

- that inductive thought is more productive than deductive thought.

TRANSFORMATIONAL METHODS, SCREENING

7. students will participate in and/or attempt to design cultural/social systems which permit a) increasingly higher levels of technology without expanding growth, OR b) a high level of basic research with a low level of applied technology.[162]

CONVENTIONAL-TRANSFORMATIONAL METHODS, SCREENING

8. students will experiment with possible effects of implementing the solution described in "What We Must Do" by a) working in the field with scientists on starting such groups, b) simulating a society whose primary problem-solving device is such groups, and c) studying the history of such interdisciplinary problem-solving attempts to explore the strengths and weaknesses of this approach.

These sample future-oriented, science-based objectives are interesting primarily because of the insight they provide into the additional skills secondary science education must convey in order to prepare students to live as citizens who

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[162] One excellent introductory source is Needham's discussion of science and technology in medieval China in Joseph Needham, The Grand Titration (Toronto, Canada: University of Toronto Press, 1969).

can help to move any of America's likely futures towards the normative future. From the eight sample objectives listed, these skills include:

- being able to approximate the potential impacts of a given technology on the future of American society (assuming that, in other respects, the United States exhibits no discontinuities from today)
- being able to forecast the rough social impacts of the attainment of present day technology in an "underdeveloped" country
- being able to predict the broad intercultural and international dynamics which may result from giving (or refusing to give) advanced science and technology to "underdeveloped" countries by "developed" countries
- being able to assess the crude interrelationships between economic stability, an adequate supply of technical manpower, and a high standard of living in a "developed" country
- being able to delineate the broad impacts of a major technological-economic discontinuity on American society, and being able to understand the most important mechanisms which presently function to prevent such discontinuities
- being able to delineate the strengths and weaknesses of rigorous modeling of societal dynamics

being able to summarize the major rational arguments against the scientific-technological conceptions and institutions operating in our present society

- being able to construct simple alternative cultural-social models for dealing with science and technology
- being able to assess the major strengths and weaknesses of societal problem-solving via interdisciplinary, science-oriented teams of experts

A comparison of this list of future-oriented, science-based skills with the contents of any of the second generation, secondary level science materials demonstrates clearly the point made earlier that the objectives now in use in secondary science education risk producing students unprepared to face the crucial challenges from its scientific prowess that mankind may encounter in the next twenty to forty years.

The following paragraphs argue that discipline-oriented inquiry is, for the most part, inadequate for teaching these skills and identify necessary characteristics of an effective vehicle for teaching these future-oriented skills.

The Inadequacy of Discipline-Oriented Inquiry as a Sole Vehicle for Teaching These Skills

The Essential Nature of the Scientific Disciplines

To discuss the type of skills conveyed by materials based on the scientific disciplines, a more detailed explication of the essential nature of the scientific disciplines must first be made. To distinguish rigorously between physics, chemistry, biology, astronomy, geology, and the other discrete scientific disciplines is very difficult--at the ACS Conference on Chemical Education, the only definition separating chemistry from the other sciences that the participants could agree on was "chemistry is what chemists do"--[163] but a number of characteristics can be delineated which separate the scientific disciplines from areas such as economics, sociology, history, religion, and future studies.

J. J. Schwab has remarked that there are at least three great genera of disciplines: the investigative (natural sciences), the appreciative (arts), and the decisive (social sciences).[164] In his Inglis Lecture at Harvard in 1961, he traced the historical development of the conception of "science" from the late nineteenth century belief that science consisted of seeking the facts of nature and reporting what was observed to the present idea that science is the imposition of man's conceptions on reality.[165] That is, a conceptual structure (such as Newtonian physics) is postulated to fit the patterns that seem to emerge in natural phenomena; scientists may then test the theories which comprise this conceptual structure by performing experiments to

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[163]"chemists," presumably, being defined as members of the ACS.

[164]Project on Instruction, Scholars Look at Schools, pg. 3.

[165]Schwab, "Teaching of Science," pp. 9-12.

see if the predictions about nature made by these theories seem fulfilled. Three common classes of conceptual structures used in the scientific disciplines are:

- reductive structures (which treat the disciplinary subject matter as something which takes on all its important properties from its own elements or parts and from the connections relating these parts to one another: e.g. nineteenth century chemistry)
- holistic structures (which treat the disciplinary subject matter as something whose parts take on all their properties from a describable, but unexplained whole: e.g. traditional physiology)
- rational structures (which treat the disciplinary subject matter as determined by some larger system of relationships of which it is a part: e.g. early gradient theory in embryology)[166]

As more is discovered about natural pehnomena, attempts are made to fit these new observations within the conceptual structure then dominant in that science; eventually, a new conceptual structure (such as Einsteinean physics) may emerge to replace the old as scientists agree that the new structure's theories offer a "better" explanation of natural phenomena. Given these dynamics, two distinct modes of scientific inves-

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[166] Joseph Schwab, "The Structure of the Natural Sciences," The Structure of Knowledge and the Curriculum, ed. by G. W. Ford and Lawrence Pugno (Chicago, Ill.: Rand McNally, 1964), pp. 46-49.

tigation emerge: "stable enquiry" and "fluid enquiry" (c.f. Schwab)[167] or, alternatively, "normal science" and "extraordinary science" (c.f. Thomas Kuhn).[168] "Normal science" refers to scientific experimentation and thought which takes as given the dominant conceptual structure within science and works to demonstrate that reality fits within that structure. "Extraordinary science" begins by postulating a new conceptual structure to describe reality and then attempts to demonstrate that this new structure offers a better explanation of natural phenomena than did the old.

To explore the question of how scientific theories are measured against reality in these two different modes of scientific investigation, the "syntactical" structures of the scientific disciplines must be discussed--that is the questions of:

> ...the kinds of evidences required by the discipline, how far the kinds of data required are actually obtainable, what sorts of second-best substitutes may be employed, what problems of interpretation are posed, and how these problems are overcome.. 169

must be considered. This issue of the syntax of the sciences is enormously complicated and (currently) controversial, but several basic points can be made:

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[167] Schwab, "Teaching of Science," pg. 15.

[168] Thomas S. Kuhn, <u>The Structure of Scientific Revolutions</u> (Second Edition, Chicago, Ill.: University of Chicago Press, 1970).

[169] Joseph Schwab, "Problems, Topics, and Issues," <u>Education and the Structure of Knowledge</u>, Fifth Annual Phi Delta Kappa Symposium on Educational Research (Chicago, Ill.: Rand McNally, 1964), pg. 28.

The syntax of normal science is fairly straightforward. Most scientists would agree with Schwab's conception of the processes underlying a normal science experiment:

> 1. The formulation of the problem (from juxtaposing a principle of enquiry--a substantive structure--and index phenomena).
> 2. The search for data that will suggest possible solutions to this problem.
> 3. Reformulation of the problem to include these possible solutions.
> 4. A determination of the data necessary to solve the problem.
> 5. A plan of experiment that will elicit the data desired.
> 6. Execution of the experiment and accumulation of the desired data.
> 7. Interpretation of the data by means of the guiding substantive structures together with previous knowledge possessed by the investigator. 170

The syntax of extraordinary science is more complex, for philosophers of science agree that "scientific theories are not only equally unprovable and equally improbable, but they are also equally undisprovable."[171] This statement has profound implications; for if it is true, then how can rational criteria be used in deciding whether to substitute a new conceptual structure for the established conceptual structure of a scientific discipline? This question is currently being debated by two schools of thought in the philosophy of science: the proponents of sophisticated method-

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[170]Schwab, "Structure Natural Sciences," pp. 38-39.

[171]Imre Lakatos, "Falsificationism and the Methodology of Scientific Research Programs," Criticism and the Growth of Knowledge, ed. by Imre Lakatos and Alan Musgrave (Cambridge, England: Cambridge University Press, 1970), pg. 103.

ological falsificationism (led by Karl Popper[172,173] and Imre Lakatos[174]) and the proponents of the psychology of discovery (led by Thomas Kuhn[175]). The former group argues that extraordinary science is dominated by an underlying methodological logic; the latter group that it is determined by the social psychology of scientific groups. For example, Popper argues that astrology cannot be a science because "by making their interpretations and prophecies sufficiently vague, they [astrologers] were able to explain away anything that might have been a refutation of the theory had the theory and the prophecies been more precise." Kuhn, on the other hand, argues that astrology cannot be a science because astrological failures do not give rise to research puzzles (too many possible sources of difficulty which are beyond the control of the experimenter) and, hence, no revisions can ever take place in astrological theory.[176] Thus far, neither group has produced a conclusive argument for why its syntax for extraordinary science is correct.

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[172]Karl Popper, The Logic of Scientific Discovery (New York, N.Y.: Harper and Row, 1968).

[173]Karl Popper, Conjectures and Refutations (New York, N.Y.: Harper and Row, 1965).

[174]Lakatos, "Falsificationism," pp. 91-196.

[175]Kuhn, Structure of Scientific Revolutions.

[176]Thomas S. Kuhn, "Logic of Discovery or Psychology of Research," Criticism and the Growth of Knowledge, ed. by Imre Lakatos and Alan Musgrave (Cambridge, England: Cambridge University Press, 1970), pg. 8.

The scientific disciplines, then, accumulate knowledge through using the classes of conceptual structures, modes of investigation, and syntactical structures just described to formulate successively "better" conceptions of the nature of reality. The Educational Policies Commission of the National Education Association set forth in its 1966 recommendations on Education and the Spirit of Science the following seven values believed to underlie the scientific disciplines:

1. Longing to know and to understand
2. Questioning of all things
3. Search for data and their meaning
4. Demand for verification
5. Respect for logic
6. Consideration of premises
7. Consideration of consequences[177]

The National Science Teachers Association Conference of Scientists (1964) delineated seven major conceptual schemes and five major items in the process of science presently underlying the scientific disciplines:[178]

Conceptual Schemes

1. All matter is composed of units called fundamental particles; under certain conditions, these particles can be transformed into energy and *vice versa*.
2. Matter exists in the form of units which can be classified into hierarchies of organizational levels.
3. The behavior of matter in the universe can be described on a statistical basis.

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[177]Educational Policies Commission, "Education and the Spirit of Science," pg. 15.

[178]Some controversy arose over whether biology was sufficiently represented--see Bentley Glass, "Theory into Action--A Critique," The Science Teacher (May, 1965), pp. 29-30, 82-83.

4. Units of matter interact. The bases of all ordinary interactions are electromagnetic, gravitational, and nuclear forces.
5. All interacting units of matter tend toward equilibrium states in which the energy content (enthalpy) is at a minimum and the energy distribution (entropy) is most random. In the process of attaining equilibrium, energy transformations or matter transformations or matter-energy transformations occur. Nevertheless, the sum of matter and energy in the universe remains constant.
6. One of the forms of energy is the motion of units of matter. Such motion is responsible for heat and temperature and for the states of matter: solid, liquid, and gaseous.
7. All matter exists in time and space and, since interactions occur among its units, matter is subject in some degree to changes with time. Such changes may occur at various rates and with various patterns.

Major Items in Process of Science

1. Science proceeds on the assumption, based on centuries of experience, that the universe is not capricious.
2. Scientific knowledge is based on observations of samples of matter that are accessible to public investigation in contrast to purely private investigation.
3. Science proceeds in a piecemeal manner, even though it also aims at achieving a systematic and comprehensive understanding of various sectors or aspects of nature.
4. Science is not, and probably never will be, a finished enterprise, and there remains very much more to be discovered about how things in the universe behave and how they are interrelated.
5. Measurement is an important feature of most branches of modern science because the formulation as well as the establishment of laws are facilitated through the development of quantitative distinctions. 179

The Types of Skills for Which Discipline-Oriented Inquiry in the Sciences is an Adequate Vehicle

One way of delineating the skills conveyed solely by

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[179] National Science Teachers Association Conference of Scientists, "Theory into Action," pg. 13.

discipline-oriented inquiry in the sciences is to examine the special skills possessed by scientists as a group, for presumably these skills come primarily from an understanding and use of science-based, discipline-oriented inquiry. This list of special skills possessed by scientists can be compared with a list of skills derived from the reasons scientists and educators have given for why science-based, discipline-oriented inquiry should be taught to secondary students. From the similarities and differences between the two lists, a basic determination can be made of which skills claimed to be taught by secondary science are dependent solely on discipline-oriented inquiry in the sciences, and which skills are dependent on additional sources of knowledge as well.

Typical special discipline-based skills possessed by scientists (normal and extraordinary) are:

- skills in designing efficient tests of predictive theories
- skills in postulating testable conceptual structures which organize masses of data
- skills in deciding between competitive conceptual structures
- skills in designing experiments to show that a particular natural phenomenon can be understood in terms of a given conceptual structure
- skills in choosing "fruitful problems" for scientific investigation
- skills in designing and using instruments to gather

reliable, reproducible data

- skills in adhering to the central values of science (i.e. honesty in reporting data)
- skills in determining which data are significant in a given problem[180]
- skills in abandoning a given problem to work in a more fruitful area determined by chance[181]
- skills in communicating with other scientists
- skills in judging the validity of scientific reports
- skills in using mathematics to describe natural phenomena

A sample of the reasons which scientists and educators have given for why the scientific disciplines should be taught to secondary students is listed below. The scientific disciplines (via inquiry):

- provide knowledge of the universe, as contemporarily understood
- give an understanding of the dependence of the other disciplines on science
- impart a conception of the constructive and destructive potential of science for humanity
- yield an understanding of the influence of science on other areas of modern life

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[180] For a good discussion of this point, see Norwood R. Hanson, <u>Patterns of Discovery</u> (Cambridge, England: Cambridge University Press, 1969).

[181] c.f. W. I. Beveridge, <u>The Art of Scientific Investigation</u> (Revised Edition, New York, N.Y.: W.W. Norton and Co., 1957).

- provide awareness of the dynamic, continually evolving character of scientific knowledge
- instill the habit of challenging hypotheses in any area of life
- provide, through the historical approach (case study), some understanding of the creative process
- give successful experiences in the rational treatment of problems and in the development of skills in the interplay of thought and experiment that leads to the generation and validation of ideas
- impart a knowledge of the human body which can quiet the anxieties growing out of ignorance of the facts of growth and development
- yield an understanding of man in relation to all other organisms and the world
- instill a comprehension of the usefulness, but arbitrariness and questionability of placing all things in systems[182]
- give a comprehension of the science likely to be encountered in later life
- remove erroneous beliefs about science and nature[183]
- help laymen to communicate with scientific specialists and to serve as intermediaries between specialists
- give an understanding of why science is crucial to

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[182]Project on Instruction, <u>Scholars Look at Schools</u>, pp. 19-27.

[183]Hurd, <u>Secondary School Science</u>, pp. 35-36.

mankind

- ensure an acceptance of the changing nature of scientific knowledge
- instill a comprehension that authority resides not in posession of information, but in competence in inquiry
- provide an understanding of the multilineal nature of some fields of enquiry[184]
- give an appreciation of the adventure of the human spirit and provide an opportunity for the exercise of artistry, disciplined imagination, and faith[185]

The skills which these reasons imply secondary students will learn through discipline-oriented inquiry fall into several categories:

- skills of understanding natural phenomena
- skills of understanding the interrelation of the disciplines
- skills of comprehending the impact of science on humanity
- skills of grasping the essential nature of scientific knowledge
- skills of understanding the creative process
- skills of using scientific values in everyday life
- skills of understanding the interrelation of natural

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[184] Schwab, "Teaching of Science," pp. 38-52.

[185] Walter Orr Roberts, "Science, A Wellspring of Our Discontent," The American Scholar Vol. 36, No. 2 (Spring, 1967), pg. 246.

phenomena and man

- skills in communicating with scientists

Comparing these two lists of skills and assuming that the list of skills possessed by scientists includes all those skills taught solely through science-based, discipline-oriented inquiry, the skills in the "reasons for teaching the scientific disciplines" list can be divided into two categories:

science-based, discipline-oriented inquiry alone

- skills in understanding natural phenomena
- skills in grasping the essential nature of the scientific disciplines
- skills of communicating with scientists

science-based, discipline-oriented inquiry plus "other knowledge"

- skills of understanding the interrelation of the disciplines
- skills of understanding the impact of science on humanity
- skills of understanding the creative process
- skills of understanding the interrelation of natural phenomena and man
- skills of using scientific values in everyday life

Thus, not all of the skills which are claimed to be taught by secondary science are dependent solely on science-based, discipline-oriented inquiry--quite a number of these skills are dependent on the acquisition of other knowledge as well. Note that the future-oriented, science-based skills derived earlier all fall within the skills which are dependent on more than just discipline-oriented inquiry in the sciences. That is, the future-oriented skills are subsets of:

- skills of understanding the impact of science on humanity
- skills of understanding the interrelation of natural phenomena and man

The Necessary Characteristics of a Vehicle Sufficient for Teaching These Future-Oriented Skills

To describe all of the "other knowledge" beyond science-based, discipline-oriented inquiry necessary to teach the future-oriented skills derived earlier is a task beyond the scope of this paper. Three points can be made about the necessary characteristics of any vehicle which can convey these skills:

First, any sufficient vehicle must be capable of including non-disciplinary knowledge, for much of the non-science knowledge described is also non-disciplinary. That is, the social sciences (psychology, economics, political science, anthropology, sociology) contain a great deal of organized knowledge about the dynamics of human civilization, but they (deliberately) do not include all the knowledge that is known. For example, a political scientist would not be the best person to consult if one wanted to get a bill through Congress--a non-disciplinary specialist (such as a lobbyist) would be a better choice. Disciplines emphasize the durable, the generalizable, and the easily reducible at the cost of much pragmatic knowledge that is impermanent, particular, or not describable within present disciplinary conceptual structures.

This point can be illustrated by considering one of the science-based, future-oriented skills described earlier:

- being able to approximate the potential impacts of a given technology on the future of American society (assuming that, in other respects, the United States exhibits no discontinuities from today)

On a more sophisticated level of assessment than would be required of a secondary student, experts in the emerging area of "technology assessment" are attempting to chart the impacts of technology on society by:

1) clarifying the nature of existing social problems as they are influenced by technology, possibly with indications of legislation needed to achieve satisfactory control.
2) providing insights into future problems, to make possible the establishment of long-term priorities and to provide guidance for the allocation of national resources.
3) stimulating the public and private sectors of our society to take those courses of action for the development of new technology that are most socially desirable....
4) educating the public and the government about the short-term and long-term effects of the range

of alternative solutions to current problems.[186] This work in technology assessment (and similar studies in policy analysis) is generating a base of pragmatic, non-disciplinary knowledge which can be used in the curriculum to teach future-oriented skills. Disciplinary knowledge will also be necessary to provide scope and generalizability, but any sufficient vehicle for teaching future-oriented skills must be able to include non-disciplinary knowledge.

Second, any vehicle which can convey this "other knowledge" beyond science-based, discipline-oriented inquiry must include some conceptual framework which the average secondary student can use to integrate both these knowledges. Otherwise, even if a student acquires the requisite knowledge to learn these future-oriented, science-based skills, he will be incapable of integrating this knowledge into a comprehended whole. Any conceptual framework which is used to facilitate this integration must have both inter-disciplinary and trans-disciplinary components (so that both disciplinary and non-disciplinary knowledge can be assimilated).

Third, any vehicle which is used to teach <u>transformational</u> future-oriented, science-based skills cannot be predicated on the assumption that the disciplines are man's highest accomplishment and his sole intellectual resource, and must be viable beyond the traditional constraints and

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[186] Committee on Public Engineering Policy, Report of the Committee, <u>A Study of Technology Assessment</u> (Washington, D.C.: U.S. Government Printing Office, 1969), pg. 3.

assumptions of the school. That is, since a transformational image of the future assumes that present societal techniques for problem-solving (including the disciplines) will not be viable for the future, the skills which a transformational image seeks to convey are based on the assumption that the disciplines are not the only organized knowledge of the culture, do not provide the best basis for societal problem-solving, and inculcate some undesirable societal beliefs (such as the reductionist view of man). Similarly, since a transformational image assumes that an educational system oriented to our society's present will not be viable for its future, any vehicle for teaching transformational skills must transcend the traditional constraints and assumptions of the school to provide a whole new range of educational experiences.

Given these three points about the necessary characteristics of any vehicle sufficient to teach these future-oriented, science-based skills, the following generalization seems warranted:

- As science-based, discipline-oriented inquiry is not a sufficient vehicle to teach many crucial future-oriented skills, the secondary science curriculum must use a broader conceptual framework as its content base. This wider framework must include both a cortical and a nuclear component, must be able to accommodate both disciplinary and non-disciplinary knowledge, and must

> contain components which transcend the present constraints and assumptions of the schools. The particular characteristics of this framework will be determined by the particular future-oriented, science-based skills it is designed to teach.

That is, a future-oriented science curriculum must necessarily, given this particular period in human history, 1) be integrated with the other disciplines and with non-disciplinary knowledge, and 2) transcend existing school structures. To the extent that this enormously complex task is perceived as impossible or infeasible, to the extent that this broader conceptual framework cannot be visualized or cannot be implemented, the attempt of our society to prepare for the long-range future through education must be abandoned and the educational system refocused to reflect its new orientation of preparing for the immediate future, the short-range tasks. This point will be further discussed in Chapter V.

CHAPTER IV

EXAMINING RECENT CRITERIA FOR STUDENT EXCELLENCE IN SECONDARY SCIENCE EDUCATION

A Brief History of the Measurement of Student Excellence in Secondary Science Education

A Comparison of the Standards for Student Excellence in the First and Second Generation Secondary Reform Courses

In attempting to evaluate the relative merits of different methods of secondary science education, measurements of excellence have focused on three areas: student performance, teacher performance, and curriculum performance. This chapter will focus on the specification and measurement of student performance; Hollenbeck[187] provides an excellent discussion of how tests may be used to evaluate teacher performance, and Welch[188] a good overview of curriculum evaluation. A summary of recent developments in instruments for specifying and measuring student excellence is contained in Appendix B.

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[187] George P. Hollenbeck, "Using Tests for Improving Teaching," The American Biology Teacher (April, 1967), pp. 271-76.

[188] Wayne W. Welch, "Curriculum Evaluation," Review of Educational Research Vol 39, No. 4 (October, 1969), pp. 429-443.

As the first three chapters have shown, traditional secondary science courses concentrated on the acquisition of facts;[189] the first generation reform courses shifted to an emphasis on disciplinary concepts, principles, and modes of inquiry; and the second generation reform courses modified this focus on the scientific disciplines slightly by adding some concern for societal issues directly related to the scientific disciplines. In all three of these types of courses, the prototype of an excellent student has been a student who has mastered the course material and who has displayed interest in science, respect for the teacher, and similar attitudes such as the previous section describes.

One way of illustrating the differences in standards for student excellence between the first and second generation secondary reform courses is to compare the PSSC, Harvard Project Physics, and ECCP textbooks and standardized tests on their handling of a typical topic. One basic topic in physical science which all three texts mention is motion along a straight-line.

The PSSC text (first generation reform) devotes one chapter to "motion along a straight-line path."[190] The

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[189] A study of the midyear examina tions constructed by Virginia high school science teachers revealed a predominant emphasis on the recall of information. Seventy-eight percent of the total items were concerned with the recall of facts, sixty-four percent of which, or fifty percent of the approximately 14,000 test items, required only the simplest form of recall. c.f. Ibid., pg. 25.

[190] Physical Science Study Commission, Physics (Second Edition, Lexington, Mass.: D.C. Heath and Co., 1965), pp. 54-81.

twenty-two pages in this chapter are divided into sub-topics as follows:

- Introduction - less than 1 page
- Position and Displacement Along a Line - 2 pages
- Velocity - 3 pages
- Varying Velocity - 2 pages
- Analysis of Position Time Graphs - 2 pages
- Slope - 3 pages
- Instantaneous Velocity - 5 pages
- Acceleration - 2 pages
- Motion with Constant Acceleration - 2 pages
- Summary - less than 1 page.

These pages are filled solely with graphs, equations, and analyses--there is no philosophical or historical discussion in the text.

In contrast, the Harvard Project Physics Text (second generation reform) has two chapters on this topic: one called "The Language of Motion" and the other "Free Fall--Galileo Describes Motion."[191] These chapters constitute forty-four pages of discussion and fifty-four homework problems. The sub-topics considered are:

<u>The Language of Motion</u>

- Introduction - 3 pages
- A Motion Experiment That Does Not Quite Work - 2 pages
- A Better Experiment - 2 pages

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[191] Rutherford, Holton, and Watson, <u>Project Physics Course</u>, pp. 9-65 (Unit 1).

- Average Speed - 3 pages
- Slope - 4 pages
- A Warning on Graphs - 2 pages
- Instantaneous Speed - 4 pages
- Acceleration - 3 pages

Free Fall--Galileo Describes Motion

- The Aristotilean Theory of Motion - 5 pages
- Galileo and his Times - 7 pages
- Galileo's Two New Sciences - 3 pages
- Why Study Freely Falling Bodies? - 1 page
- Galileo's Definition of Uniform Acceleration - 2 pages
- Galileo Cannot Test his Hypothesis Directly - 1 page
- Looking for Logical Consequences of Galileo's Hypothesis - 3 pages
- Galileo Turns to an Indirect Test - 4 pages
- Doubts about Galileo's Procedure - 1 page
- Consequences of Galileo's Work on Motion - 4 pages

The first chapter of the Harvard Project Physics discussion covers roughly the same material as the chapter in PSSC; the second chapter is a philosophical and historical analysis of the scientific ideas underlying the conceptual framework presented in the first chapter. There is no material in the PSSC text corresponding to this second chapter of Harvard Project Physics (although there is a two-paragraph discussion of Galileo's work later in the PSSC text.)

The ECCP textbook (second generation reform) devotes three pages to a discussion of straight-line motion as a subtopic illustrating the uses of the integrator block of an analog computer.[192] Thus, the three different texts have radically different discussions of the same basic topic: the second generation reforms focus on philosophic, historical, and technological issues in addition to disciplinary concepts (in the case of the ECCP course, instead of disciplinary concepts).

The homework problems on straight-line motion illustrate this same point, although the difference between first and second generation courses is less pronounced. The PSSC chapter's homework set consists of twenty-nine "find-the-correct-quantity" graph-velocity-acceleration problems.[193,194] The Harvard Project Physics homework set for the first chapter has eleven "find-the-correct-quantity" problems, and five problems which ask the student to devise scientific experi-

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[192]Engineering Concepts Curriculum Project, Man-Made World, pp. 214-216.

[193]Physical Sciences Study Commission, Physics, pp. 76-81.

[194]A typical "find-the-correct-quantity" problem is: "What is the displacement of a car which travels at a steady velocity of 40 mi./hr (a) for 3 hrs. (b) for 1/2 hr.?" Ibid., pg. 77.

ments.[195,196] The second chapter's homework set has seventeen "find-the-correct-quantity" problems, four "devise-an-experiment" problems, and six problems which require a historical understanding of science.[197,198] The ECCP chapter's homework set has five "find-the-correct-quantity" problems concerned with straight-line motion. Again, the major difference between the first and second generation reform courses is that a second generation course (Harvard Project Physics) has problems reflecting a philosophic and historical perspective as well as problems focused on finding the correct disciplinary solution.

The PSSC course and Harvard Project Physics course have standardized tests which can be used by the teacher to evaluate student performance. The ECCP teacher's guide has a set of evaluation questions for each chapter which serve the same purpose. The PSSC standardized test which covers the topic of straight-line motion (and also the contents of

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[195] Rutherford, Holton, and Watson, Project Physics, pp. 31-35 (Unit 1).

[196] A typical "devise-an-experiment" problem is: "Design and describe experiments to enable you to make estimates of the average speeds for some of the following objects in motion.
(a) a baseball thrown from outfield to home plate
(b) the wind
(c) a cloud...." Ibid., pg. 32 (Unit 1).

[197] Ibid., pp. 61-65 (Unit 1).

[198] A typical "historical-understanding-of-science" problem is: "Show to what extent the steps taken by Galileo on the problem of free fall...follow the general cycle in the scientific process." Ibid., pg. 65 (Unit 1).

five other chapters) has four multiple-choice questions on straight-line motion--these all are "find-the-correct-quantity" questions which utilize a graph of velocity vs. time.[199] The Harvard Project Physics course produced four tests which have some questions on straight-line motion. Out of thirty-five questions on the topic, eighteen are "find-the-correct-quantity" essay questions, two are multiple choice questions which require understanding a definition, seven are questions requiring historical understanding (three multiple choice; four essay), and two are multiple choice questions calling for an understanding of how a scientist solves problems.[200] Of the two ECCP evaluation questions relevant to straight-line motion, one is a true-false question which requires understanding a definition, and the other is a multiple-choice question which requires finding the correct quantity using a graph.[201] Again, while the difference is not pronounced, a second generation course (Harvard Project Physics) has test questions which focus on historical and philosophical points in addition to questions purely on disciplinary concepts. This distinction between the first and second generation reforms also holds for all the other physics topics

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[199] Tests of the Physical Science Study Committee: Series N (Princeton, N.J.: Educational Testing Service, 1965), pg. 6 (Test 1).

[200] The Project Physics Course Tests Unit 1 (New York, N.Y.: Holt, Rinehart, and Winston, 1970), Tests A-D.

[201] Engineering Concepts Curriculum Project, Teacher's Manual, pp. 126-128.

considered in these three courses.[202]

Thus, the standard for student excellence in first generation secondary reform courses is that the student understand the use of disciplinary concepts for prediction of phenomena. In second generation secondary courses, the standards for student excellence are more diverse; the excellent student will understand the philosophic and historic nature of the scientific disciplines as well as the use of disciplinary concepts for prediction of phenomena. Of course, in both first and second generation courses, there are other implicit standards of excellence such as respect for the teacher, a good attendance record, etc.

A Comparison of the Measurement of Student Excellence in the First and Second Generation Secondary Reform Courses

As mentioned earlier, some specifications of student performance intrinsically contain ways to measure that performance. For example, the behavioral objective "the student should be absent no more than four times a year" can be measured by the teacher's direct observation. This section will discuss the instruments used by the first and second generation secondary reform courses to measure student performances not easily susceptible to direct observation.

The last section has discussed the fact that the

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[202]For example, the topic of "Motion in the Heavens"

first and second generation secondary reform courses focused more on concepts than on facts. In New Directions in Teaching Secondary School Science, Hurd discussed how a student's understanding of a concept can be measured:

> Frequently, we judge whether a student has formed a concept by his ability to verbalize or symbolize it. However, we need to recognize this is not certain proof he understands the concept....The student who understands a concept is able to distinguish exemplars from non-exemplars; to interpret new situations using the concept; to use the concept as a hypothesis in problem solving; to make valid inferences or generalizations; to know how to record new and relevant information; to extract information from the concept and in other ways go beyond the original learning; he 'moves around' in the subject with greater ease and confidence; he appears to learn faster in the topic area. 203

Most of these performances are not susceptible to direct observation by the teacher (especially a teacher with ten to thirty students). Therefore, the first generation courses were forced to devise non-observational instruments to measure a student's understanding of disciplinary concepts, and the second generation courses non-observational instruments for philosophic, historic, and technological concepts as well.

The complete section on such instruments in the PSSC Teacher's Guide is called "Tests" and reads as follows:

> Two complete sets, each containing ten achievement tests (two for each of the four parts of the course and two comprehensive tests covering the first and second halves of the course), have been prepared with the co-operation of Educational Testing Service. These are objective tests. Because of their emphasis on the application of knowledge rather than the recall of facts, the tests are valuable as teaching devices as well as for testing purposes. Class discussion of tests

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[203] Hurd, Secondary School Science, pg. 70.

> following their completion and scoring can be a useful teaching technique.
>
> While these tests can contribute to the evaluation of students' progress, they are not intended as sole criteria for judging student accomplishment. For this purpose the tests should be supplemented by teacher devised procedures for considering various other aspects of a student's work--such as laboratory and homework. For examination purposes most teachers will want to supplement these tests with their own quizzes and examinations. 204

All of the questions on the PSSC tests (Series N) are multiple-choice (35 questions in 45 minutes). The Handbook which comes with the Series suggests that the teacher, in evaluating student performance, prepare a continuum of test scores, paying special attention to the medium, upper, and lower quartile points on the continuum. Thus, the primary instruments for measuring student excellence in the first generation reform course in physics are standardized multiple-choice tests, supplemented by teacher-created tests and teacher observation of homework and lab.

In marked contrast to the brevity of the discussion of student evaluation in the PSSC Teacher's guide, the Harvard Project Physics Teacher Resource Book devotes sixteen paragraphs to the topic of "Tests and Student Evaluation." This section can be summarized as follows:[205]

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[204] Physical Science Study Committee, Teacher's Resource Book and Guide (Second edition, Lexington, Mass.: D.C. Heath and Co., 1965), pg. x (part 1).

[205] Gerald Holton, James F. Rutherford, and Fletcher G. Watson, Teacher Resource Book: Project Physics (New York, N.Y.: Holt, Rinehart, and Winston, 1970), pp. 14-17 (Unit 1).

Three reasons are given for why students should be tested: the results can be used in course evaluation, the student's instruction can be individualized, and the student can be graded. The section then states that:

> Clearly, the ritual of formal testing, with its tensions, the inevitable artificial numerical problems, and pressures of time can at best only provide one of many kinds of information on which to assess student achievement. Although Project Physics had carefully produced four different tests for each Unit, scores on these tests should not be taken as the sole basis on which each student's achievement is assessed and graded.

The suggestion is then made that "interest expressed by student questions and self-initiated work, extra reading, creation of models representing theories, observations of the way physics operates in the world, literary and other artistic elaboration or criticism of concepts, and historical studies" are other student behaviors deserving of teacher recognition. The instruments which are listed as being possible ways of measuring achievement in these areas are research papers, creative writing, critical book reviews, debates and discussions, adaptations of the laboratory, further mathematical explorations of the laws of physics, and classroom leadership functions. The discussion then outlines some of the characteristics of the standardized tests prepared for Harvard Project Physics, and concludes by reaffirming that tests should not serve as the sole basis of grades.

Of the four alternative tests devised by Harvard Project Physics for each unit, two have fifteen multiple choice questions and six problem-and-essay questions (three of the six must be done). The third test consists of forty multiple choice questions, and the fourth test has eight essay questions (six of the eight must be done).

The ECCP Teacher's Manual devotes 3 pages to discussing the related topics "Feedback and the Educational Processes" and "Measuring Objectives in the Affective Domain."[206] The section on "Feedback and the Educational Processes" explains that cognitive objectives for student performance are listed at the beginning of each chapter in the manual, that the Evaluation sections of the manual (one for each chapter) consist of test items for measuring student achievement of the chapter objectives, and that six standardized tests for the ECCP objectives may be purchased if desired. Each of the evaluation questions is labeled as measuring student understanding of the cognitive objective at one of three levels:

Level 1: This level ranges from _imitating_, _duplicating_, and _following immediate instructions_ to _recalling_ the essential features of the activity when encountered later.

Level 2: Level 1 plus _discriminating_, _reformulating_, _interpreting_, and _predicting_. Here the student can discriminate among a mass of data to form a model from which he can make justifiable predictions. This represents a rather high level of performance.

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[206]Engineering Concepts Curriculum Project, _Teacher's Manual_, pp. xiv-xvi.

Level 3: Levels 1 and 2 plus creating, formulating new hypotheses, new questions, and problems. At this level a student emonstrates that he can make discoveries that are new to him and can restructure and reorganize his knowledge on the basis of these discoveries and insights. Very few students are expected to attain this level consistently.

Typical of the cognitive objectives is the one related to understanding straight-line motion: "Students should be able to explain the integrator as a device for measuring area, and explain why the integral of an acceleration is the velocity and why the integral of the velocity is the displacement."[207] The evaluation questions for each chapter are all multiple choice; typically, these questions measure about 65 percent level 1 performance and 35 percent level 2 performance, with an occasional level 3 question.

The ECCP section on "Measuring Objectives in the Affective Domain" lists sixteen affective objectives to go with the approximately one hundred fifty cognitive objectives for the course. These objectives are classified into three categories: interaction of science and technology (4 objectives); matching technology to people, society, and the environment (4 objectives); and use of technological concepts (i.e. systems analysis) and tools (i.e. digital computer) for analyzing and making decisions about complex problems (8 objectives). Typical objectives from each group are, respectively:

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[207] Ibid., pg. 105.

Students should: recognize that technology will create entirely new possibilities for people and society. As a result, the world will be a different place to live in the future, and that only knowledge of both technology and society can insure that it will be a better place in which to live.

Students should: recognize that when using the products of technology, it is important to match machines to people and technological systems to society.

Students should: attempt systemic (rational) approaches to decision-making and avoid emotional reactions to complex problems.

The Teacher's Manual states that a thirty statement attitude survey for measuring student performance on these objectives (with a five point rating scale from Strongly Agree to Strongly Disagree) has been developed and can be ordered.

Overall, the first generation physics course uses standardized multiple-choice tests as its primary means of measuring student excellence, although a brief statement is made that homework problems and laboratory work should also be taken into consideration. Of the two second generation courses, Harvard Project Physics has both constructed alternative tests (multiple-choice and essay) and briefly suggested a variety of ways beyond tests of measuring student excellence, while the ECCP course has a short list of affective objectives along with its cognitive objectives. Thus, the second generation courses have suggested more diverse ways of measuring student excellence, although the instruments actually evolved and supplied by the curriculum developers are fairly similar to those used in the first generation course.

An Overall Perspective on Current Ways of Measuring Student Excellence in Secondary Science Education

In a typical classroom, both the standards for student excellence and the ways in which this excellence is measured are determined more by the curriculum than by the teacher. This is especially true in the sciences, for teachers are keenly aware that there is more agreement among scientists on how to critique a scientific experiment than there is among those in the arts on how to critique a poem. This section will discuss the major long-term impacts that the first and second generation secondary reform courses have had on students because of the standards and the ways of measuring these standards in these courses.

Long-term, the measurement of excellence in a secondary science course affects a non-science student in three ways:

1) high school grades are a major determinant in college admissions,
2) a student considers the truly important things in science to be those on which his grade has been based, and
3) a student's beliefs about his capabilities for using or assessing scientific processes in every-day life are largely determined by his grades in science courses.

Given these effects, the measurement of excellence in the first generation reform courses has had three consequences: non-science students have been discouraged from taking these courses; non-science students in these courses have formed a conception that the important contribution of science has been the exact predictions of physical events that science has made; and many non-science students have concluded that they were incapable of using or assessing scientific processes in everyday life.

The measurement of excellence in the second generation reform courses has also had three consequences: non-science students may have been somewhat discouraged from taking these courses; non-science students in these courses have formed a conception that the important contributions of science have primarily been the exact predictions of physical events science has made and secondarily been the philosophical, historical, and technological impacts science has had; and a fair number of non-science students have concluded that they were incapable of using or assessing scientific processes in everyday life.

The ways in which both the first and second generation reform courses have measured excellence may well have discouraged many non-science students from taking these courses. The highly difficult content of the first generation courses and the fact that these courses were prepared for the "upper-ability" student must have given many interested non-science students pause for thought, as the enrollment figures in Chapter II show. Why should a student jeopardize his college admission competing for grades in a course in which the range of abilities rewarded is very limited and the "average" student is very bright? Often, the answer "because the first generation courses are better" has not been enough. The second generation courses were designed more for the non-science student, but these still were often tested and often taught only on the "high-ability" tracks in secondary schools. The wider range of abilities these courses say they reward help to make the second generation courses more attractive, but the fact that the only evaluation instruments supplied by the publishers are standardized tests makes one wonder how seriously many teachers take the few paragraphs in the teacher's manual which say that more than tests should be used for student evaluation.

The ways in which excellence is measured in the first and second generation reform courses have also implied a relatively narrow conception of the important contributions of science to non-science students. This is especially true in the first generation courses--test after test filled with "find-the-correct-quantity" questions inevitably implies that science is truly important because it can make exact predictions of physical events by manipulating mental concepts. While this is one important aspect of science, it receives disproportionate weight when it becomes the sole means for student evaluation. The second generation courses, by discussing philosophic, historic, and technological concepts as well, have broadened this picture of the contributions of science. Still, many of the test questions and homework problems in the second generation courses focus on "find-the-correct-quantity;" and some focus on "find-the-correct-historical-analysis," which is not much better.

Conceptual structures in the sciences are subject to two criteria--"reliability" and "validity"--which measures of student excellence should be subject to as well.[208] Reliability posits that the conceptual structure be unambiguous, that the terms used be clear, and that measurements of these terms can be precisely made and the results replicated. Validity posits that the conceptual structure adequately reflect the richness and complexity of the subject matter it is applied to. The criteria on which excellence is measured in the first and second generation courses may give a reliable picture of the contributions of science--but they do not give a valid one.

The ways in which excellence is measured in the first and second generation reform courses have also caused many students to conclude that they could not use or assess scientific processes in everyday life. A student who decides that he had better not take a secondary science course because it is "too hard" for him cannot then feel very confident in using rational thought, models, objective analysis, or other scientific processes in his everyday life. Nor can he feel competent as a citizen to assess independently the nation's science policy. A student who takes a first or

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[208] Schwab, "Structure of Disciplines," pg. 27.

second generation reform course and gets a C- cannot feel competent in these everyday areas either--even though his potential skills in these areas were neither used as standards of excellence nor measured. The impression this student receives is that to understand the important parts of science one must be a master at working multiple-choice and essay questions at high speed--and yet in actuality scientists working on scientific investigations or analysts making decisions about the role of science in public policy utilize very different cognitive skills. The narrow definition of excellence in the reform courses undercuts the basic functions they were intended to perform.

The ways in which excellence is measured in these courses also reinforce other measures of excellence which have a major impact on students' beliefs. The heavy emphasis on homework problems and tests in the first generation courses has influenced science teachers to place more reliance on these instruments of evaluation. The second generation courses, with their broader suggested range of evaluative techniques, are less guilty of this; but still--by developing only tests as evaluation instruments--these courses reinforce teachers' tendency toward testing to a significant degree. Both sets of courses, by structuring their evaluations around the grading system, reinforce grading in the schools--and both by their selection of test content and testing procedures reinforce the use of the CEEB and similar instruments as multi-aptitude measures. All in all, the first and second generation "reform" courses are ringing affirmations of testing as a measure of excellence and of grading as a symbol of it.

John Gardner criticizes this attitude in Excellence:

> Consider the relatively narrow bottleneck through which most youngsters enter a career as a scientist. What they need to a very high degree is the ability to manipulate abstract symbols and to give the kind of intellectual response required on intelligence tests... on the other hand, if one looks at a group of mature scientists--in their fifties, let us say--one finds that those who are respected have gained their reputations through exercising a remarkable variety of talents. One is honored for his extraordinary gifts as a teacher...Another is respected for the penetrating ideas he puts into the stream of science...Another is respected--though perhaps not loved--for his devastating critical faculty...Some are specialists by nature, some generalists; some creative, some plodding; some gifted in action; some in expression. 209

If this is true of scientists, what about citizens!

Gardner goes on to say:

> The best aptitude and achievement tests are remarkably effective at sorting out students according to their actual and potential performance in the classroom. But even in this context they are far from perfect, and any system of identification of talent which assumes them to be perfect will commit grave mistakes. Of all the mistakes made in using the tests, perhaps the most are made in trying to apply the results beyond the strictly academic or intellectual performances for which the tests were designed....This error produces grievous difficulties when we try to identify young people who will exhibit high performance in later life. Performance in later life places heavy emphasis on precisely those attributes not measured by scholastic aptitude and achievement tests. The youth who has these unmeasurable traits--e.g. zeal, judgment, staying power--to a high degree may not be identified in school as a person of high potential, but may enjoy marked success

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[209] John W. Gardner, Excellence (New York, N.Y.: Harper and Bros., 1961), pg. 129.

> in later life....By all odds, the most important rule is that the tests should not be the sole reliance in identifying talent. 210

Testing, Testing, Testing, the 1962 report of the Joint Committee on Testing of the American Association of School Administrators, the Council of Chief State School Officers, and the National Association of Secondary School Principals, also takes a critical view of many ways that standardized tests are used. Some of the major criticism of testing made in this report are:[211]

1) tests tend to become ends in themselves, to acquire a mystique of their own, especially when the educational goals being measured are not well defined.

2) "in comparison with the scope and duration of experiences to which a human being is subjected during his lifetime, the standardized test is a low order hurdle...an indirect measurement of only a segment of the performance of a pupil at a particular time."[212]

3) test questions necessarily are limited to areas in which "right answers" exist.

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[210] Ibid., pg. 51.

[211] American Association of School Administrators, Council of Chief State School Officers, and National Association of Secondary School Principals, Testing, Testing, Testing (Washington, D.C.: the Associations, 1962), pp. 8-27.

[212] Ibid., pg. 9.

4) tests, by assuming that answers to a few questions provide an index of an individual's potentialities, create a reductionist image of man.

5) standardized tests at the secondary level tend to presuppose that the sole goal of the high school is to prepare students for college, with the result that the narrowly defined standards for success on these tests reinforce only a narrow segment of high school and college activities.

6) tests discriminate against some of the population: the test-shy, the emotionally disturbed, the unmotivated, the late bloomers, and the culturally disenfranchised.

Proponents of present systems of testing have answered these criticisms in two ways: First, as Marjorie Kirkland states in her article "The Effect of Tests on Students and Schools,"[213] no one in testing has proposed that standardized tests be the sole criterion for judging student excellence. In fact, she argues, those concerned with creating and evaluating tests have always been aware of the many faults of tests and of the varied, sometimes harmful effects tests have on students. Kirkland's article summarizes much of the recent research that has been done in areas such as:

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[213] Marjorie Kirkland, "The Effect of Tests on Students and Schools," Review of Educational Research Vol. 41, No. 4 (Oct., 1971), pp. 303-350.

- The effect of tests on student cheating, grouping, self-concept, motivation, level of aspiration, study practices, anxiety, response set, opportunities.
- The use of coaching and practicing to influence test scores.
- The examiner-examinee relationships generated by tests.
- The effect of tests on parents, teachers, schools and society.

This response to criticisms of testing can be summarized by saying that tests should not be abandoned simply because some educators do not recognize their faults and misuse them.

The second response of proponents of present systems of testing to criticisms of testing has been that tests provide a more accurate means of predicting future excellence than intuition. Therefore, they argue, educators can only discharge their obligation to science students responsibly by using tests, grades, and similar indicators rather than using guesswork. Earlier in this chapter, the term "predictive validity" was defined: predictive validity reflects whether a test measures the performances it is supposed to measure. For example, a test might have a validity of 0.40 as an indicator of freshman grades in college. This means that if the test predicted a particular student would be in the top fifth of his freshman class in grades, 38 percent of the time he would be in the top fifth, 55 percent of the time he would be in the middle three fifths, and 7 percent of the time he would be in the bottom fifth. Similarly, if the test predicted he would be in the middle three fifths of his freshman class in GPA, 64 percent of the time he would be in the middle three fifths, 18 percent of the time in the top fifth, and 18 percent of the time in the bottom fifth.

The higher the validity, the better a predictor of that particular performance a test is: a validity of 1.00 would mean the test was never wrong, and a validity of 0.00 would mean that the test was no better predictor than choosing at random. Some representative validity figures are summarized below:[214]

Correlation Coefficient	Standing on Prediction	Precent of students in each criterion group		
		Bottom fifth	Middle 3/5	Top Fifth
0.30	Top fifth	10	57	33
	Middle 3/5	19	62	19
	Bottom fifth	33	57	10
0.40	Top fifth	7	55	38
	Middle 3/5	18	64	18
	Bottom fifth	38	55	7
0.50	Top fifth	4	52	44
	Middle 3/5	17	66	17
	Bottom fifth	44	52	4
0.60	Top fifth	2	48	50
	Middle 3/5	16	68	16
	Bottom fifth	50	48	2

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[214] W. H. Angoff, ed., The College Board Admissions Testing Program (Princeton, N.J.: Educational Testing Service, 1971), pg. 126.

Numerous studies have established that IQ tests generally have the highest validity in predicting future academic performance,[215] that grades have the second highest validity for predicting academic performance[216] and that multiple aptitude tests such as the CEEB examinations are third best.

The sixth and seventh editions of the Mental Measurements Yearbook[217] provide a good overview of the predictive validities of specific tests. Some representative validity figures for predicting college grades are:[218]

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[215] c.f. A. N. Frandson and J. B. Higginson, "The Stanford-Binet and the Wechsler Intelligence Scale for Children," Journal of Consulting Psychology (1951), pp. 236-238. E. A. Hinkleman, "Relationship of Intelligence to Elementary School Achievement," Educational Administration and Supervision Vol. 41 (1955), pp. 175-179. G. McBee and R. L. Duke, "Relationship between Intelligence, Scholastic Motivation, and Academic Achievement," Psychological Reports Vol. 6 (1960), pp. 3-8. R. N. Cassell and P. Knox, "Improving High School Learning Predictions with Multiple Junior High Test Scores," California Journal of Educational Research Vol. 21 (1970), pp. 14-20.

[216] c.f. J. R. Hills, "Predictions of College Grades for All Public Colleges of a State," Journal of Educational Measurement Vol. 1 (1964), pp. 155-59. J. R. Hills, J. A. Klock, and M. Bush, "The Use of Academic Prediction Equations with Subsequent Classes," American Educational Research Journal Vol. 2 (1965), pp. 203-206.

[217] Buros, Mental Measurements Yearbook (1965,1970).

[218] There is considerable evidence that graduate school performance is less predictable by grades than college performance, so these correlations are higher than those for predicting graduate work. c.f. D. E. Levin, The Prediction of Academic Performance (New York, N.Y.: the Russell Sage Foundation, 1965).

	SAT-Verbal	SAT-Math	High School GPA	Three Predictors Combined
predictive validity for freshman grades in science (averaged from ten different studies) 219	0.34	0.32	0.54	0.58

	SAT-V	SAT-M	HSGPA	Adv Math Test	CEEB Chem or Physics Test
predictive validity for grades in chemistry of freshman engineering students (single study-636 students) 220	0.01	0.09	0.32	0.18	0.29

	SAT-V plus SAT-M
predictive validity for overall freshman GPA (average of many studies) 221	0.30 - 0.55

	Appropriate CEEB Achievement Test
predictive validity for freshman grades in a particular subject (average of many studies) 222	0.30 - 0.55

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[219] Angoff, College Board, pp. 132-133.

[220] Ibid., pg. 142.

[221] Benno G. Fricks, "The CEEB Tests," Mental Measurements Yearbook, ed. by O. Buros (Sixth Edition, New Jersey, Gryphon Press, 1965), pg. 976.

[222] Ibid., pg. 976.

These validity figures have been challenged for several reasons. First, no predictive validity data is available on many standardized tests, including the PSSC tests and the ACS-NSTA standardized secondary level chemistry examinations. As a result, it is impossible to tell if these tests have as high a predictive validity as measures such as the CEEB achievement tests, or if they are completely useless as indicators of freshman grades in college.

Second, some well-documented predictive validity findings are strangely analomous. For example, the CEEB Achievement Tests in Mathematics, Biology, and Social Studies (!) do as good a job of predicting freshman chemistry grades as the CEEB Achievement Test in Chemistry.[223] This certainly casts some doubt on whether the conceptual understanding of chemistry measured by the CEEB Chemistry Achievement Test is basic to success in freshman chemistry.

Third, the use of an overall index of predictive validity masks the cultural bias of standardized tests. There is substantial evidence to show that minority group members are discriminated against by the CEEB test questions. For example, a summary of studies has shown that white males have a higher mean score on the SAT tests, especially on the SAT-Math test, than white females, black males, or black

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[223] Ibid., pg. 979.

females. The figures:[224]

		White		Black	
		Male	Female	Male	Female
Number of students in sample		4458	2677	371	528
SAT-Verbal	Mean	449	442	268	268
	Standard Deviation	102	93	52	51
SAT-Math	Mean	503	438	310	297
	Standard Deviation	106	87	42	44

Fourth, no systematic predictive validity studies have been done to correlate these standardized tests with success in a profession.[225] Ultimately, the purpose of educational screening is to ensure that the most talented people enter professional roles--yet tests have not been judged on this

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[224]Angoff, College Board, pg. 170.

[225]The one type of standardized test which has been examined for correlation with success in a profession is the Intelligence (IQ) test. The few studies which exist in this area show that IQ scores may function as a threshold variable in relation to occupational achievement, but once at or above this threshold, no correlation exists between test scores and success. c.f. D. A. Goslin, "Standardized Tests and Testing," Science (Feb. 1968), pp. 851-55. L. M. Terman, The Gifted Group at Mid-Life (Stanford University Press, 1959).

basis. Thus far, tests have been correlated only with academic grades...which are not necessarily good indicators of future success in the professions.[226] Until well-designed validity studies are done which correlate standardized tests with substantial contribution to the sciences, the appropriateness of standardized tests as a mechanism for screening science students remains questionable.

Overall, then, the question is very complex as to whether the benefits of standardized testing outweigh its misuses, its side-effects on the beliefs of students, and its dubious ultimate validity as a predictor of professional success. Given this, the heavy reliance of the first and second generation reforms on standardized testing and the rather half-hearted way that these curricula--especially the first generation reforms--have treated the concept of validity and the whole issue of student evaluation by other means than testing is surprising and disappointing.

Ultimately, much of the issue of how student excellence should be measured becomes an issue of whether grades should be given, since a major justification for emphasizing

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[226]This statement is true even of college grades in a highly specific field such as engineering. c.f. J. J. Anderson, "Correlation Between Academic Achievement and Teaching Success," Elementary School Journal Vol. 32 (1931), pp. 22-29. Donald P. Hoyt, The Relationship Between College Grades and Adult Achievement (Iowa City, Iowa: American College Testing Program, 1965). R. A. Martin and J. Pacheres, "Good Scholars Not Always the Best," Business Week (Feb. 24, 1962), pp. 77-78. J. B. Pallett, Definition and Predictions of Success in the Business World (unpublished Ph.D. dissertation, University of Iowa, 1965).

standardized tests in the first and second generation reforms has been that teachers need some criterion on which to award grades. The opponents of grading have advanced these major arguments against it:[227]

1) grades create the temptation to cheat[228]
2) grades bias teachers to believe that some children, who have not gotten high grades in the past, are not capable of doing high quality work[229]
3) grades are not reliable: studies have shown that different teachers will give the same test paper widely different grades. This is not only true for "subjective" subjects such as English, but for "objective" subjects such as science and mathematics.[230] In fact, different teachers use

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[227]Kirschenbaum, Simon, and Napier, Wad-Ja-Get?, pp. 179-202. Also, Herbert A. Thelen, "The Triumph of 'Achievement' over Inquiry in Education," Elementary School Journal Vol. 60, no. 4 (Jan., 1960), pp. 190-197.

[228]William Bowers, Student Dishonesty and Its Control in College (New York, N.Y.: Bureau of Applied Behavioral Science, 1964). James Q. Knowlton and Leo Hamerlynck, "College Students and Cheating," Journal of Educational Psychology (Dec., 1967) pp. 379-85.

[229]R. Rosenthal and L. Jacobson, Pygmalion in the Classroom: Self-fulfilling Prophecies and Teacher Expectations (New York, N.Y.: Holt, Rinehart, and Winston, 1969).

[230]Daniel Starch and Edward C. Elliot, "Reliability of the Grading of High School Work in English," School Review Vol. 20 (1912), pp. 442-57; and "Reliability of Grading Work in Mathematics," School Review Vol. 21 (1913), pp. 346-54.

up to fifty different criteria in grading.[231] This "spread" on grading occurs even when teachers are given very specific criteria to guide their grading.[232] Further, if a teacher grades the same paper once now and again in two months, the grades usually differ by 10 percentage points or more.[233]

4) female students generally receive higher grades than male students, even when the same levels of achievement have been shown.[234]

5) grades do not motivate all students: grades usually only motivate students who have done well under the grading system. Students who receive lower grades are unmotivated by grading.[235] The

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[231] C. W. Odell, "High School Marking Systems," School Review Vol. 33 (1925), pp. 346-54.

[232] P. D. M. Edwards, "The Use of Essays in Selection At Eleven Plus: Essay Marking Experiments: Shorter and Longer Essays," British Journal of Educational Psychology Vol. 26 (1936), pp. 128-36.

[233] E. W. Tieg, Educational Diagnosis (Monterey, Calif.: California Testing Bureau, 1952).

[234] E. Caldwell and R. Harnett, "Sex Biases in College Grading," Journal of Educational Measurement Vol. 4 (1967), pp. 129-32.

[235] I. L. Child and E. Whiting,"Determinants of Level of Aspiration: Evidence from Everyday Life," Journal of Abnormal Psychology Vol. 44 (1949), pp. 303-14. Robert Fox, Ronald Lippitt and Richard Schmuck, Pupil Teacher Adjustment and Mutual Adaptation in Creating Classroom Learning Environments (Ann Arbor, University of Michigan, 1964). HEW-USOE Cooperative Research Project #1167.

Eight Year Study has demonstrated that students can be motivated by schools without grading systems.[236]

6) grades are not a good indicator of occupational success,[237] so they should not receive such emphasis in screening.

7) grades are a poor means of feedback. The strengths and weaknesses of the student are not revealed; no recommendations for improvement are made. All the grade does is give an "objective" overall index of how well that student is performing in that subject relative to his peers in that classroom. Even, then, without knowing the teacher's standards for grading, it is difficult to interpret whether a grade is being given on a curve,[238] or whether it reflects how well the student is doing in terms of his capabilities or in terms of the set standards of the teacher.

8) grading patterns are similar from school to school, but not within schools. Some instructors give a high percentage of "A's," some instructors a low

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[236] Chamberlin, et al., Adventures in American Education (New York, N.Y.: Harper and Bros., 1942).

[237] See footnote 300.

[238] Willia Wetzel, "The Use of the Normal Curve of Distribution in Estimating Student Marks," School Review (1929), pg. 29. O. M. Smith, "Grading Without Guesswork," Educational Psychology Measurement Vol. 13 (1953), pp. 367-90.

percentage.[239] As a result, a student's record may be largely affected by which instructors he is taught by, rather than by his abilities.

Proponents of grading have defended grades as a measure of student excellence by arguing thus:

1) grading motivates students and gives them an incentive to succeed. Without grades, many students are not mature enough to continue to work hard.

2) grades are required by many colleges; the student who does not have high school grades is at a disadvantage in competing for admissions.

3) students need the experience of meeting teacher expectations and competing for grades in school so that they can meet employers' expectations and compete for advancement in later life.

4) grades provide a valuable source of feedback about a student's performance to the student and his parents.

5) grades are necessary to maintain high academic standards in the secondary schools. Without grades, many teachers might evaluate students on completely arbitrary criteria--with grades, the teacher can be compared to other teachers and is

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[239] B. C. Kirby, "Three Error Sources in College Grades," Journal of Experimental Education Vol. 31 (1962), pp. 213-18. Temple University, Report of the College Ad Hoc Committee on Grading Systems (Penna.: Temple University, 1968), pp. 41-48 (mimeo).

compelled to make his criteria for evaluation known.

6) grades are an easy means for teachers to evaluate pupils, and teachers have no time to spare for more time-consuming, cumbersome techniques. Grades are also an easy administrative device for sorting students according to ability.

7) parents and students expect grades and resist attempts to do away with grading systems--therefore, grades must serve a useful function for them.[240]

Overall, the issue of whether grading is more helpful than harmful is unresolved. Certainly, the casual acceptance of grading and standardized tests by the first and second generation reform courses indicates that far too little attention was given by these reforms to this important educational issue. The remainder of this chapter will explore how student excellence in secondary science courses should be measured, given our probable futures.

A Future-Oriented Analysis of the Types of Student Excellence Secondary Science Education Should Attempt to Foster

In Chapter III, a sample set of future-oriented educational objectives was formulated using the five basic alternative forecasts. A partial list of future-oriented skills that secondary science education should attempt to convey to

[240] Hedges, Testing and Evaluation, pp. 203-204.

students was derived from this set of objectives. One way of arriving at the types of student excellence secondary science education should attempt to foster is by examining the types of student excellence suggested by these future-oriented skills and objectives:

Skill #1: the student should be able to assess the crude impacts of a given technology on the future of American society (assuming that, in other respects, the United States exhibits no discontinuities from today)

Typical Objective: the student should be able to demonstrate that every five years there will probably be a complete revolution in the technology of central war (discuss implications for the United States Defense budget)

Types of Excellence: there are actually three complex sets of dynamics which interact in this problem: the dynamics of how new weaponry or anti-weaponry systems are developed, the dynamics of how one offensive or defensive set of technologies replaces another, and the dynamics of how the Defense Budget is determined (both within the Army and within the government). An excellent analysis of this issue would consider the interrelations of all these sets of dynamics, arriving at the conclusion that there will be a complete revolution in the technology of central war every five years. This would certainly involve abilities on levels two, five, and six of Bloom's taxonomy: comprehension of the inner workings of the three sets of dynamics, synthesis of the interrelations of the three sets, and evaluation of the synthesis to ensure internal consistency, logical accuracy, etc. A comprehension of systems theory and of technology assessment would be valuable background for formulating an excellent response to this problem.

Skill #2: the student should be able to forecast the rough social impacts of the attainment of present day technology in an "underdeveloped" country.

Typical Objective: the student should be able to discuss what cultural/social factors have been found to bring about decreased population growth, and what this implies for the amount of research and development needed in "under-developed" countries to stabilize population.

Types of Excellence: the first section of this objective requires the recall of knowledge, the second section calls for an application of this knowledge to a specific situation (Levels one, three in the cognitive taxonomy). A comprehension of the relationships between a country's level of research and development and its cultural institutions would certainly be needed. An excellent response to the objective might well include the use of a particular country as an example, including a discussion of that country's religious and cultural beliefs about population growth. A comprehension of cultural evolution and of the anthropological work that has been done on the effect of post-industrial technologies on pre-industrial cultural institutions would be important background knowledge in preparing such a response.

Skill #3: the student should be able to predict the broad intercultural and international dynamics which may result from the "developed" countries giving (or refusing to give) advanced science and technology to "underdeveloped" countries.

Typical Objective: the student should be able to discuss what level of technology is needed to reduce natural resource depletion sufficiently to allow all the world in the year 2000 to live at our present standard of living indefinitely.

Types of Excellence: again, several complex sets of dynamics interact in this problem: how technologies affect natural resource depletion, how the standard of living is affected by the level of natural resources available (and which resources are likely to be depleted first), and how the standard of living affects population growth. An excellent response would begin with the fact that population would have to stabilize at some point for "indefinite" life support. After synthesizing the interrelations of the different sets of dynamics, such a response might analyze some of the international and logistical problems which would arise as the "developed" countries worked to bring the "underdeveloped" countries up to the high level of technology necessary to satisfy the constraints of the objective (level 4, cognitive taxonomy). Overall, the cognitive abilities needed would be similar to those involved in the objective illustrating skill #1.

Skill #4: the student should be able to assess the crude interrelationships between economic stability, an adequate supply of technical manpower, and a high standard of living in a "developed" country.

Typical Objective: the student should be able to demonstrate the gross economic effects of a shortage of technical manpower in the United States and in the world.

Types of Excellence: this objective calls for a comprehension of how technical manpower levels affect the gross economy of the United States, and of how the United States economy affects the world economy. An excellent analysis might include both a detailed discussion of the short-term economic effects of such a shortage for various sub-sets of the world, and a brief look at the long-term impacts that this shortage might have on the dynamics of the world economy and on world technical manpower development.

Skill #5: the student should be able roughly to understand the broad impacts of a major technological-economic discontinuity on American society, and be able to understand the most important mechanisms which presently function to prevent such discontinuities.

Typical Objective: the student should study and discuss different designs for a technological-political-economic complex of institutions which could support a civilization of equivalent complexity to ours and yet could tolerate discontinuities in policy equivalent to the MIT solution (World 3 model).

Types of Excellence: obviously, many different student activities could satisfy this objective. Research papers, book reviews, debates and panels, and simulations are four alternatives which immediately present themselves. An excellent student-designed simulation, for example, might define five or six distinct components of the technological-political-economic complex and delineate a set of processes for interaction between them. By periodically adding constraints corresponding to major discontinuities, the dynamics of this system could be studied to determine if these could tolerate discontinuities more easily. For any sort of project, a comprehension of the systemic interrelations between technology, politics, and the economy and of the effects of discontinuities on systems would be required. Excellent projects would be characterized by originality, use of alternative systems from other cultures, and a firm grasp of the realities involved in transforming our present technological-political-economic system to a different one.

Skill #6: the student should be able roughly to understand the strengths and weaknesses of rigorous modeling of societal dynamics.

Typical Objectives: the student should be able to discuss and critique the basic assumptions underlying the postulated interrelationships in the World 2 and World 3 models.

Types of Excellence: a student working on this objective would be given diagrams of the World 2 and World 3 models, since the purpose of the objective is not to determine if the student can memorize a systems model, but if he can critique it. A basic comprehension both of the ways in which a systems model functions and of the empirical data which substantiates the model's assumption would certainly be necessary for a student to fulfill this objective. An excellent analysis would include a discussion of the strengths and weaknesses of the World 3 model as a predecessor to World 2, and a quick projection of what a "World 4" model might look like. Such an analysis might also examine which assumptions underlying the World 3 model might be expected to change in the next thirty years.

Skill #7: the student should be able to summarize the major rational arguments against the scientific-technological conceptions and institutions operating in our society at present.

Typical Objective: the student should be able to discuss the arguments underlying the claim that the "technological imperative" is dysfunctional (c.f. pg. 126).

Types of Excellence: this objective requires the recall of knowledge. An excellent response might include a detailed discussion of several examples of the "technological imperative" in our society, and an outline of some alternative scientific-technological conceptions and institutions that would answer the arguments against the "technological imperative" and yet provide many of the benefits that our present conceptions and institutions do.

<u>Skill #8</u>: the student should be able to construct simple alternative cultural-social models for dealing with science and technology.

<u>Typical Objective</u>: the student will design a cultural-social system which permits a high level of basic research with a low level of applied technology.

<u>Types of Excellence</u>: this allows for many of the same student alternatives as the objective for Skill #5. The focus here is on a smaller subsection of the technology-society interface, but the basic abilities and types of excellence involved are similar to those in Skill #5. An excellent response might well include in the discussion or simulation an overview of the difficulties involved in our country's converting to this new cultural-social system.

<u>Skill #9</u>: the student should be able to assess the major strengths and weaknesses of societal problem-solving via interdisciplinary, science-oriented teams of experts.

<u>Typical Objective</u>: the student should be able to discuss with a scientist the advantages and disadvantages of societal problem-solving via inter-disciplinary, science-oriented teams of experts (e.g. the

Manhattan project).

Types of Excellence: This objective involves both cognitive and affective abilities. An excellent response to this objective might entail:

a) being able to outline the histories and results of several past interdisciplinary problem-solving attempts, both successful and unsuccessful;

b) being able to demonstrate that many of the successful attempts had far-reaching, unexpected consequences beyond their immediate goals;

c) being able to discuss alternative means of problem-solving and to give their advantages and disadvantages;

d) being able to interest and involve the scientist in the discussion on a personal level;

e) being able to intrigue the scientist sufficiently that he agreed to devote some time to joint work on the topic; and

f) being able to leave the scientist with a favorable impression of the student's approach to the subject.

This sample set of types of student excellence can be used to generalize about some of the future-oriented types of excellence secondary science education should attempt to foster. The first generation reform courses utilized their problem-sets and tests to promote student excellence in manipulating disciplinary concepts to "find-the-correct-quantity." The second generation reform courses emphasized a slightly broader definition of student excellence which included "devise-an-experiment" and "demonstrate-historical-understanding" skills. The types of excellence fostered by the above objectives are broader still; the following list is a minimum description:

1) the excellent student has a comprehension of many aspects of modern society (how new weaponry or anti-weaponry systems are developed, how technologies affect natural resource depletion; how the United States economy affects the world economy, etc.)

2) the excellent student has a knowledge of appropriate illustrations of his comprehension (the religious and cultural beliefs of a particular country about population growth, several examples of the "technological imperative" in our society, the histories and results of several past interdisciplinary problem-solving attempts)

3) the excellent student can synthesize the interrelations of several complex sets of dynamics (how new weaponry or anti-weaponry systems are developed--how one set of offensive or defensive technologies replaces another--how the Defense Budget is de-

termined)

4) the excellent student can evaluate such a synthesis to determine its internal consistency, logical accuracy, plausibility, etc.

5) the excellent student can analyze some of the problems which may arise within his synthesis (the international and logistical problems which would arise as the "developed" countries worked to bring the "underdeveloped" countries up to the high level of technology necessary to satisfy the constraints of the objective).

6) the excellent student comprehends and can apply to a particular problem many tools useful in analysis of the science/society interface (systems theory, technology assessment, cultural evolution)

7) the excellent student can creatively design debates, panels, simulations, etc. if the subject matter can be better treated in these ways than through a written exposition.

8) the excellent student can interest persons in an issue, convince them of his sincerity in approaching the issue, and intrigue them with the idea of working with him on the issue.

Overall, inasmuch as these types of excellence are directed towards any single goal, they are directed towards two related areas of competence. The first is cognitive competence to formulate alternative conceptualizations about issues involving science and society and to choose the best resolution from among these alternatives. For example, after assessing the major strengths and weaknesses of societal problem-solving via interdisciplinary, science-oriented teams of experts, a student might conceptualize some alternative approaches to societal problem-solving and decide that he found one particular alternative to be a better approach than our present methods. The second is affective competence to interest others in the conceptualizations made, to help them follow the same chain of reasoning to a decision, and to involve them in devising concrete steps by which the decision may be actualized. In this case, the student might approach several scientists who had experience in societal problem-solving, outline his reasoning, and attempt to interest them in working jointly on testing his new approach. Clearly, the types of excellence involved in these sorts of competencies are very different from the student excellences fostered by the first and second generation reform courses and are also different from the special sorts of excellences these reforms associated with future scientific prowess.

In the previous chapter, a distinction was made between conventional and transformational organizing images for education. In general, those types of excellence which deal primarily with choosing among alternatives and with helping others follow a chain of reasoning can be taught purely within a conventional organizing image; but the other types of excellence listed above require a transformational component of education as well. Hence, any science curriculum which attempts to convey these other types of excellence must move beyond the processes for fostering excellence now being used in the schools. In particular, as the discussion in Chapter III indicates, extended "field trips" into the community, first hand experience with other cultural-societal systems, and involvement with national and international political issues must become a part of the science curriculum if skills such as those outlined above are to be conveyed.

The Inadequacy of Present Ways of Measuring Student Excellence for Fostering These Future-Oriented Skills

Measuring Future-Oriented Types of Student Excellence

As stated earlier in this chapter, some specifications of student performance intrinsically contain ways to measure that performance by direct observation. For example, a teacher observing a student-created simulation can tell by the actions of the participants if the simulation is well-planned and interesting. This section will discuss what instruments can be used by secondary science courses to measure future-oriented student performances not easily susceptible to direct observation.

Student performances based on a comprehension of modern society and on a knowledge of specific illustrations of this comprehension can be partially measured by direct comparison of the student's performance with the work of experts in the appropriate area. For example, a student's exposition on how new weaponry or anti-weaponry systems are developed can be compared to selected abstracts from the writings of weapons development experts and Department of Defense analysts. A student's factual statement delineating the religious and cultural beliefs of a particular country about population growth can be compared to the statements of cultural anthropologists and population experts.

However, the student's performance can only be partially measured by such comparisons, because the "facts" in these areas are not unilaterally certain. The processes by which new scientific concepts replace old were thought to be well understood until Thomas Kuhn wrote The Structure of Scientific Revolutions; now this "well understood" area is the subject of controversy. Care must be taken in measuring a student's conceptualizations against some standard so that original and creative alternative perspectives are not stifled.

A student's abilities to synthesize the interrelations of several complex sets of dynamics, to evaluate such a synthesis to determine its internal consistency and plausibility, and to analyze some of the problems which may arise within his synthesis are even harder to measure. Gross errors which produce ludicrous results (not plausible with "real world" events) can be detected, so the student's performance can be measured in this respect. So little is known, however, about the subtle interactions taking place in many science/society systems that even experts cannot agree on which of many alternative explanations is "correct." As a result, no consistent standard exists against which most student performances in these areas can be measured.

Student performances based on a comprehension of tools such as systems theory and technology assessment can be partially measured by comparing students' solutions with the work of experts. For example, technology assessment uses many morphological instruments to determine possibly useful combinations of components--a student's list of possible useful combinations for a particular problem can easily be compared with the list of an expert who has considered the same problem. Again, one reason such approaches offer only a partial means of measuring performance is that even experts occasionally overlook a part of some problem's solution which an insightful student analysis may reveal.

Finally, student performances in creating debates, panels, and simulations or in being able to interest and involve persons with an issue can best be measured by direct observation. This may become impractical in a class of ten to thirty students, but it is difficult to see how any feedback on the strengths and weaknesses of his performance could be given to the student without some form of direct observation taking place. The use of videotape and of older students working with younger students may provide one way past the difficulty of having the teacher personally observe all performances.

Overall, some of the future-oriented types of excellence described in the last section can be measured--and some cannot. Unquestionably, measuring these types of excellence will involve more time and effort than judging student performances on "find-the-correct-quantity" problems. Classroom patterns may have to be changed to allow the teacher to do more direct observation; evaluation of written answers will have to be done very carefully to avoid stifling student creativity. The additional work involved in these measurements is more than justified, however, by the fact that students will be learning skills and knowledge they can directly utilize as citizens in the next thirty to fifty years.

A New Perspective on Measuring Student Excellence in Secondary Science Education

The fact that there is no easy way to measure some of the future-oriented types of excellence described above may seem to indicate that these cannot be taught in the classroom. How can students be motivated by materials on which they are not evaluated? How can students receive feedback on their performances if these performances are not measured? How can students be graded and screened in the absence of measurement?

The last question of these three is the easiest to answer. Students do not need to be graded and screened on performances relating to excellent citizenship because they will not be graded and screened as citizens. There is some rationale for using future-oriented types of excellence for screening students who want to be professionals in areas deeply involved with science--only a few such jobs exist, and these positions should be filled by the best qualified applicants. There is no rationale, however, for using future-oriented science-based types of excellence appropriate for all citizens as a basis for screening non-science students. Since the vast majority of secondary students fall into this latter category, the fact that future-oriented types of excellence cannot easily be used for screening becomes less important.

Further, there is very little rationale for using discipline-based types of excellence appropriate for scientists in screening persons who do not wish to become scientists. Given the tenuous correlation between high school grades and college grades, and the even more nebulous relationship between high school grades and success in a profession, using high school grades in one field to screen applicants in another field seems inappropriate. Therefore, as a first approximation, only secondary students who want to become scientists or deeply involved in areas related to science should be screened on any of their performances in science courses. Chapter V will discuss some reasons why preparing special courses for these science-interested students is dysfunctional.

One major reason for grading as a means for fostering excellence disappears when most students do not have to be screened on their performance in secondary science courses. As discussed earlier in this chapter, there are many good reasons why grading should not be used in secondary science: a "below-average" student believes that he is incapable of using scientific processes in everyday life, students believe that the truly important things in science are those on which their grade is based (but grades are based on the most easily measured things in science), grades are not reliable, etc. Several alternative ways of fostering excellence other than grades exist; these systems offer new approaches to student feedback and student motivation. Some of these alternative systems seem more appropriate for secondary science than grading, given that secondary science must convey future-oriented skills.

Kirschenbaum, Simon, and Napier[241] discuss the following eight major alternatives to traditional grading:

A. Written evaluations

Description: sent to students, colleges, employers, parents...

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[241] Kirschenbaum, Simon, and Napier, Wad-Ja-Get, pp. 292-307.

Advantages: encourages teacher to think of students as individuals; better medium for feedback than grades

Disadvantages: very subjective; useless if written in vague terms; extra work for teacher, records office

B. Self-evaluation

Description: student writes out an evaluation of his progress, teacher adds comments and reactions of his own, then the combination is used as a written evaluation

Advantages: valuable learning experience for students; many of advantages of written evaluations

Disadvantages: some students abuse system; enormous pressure for high grades makes it hard for students to be honest about weaknesses; many of disadvantages of written evaluations

C. Give Grades, But Don't Tell Students

Description: supplemented by advising system to give students feedback

Advantages: students compare themselves to each other in a more meaningful sense

Disadvantages: many pressures remain to work for high grades; students feel the extra tension of trying to guess how they're doing

D. Contract System

Description: two kinds of contract systems: group and individual; a group contract system guarantees a specified grade to anyone who performs a certain type, quantity, and quality of work. For example, a group contract might read "Anyone who only comes to class regularly <u>or</u> only turns in all the required work will receive a D. Anyone who comes to class regularly <u>and</u> turns in all the required work will receive a C." An individual contract allows the teacher and student to negotiate in advance what the student will do and what grade he will receive for this work.

Advantages: much student anxiety eliminated; some subjectivity eliminated; diversity encouraged in individual system

Disadvantages: easier to judge on basis of quantity than quality, so quality tends to become de-emphasized

E. Mastery Approach or Performance Curriculum (Five-Point System)

Description: a complete behavioral objectives approach. Students examined whenever they wish to see if they have mastered enough objectives to attain a particular grade

Advantages: grades tied to performance levels; teacher subjectivity reduced; focus on student success, not student failure; student can master objectives through any process he desires

Disadvantages: needs considerable skill on part of teachers; restricts teacher's role in classroom; restricts students from evolving and working toward their own goals; total faculty must be involved

F. Pass/Fail Grading

Description: group contract system with two grades

Advantages: students less competitive; many students explore more, still work hard

Disadvantages: teacher responsible for giving lots of feedback; does not distinguish between students of different abilities;

some students do little work; student who is in danger of failing is still being graded

G. Credit/No Record

Description: self-explanatory

Advantages: same as pass/fail, except students in danger of failing no longer need to worry about grades

Disadvantages: same as pass/fail, except failing students not graded

H. Blanket Grading

Description: pass/fail with a single grade substituted for the pass (A/fail, B/fail, etc.)

Advantages: same as pass/fail

Disadvantages: same as pass/fail

Many evaluation systems can be formed which are combinations of these eight ideal types. One such system that seems especially promising for future-oriented secondary science education is a combination of the Contract and Credit/No Record systems. Such a combination might work as follows:

Each student can choose between one of two grading options and can switch between the top options at any time. Option One is Credit/No Record--the student and teacher individually contract for what the student must do to achieve a Credit in the course. Five or six alternative contracts might be given out to all students in order to illustrate the diversity possible within this system. Non-science students might find this option more attractive.

Option Two also uses individualized contracts, but these are on a Grade/No Record basis. Each student negotiates with the teacher what he must do to achieve a certain grade in the course. A student might negotiate two or three different contracts for different grades so that if the original grade he sought proves to be too difficult he would have some option other than a Credit or a No Record. Science students might find this option more attractive.

The use of this alternative to grading would not eliminate all of the problems involved in measuring student excellence, but it would answer many of the criticisms of grading discussed earlier while retaining the strengths of grading. The temptation to cheat would disappear as students ceased to be competitive with each other. Students would be able to learn science in their own way and at their own speed and to be motivated more by their own goals and by the judgments of their peers than by a drive to please the teacher. The pressures of working for a high grade or of being graded by performance on tests would become an option that each student could accept or reject. Grading would become more reliable and less subjective because the criteria for a given grade would be clearly delineated. Overall, this system is more work for the teacher than traditional grading. However, it is more just, better adapted to science for non-science students, and offers more alternatives to both student and teacher than traditional grading.

Within this overall framework, many problems of evaluating student excellence remain. Many student performances will be difficult to evaluate. The teacher will have to spend a great deal of time giving students feedback, and helping students used to traditional grading to adjust to the different kinds of motivation inherent in this new system. Any new secondary science curriculum projects will have to spend far more time than the first and second generation reforms on preparing materials which help the teacher to understand the difficulties of measuring student performance--materials which provide well-delineated alternatives to standardized testing and which recognize that many forms of excellence cannot be easily measured. Only in this way can secondary science education give students a true picture of what science will mean to them for the rest of their lives, and of how they can rise to meet the challenges of excellence in a technological democracy.

CHAPTER V

EXAMINING ELITISM IN SECONDARY SCIENCE EDUCATION

A Brief History of Elitism in Secondary Science Education

The "Gifted" and the "Disadvantaged" in the Secondary Science Curriculum

There are two major ways in which the secondary science curriculum is elitist: students are classified as "gifted," "average," or "disadvantaged" (intellectual elitism) and secondary-level science courses are designed to be taught only to 15-17 year old students (chronological elitism). This chapter will argue that both of these forms of elitism as they currently exist are dysfunctional and will discuss alternatives to the present forms of elitism in secondary science education. First, the prevalence of both types of elitism in the first and second generation reforms must be cited.

Before World War II, traditional science courses in the schools were designed for all students, with no curricular distinction made between science-oriented and non-science-oriented students, or between "bright" students and "not-so-bright" students.[242] The emphasis on highly specialized manpower and hierarchical authority during World War II changed this non-elitist orientation. After the war, the Progressive movement in education initiated a movement for "life-adjustment education," which argued that students can be divided into different levels of "giftedness" and that only 20 percent of all secondary students should receive college-preparatory education.[243] "Life-adjustment education" was crushed by critics of the Progressive movement in the early '50's, but the issue of intellectual elitism again became important with the launching of Sputnik (1957). Admiral Rickover, the College Entrance Examination Board, the National Education Association, and similar groups all called for the development of special curricula for the "gifted" science student.[244]

John Hersey mirrored and mocked the educational mood during this period in his satiric novel The Child Buyer (1960).

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[242]Except by the use of tracking systems, or special courses with special pre-requisites. c.f. Fowler, Secondary Science, pg. 9.

[243]Lawrence A. Cremin, The Genius of American Education (New York, N.Y.: Vintage Books, 1965), pp. 45, 58-59.

[244]H. G. Rickover, The Education of Our Talented Children (New York, N.Y.: Thos. Alva Edison Foundation, Inc., 1957). National Education Association, The Identification and Education of Our Academically Talented (Washington, D.C.: National Education Association, 1958). Charles C. Cole, Jr., Encouraging Scientific Talent (New York, N.Y.: College Entrance Examination Board, 1956).

The plot of this novel concerns the efforts of private defense-oriented industries to purchase "gifted" children from their parents and reduce them, through drugs and surgery, to efficient thinking machines. The process by which "gifted" children are "educated" in the novel is as follows:

- Each child is removed from human contact, brainwashed, and given a drug which removes all his past memories.
- This human tabula rasa is then filled with knowledge and cognitive skills pertaining to defense projects, and with a religious desire to serve as a calculating machine.
- Enormous amounts of data are then fed to the "gifted" child by computers, and all five senses are surgically removed to ensure that no emotions can develop, no extraneous data can enter in.
- When the "gifted" children have exhausted the possibilities of their data, most are disposed of, save for an unsterilized few who can serve as "breeders" for future "gifted" children.[245]

While savagely overdrawn, this satire does reflect the extremist nature of the "reforms" proposed during this period.

On the surface, the first generation reforms resisted these pressures to prepare courses for the "gifted" student; BSCS produced courses for several "types" of students, but the other reforms all developed a single course for all

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[245]John Hersey, The Child Buyer (New York, N.Y.: Bantam Books, 1960), pp. 181-185.

students. However, a closer examination of these reforms does reveal that first generation courses were biased towards a particular "type" of student considered intellectually "superior:" the college-bound, science-oriented, mathematically-inclined student. The vast majority of the population which tested the first generation reform courses was made up of such students--a factor which contributed to the failure of the first generation reforms in the schools as "unsuited" for most students. Further, many students chose not to take the first generation courses on the grounds that the material was too difficult--with the result that only "bright" students took these courses.

The second generation reforms were a little better. For example, the ECCP course was supposedly designed for the large majority of high school students who do not take physics--less than forty percent of these students go on to college. The student population which tested the ECCP course was composed of ninety-six percent college-bound students, twenty-seven percent of whom planned to major in science or mathematics.[246] Again, a particular "type" of student considered brighter than most was used as the prototype for curriculum preparation.

Brandwein's two instruments for finding "gifted" students focused on a narrowly selected student population:

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[246]Hurd, Secondary School Science, pg. 205.

"high IQ, high reading and math achievement scores, college-bound, high grade point average..."[247] Perhaps the clearest illustration of the biased nature of the intellectual elitism underlying all of the reform courses comes from the two BSCS "special" courses: one for "gifted" students, the other for "slow learners."

The "gifted student program" of BSCS was developed in 1960; its purpose was to provide "increased learning opportunities and challenges for the gifted and the talented student." Four volumes of special research problems were selected as having the following characteristics:

> 1) the problem must not have a known answer;
> 2) the problem must be small enough to be reasonable to a high school student, but this should not mean a solution is ensured;
> 3) the experimental problem should be practical in terms of cost and equipment needs; and
> 4) the student should be under 'the gentle burden of independent research' and learning to cope with a problem. 248

Jerome Metzer describes the "gifted" students the BSCS course was prepared for as follows:

> The Educational Policies Commission has suggested that students who are highly gifted have IQ's of 137 or more, and that those with IQ's between 120 and 136 are moderately gifted. Furthermore, the gifted usually express themselves clearly and accurately. They read one or two years ahead of their class and are one or two years ahead of their class in mathematics. They grasp abstract concepts better than the average. They want to know the reasons for things instead of just accepting them....Such students could conceivably

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[247]Brandwein, Gifted Student, pp. 89-93.

[248]Hurd, Secondary School Science, pg. 164.

> become research biologists if they were properly incubated and subsequently nurtured. 249

The counterpart to the BSCS "gifted students" course was the development in 1963 of a BSCS course for the "slow learner." According to BSCS, "slow learners" compose twenty to twenty-five percent of tenth grade students. These students: "scored below the fiftieth percentile on general aptitude tests, read several years below grade level, have difficulty with mathematical and verbal communication, and had a poor academic record. In addition, they had a poor attitude towards school, they made few attempts to study, and were apathetic and indifferent."[250] "Slow learners" were also rated by their teachers as being more motivated than other students by Skinnerian psychology--by immediate awards and evaluations--the interest span and the attention span of these students was considered short.

Students such as these were classified by BSCS into three categories: "the underachieving truly slow, the achieving truly slow, and the under-achieving average and above average in academic potential." The large majority of "slow learners" was classified as "truly slow," with IQ 75-90, "forming a group between the average and the mentally retarded."[251]

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[249] Jerome Metzner, "The Gifted Student Program of the BSCS," American Biology Teacher (May, 1964), pp. 341-42.

[250] Hurd, Secondary School Science, pg. 161.

[251] Lorenzo Lisonbee, "Teaching Science to the Slow Learner--The BSCS Point of View," School Science and Mathematics (Jan., 1965), pg. 40.

The BSCS course prepared for these "slow learners" emphasized materials "at a simpler reading level, supported by multiple sensory aids, developed to a large extent through laboratory work, incorporating learning and study skills to develop good habits, and adaptable to a wide range of student interests."[252] The text was limited to five major topics so that the "slow learners" would not be "overwhelmed" by too much reading material, too many ideas. In fact, there deliberately were only sixty-two "ideas" (e.g. "life comes from life") in the entire course.

BSCS hoped that teachers using its "slow learners" course would "consider the teaching of slow learners important, have some competency for teaching slow learners, understand the importance of laboratory experiences for slow learners, have little doubt that these youngsters can learn and appreciate the modern concepts in biology, and have a good background in modern principles of biology." In fact, it was noted that "some of these teachers actually prefer the slow classes to regular ones."[253]

From these examples of discrimination, a pattern of biased intellectual elitism can be seen in the first and second generation reform courses. Students are grouped into three "types:"

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[252] Hurd, Secondary School Science, pg. 162.

[253] Lisonbee, "Slow Learner," pg. 45.

<u>Type 1</u>: ("gifted")	IQ 120 or over, high reading and math scores, college-bound, science-oriented, good ability to deal with abstractions, high grade point average
<u>Type 2</u>: ("average")	IQ 90-120, average in all achievement scores, average academic achievement
<u>Type 3</u>: ("slow learners")	IQ 75-90, low reading and math scores, low general aptitude scores, poor academic record

Two assumptions are made;

1) that some unitary "Intelligence" important to mastering science exists, and
2) that Type 1 students are more "Intelligent" than Type 2 students, who are more "Intelligent" than Type 3 students.

Within the context of these classifications and assumptions, BSCS prepared different curricula for Type 1, 2, and 3 students--the other first and second generation reforms developed a single curriculum biased towards Type 1 students.

This sort of intellectual elitism is biased and dysfunctional because it can easily be shown that these three "types" of students are highly correlated with factors known to have no relationship to general aptitude or to success in the scientific professions. A students' race, sex, parental income, ability to perform well in testing situations, and willingness as a secondary student to choose a specialized career should have no influence on which ideas he is exposed to or on his professional aspirations. By assuming a unitary "Intelligence" correlated with these particular student "types," the first and second generation reforms biased secondary science education towards certain students and against others regardless of actual ability.

In Chapter IV, the bias of testing instruments against the test-shy, the emotionally disturbed, the unmotivated, and the late bloomers was discussed. The ways in which grading discriminates against pupils who are not "respectful" and "obedient," or who have a hard-grading teacher rather than a lenient-grading teacher were delineated. Many of the major distinctions between Types 1, 2, and 3 students are made on the bases of grades, achievement tests, and IQ tests. By classifying students on these bases, the first and second generation reforms are biased against the many students who do not test well, who are not subservient to teachers, or who are still "finding themselves." Gardner speaks out against this in Excellence:

> An equally important rule (in using aptitude tests) is that diagnosis of young persons' aptitudes and achievements must be a continuing process....Early separation of the very gifted and the less gifted violates our principle of multiple chances. We believe that the youngster should have many successive opportunities to discover himself. 254

While the descriptions of the three "types" of students contain no overt social class bias, the ways in which terms

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[254] Gardner, Excellence, pp. 51, 69.

such as "college-bound" and "science-oriented" are interpreted convey subtle meanings strongly tied to social class. The "science-oriented" student is defined as a person who participates in a host of extracurricular activities related to science, does all his homework plus extra reading, prepares science projects for science fairs, works in the lab during his lunch hour, etc.[255] The "college-bound" student is defined as a student who takes four years of English, mathematics, languages and has a high grade point average in all these areas--plus masters the art of taking achievement tests. The activities of a "college-bound, science-oriented" student cumulate to a twelve-hour a day, seven-day a week schedule...which a motivated middle class student might choose to keep. But what about the student who has to work both days every weekend to help his parents make ends meet? What about the student who must go home right after school to take care of younger siblings because his mother and father both work and cannot afford a sitter? What about the student who attends a "poverty-level" school with no science lab? These students are discriminated against by the first and second generation reforms because of their parents' social class.

Similarly, no overt descriptions of race are contained in the descriptions of the three "types" of students, but these "types" have a high correlation with a student's race.

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[255]Brandwein, Gifted Student, pg. 90.

BSCS accepted this with no surprise, calmly noting that "all slow learners do not come from the culturally deprived, but there is evidence indicating that a good portion of them do."[256] Chapter IV has already discussed how IQ tests and achievement tests are strongly biased against non-white students. The distribution of science equipment is also racially skewed; three times as many black students attend schools without a chemistry laboratory as white students; three and one-third times as many black students attend schools without a physics laboratory as white students.[257] In general, non-white students are segregated into urban schools which have an average per pupil expenditure which is less than seventy-five percent the per pupil expenditure in suburban schools.[258] As a result, the first and second generation reform courses are less available to non-white students because of the high cost of textual materials and laboratory equipment for these courses.

The phrases "short interest and attention span, motivated primarily by immediate rewards"[259] in the description of Type 3 students are racially loaded terms close to the racial stereotypes common during slavery. These stereotypes

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[256] Lisonbee, "Slow Learner," pg. 39.

[257] Frederick Mosteller and Daniel P. Moynihan, eds., On Equality of Educational Opportunity (New York, N.Y.: Vintage Books, 1972), pg. 9.

[258] B. Jones, et al., Urban Education: The Hope Factor (Philadelphia, Pa.: W. B. Saunders Co., 1972), pg. 94.

[259] Lisonbee, "Slow Learner," pg. 45.

now denote functional inferiority (due to "disadvantaged" cultural and family background) rather than innate inferiority, but the underlying reasoning is identical.[260] The low proportion of non-white students majoring in science on the college level is undoubtedly partially due to this systematic racial bias inherent in the intellectual elitism of the first and second generation reforms.

The first and second generation reforms also are sexually biased; male students are far more likely to be considered "gifted" in science than female students. The prejudice against women as scientists is deep-rooted:

- Not until 1969 did Caltech, a very prestigious technical institution decide to admit women undergraduates.
- A recent longitudinal study of "The Development of Creative Scientists" used an exclusively male population as its experimental subjects.[261]
- Despite urgings by manpower experts that science courses be less biased in favor of men,[262] the woman scientist is still a rarity.

The sexual bias in the first and second generation reforms is more passive than active; a climate unfavorable to the development of women as scientists exists and these

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[260] William Ryan, Blaming the Victim (New York, N.Y.: Vintage Books, 1971), pp. 31-34.

[261] Parloff, "Creativity."

[262] Brown, Bonner, and Weir, Next Hundred Years, pp. 135-136.

courses have done nothing to dispel it. The predominant number of "gifted" students identified by Brandwein with his "Man to Man Rating Scale" were male.[263] As discussed in Chapter IV, achievement and intelligence tests are sexually biased. In an article discussing "Learning and Motivation: Implications for the Teaching of Science," familiar sexual stereotypes are brought out:

> Girls have a marked superiority over boys in the language area. Since school is essentially a verbal, symbolic, linguistic experience, it's small wonder that girls do better than boys. On the other side of the ledger, it can be reported that boys are somewhat better than girls in math and science. This slight superiority can be attributed to the fact that analytical thinking is associated with the greater aggressiveness of males...we are constrained to point out that males are superior to females in transfer training. 264

Because these sexual biases are ignored by the reform science curricula, secondary science intellectually discriminates against women.

Because students are rated "gifted" or "average" depending on how early they specialize in science, secondary science intellectually discriminates against students with a broad cognitive background. Students interested both in science and in other subjects are pressed by "early identification" programs to declare allegiance only to the sciences.[265] The first and second generation courses demand

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[263]Brandwein, Gifted Student, pg. 30.

[264]Walter B. Waetjen, "Learning and Motivation: Implications for the Teaching of Science," Science Teacher (May, 1965), pg. 23.

[265]Cooley, "National Welfare."

a phenomenal amount of extra work of a student who wishes to achieve high grades in science--work which is primarily based on a narrow disciplinary context and which does not overlap with other areas of study. As Brandwein's descriptions of the "gifted" student indicate, a Type 1 student is "science-oriented"--which is defined as meaning that every spare hour of the student's time is devoted to scientific activities. As a result, before they have even entered college, students are constrained to be either scientists full-time or non-scientists.

All of these biases in the intellectual elitism of the first and second generation reform courses have created a hierarchy of student "types" largely unrelated to student abilities. A major justification for intellectual elitism has always been that different students have different innate abilities, and that only by treating students as different "types" rather than as a single "composite" can education be maximized. The history of secondary science education since World War II indicates that this "maximization" has consisted as much of separating students by sex, race, social class, testing ability, and willingness to specialize as separating students by ability to grasp secondary-level science.

"Youth and Maturity" in the Secondary Science Curriculum

Chronological elitism is a second major factor in secondary science education as intellectual elitism. High School and university science curricula use age as a means of segregating students into "types" and rigorously treat these "types" as entirely different entities:

Type A	ages 15-17	"high school" student	Type A_1 college-bound Type A_2 not college-bound
Type B	ages 17-25	"college" or "graduate" student	Type B_1 science major Type B_2 non-science major
Type C	ages 26 and older	"continuing education" student	Type C_1 professional in science Type C_2 not a professional in science

Type A, Type B, and Type C students are taught with entirely different curricula.

All of the first and second generation reforms were designed for Type A students--even though many Type B_2 and Type C_2 students could profit more from secondary level science courses than from college-level science courses. The reform groups chose to ignore the fact that college students who are not science majors are generally taught diluted versions of the college courses designed for science majors, even though many non-science students have not taken high school science courses. The reformers also disregarded the lack of access most adults have to high quality science courses which do not presuppose a strong high school science preparation.

Passivity is the major reason why the first and second generation reforms prepared secondary level curricula only for a narrow age-based segment of the total population. The reformers--with one exception--approached the national science society problems which culminated in the late 1950's and early 1960's using a passive traditional model: develop new courses to be taught in schools and to be taken by persons of appropriate ages.

The proposed American Chemical Society reforms (described in Chapter II) are an exception; these have adopted an aggressive, non-traditional approach to changing science education. In addition to preparing a course for secondary students, ACS plans to prepare position papers, television programs, and continuing education courses to give the rest of American society access to high quality chemistry education. Unfortunately, even these reforms are somewhat based on chronological elitism--younger and older persons are treated differently.

The ultimate cultural and economic assumptions underlying our customs of terminating formal education at a certain age, segregating students by age, and isolating education away from adult life in schools have never been examined by the reformers. This is unfortunate since it is questionable whether these assumptions are still relevant, given the forces which have led to pressures for science education reform, given the likely futures America faces.

The cultural and economic assumptions underlying chronological elitism in education go back to medieval times and earlier. The three major cultural assumptions are that:

1) younger people know less than older people
2) what a person can learn depends on his age
3) mixing people of different ages retards learning

The two major economic assumptions are that:

1) it is cheaper for the society to educate its citizens while they are young
2) educating young people keeps the job market from overemployment

Margaret Mead documents the first and third cultural assumptions in Culture and Commitment.[266] Post-figurative cultures are oriented to the old as a source of wisdom, co-figurative to the peer group, and pre-figurative to the young. Part of the chronological elitism underlying education comes from our post-figurative past: formal education ceases at a certain age because the old are intrinsically wise, mixing people of different ages retards learning because background information must be explained to the young.

The whole notion of "stages of development" as outlined by Bruner, Gagne, Piaget and other psychologists il-

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[266]Margaret Mead, Culture and Commitment (Garden City, New York: Doubleday and Co., 1970).

lustrates the second cultural assumption. Although the theories of the various developmentalists differ, all agree that the older a person is--up to a certain point--the more he can learn. Past a certain age, learning is assumed to become more difficult; "you can't teach an old dog new tricks." Given these beliefs, segregating people into groups based upon age and terminating education at a certain age becomes plausible.

The first economic assumption is manifest in the emergence of the concept of "human capital" in the economics of education.[267] This concept entails estimating, as one cost of education, the income foregone by students and estimating, as one return of education, the increased earning capacity of students.[268] Within the context of this concept, it becomes economically advantageous to the society to focus education on the young. The costs foregone by younger students are less appreciable than those foregone by older students, and the total earning capacity of the student throughout his lifetime is increased by his attending school while young.

The second economic assumption is based on the empirical dynamics of economic growth. When the number of workers has exceeded the number of jobs, overemployment and

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[267]M. Blaug, ed. Economics of Education 1 (Baltimore, Md.: Penguin Books, 1968), pp. 11-136.

[268]T. W. Schultz, "Investment in Human Capital," American Economic Review Vol. 51 (1961), pg. 12.

recession have occurred. When fewer workers than jobs have existed, underemployment and a rising Gross National Product have occurred. By gradually extending the amount of education needed for certification as an employee, enough young people have been kept off the job market so that there has not been a great surplus of prospective workers.

These cultural and economic assumptions have created a hierarchy of student "types" based upon age. The first and second generation reforms unquestioningly accepted these assumptions and developed secondary science courses only for fifteen to seventeen year old students. The next section will argue that these cultural and economic assumptions are generally no longer valid, that the benefits of present systems of segregating students by age are less than the costs, and that there is no longer any reason for continuing chronological elitism in secondary-level science education.

The Dysfunctional Nature of Present Forms of Elitism in Secondary Science Education

Elitism and the Self-Fulfilling Prophecy

Elitism postulates that a range of innate abilities exists; and that persons of one level of ability should be given different education, different responsibilities, and different rewards than persons of a different level of ability. In education, elitism results in tracking systems of various kinds: "gifted" children learn one set of material, are allowed one set of aspirations; "disadvantaged" children learn another set of material, are allowed another set of aspirations. Assuming that such a thing as "innate ability" does exist and does differ from person to person, one issue which has always been a problem to elitists is: how does one determine who is "able" and who is not? As already discussed, secondary science education adopted a fairly crude answer to this question: "ability" has been determined by factors easily subject to bias such as age, grades, IQ, achievement tests...

Hopefully, enough has been written about the lack of any relationship between innate ability and sex, race, or social class that no further discussion is necessary about why a science curriculum biased along these lines is dysfunctional.[269] A conclusive argument for the necessity of racial integration in education has been put forward by Thomas Pettigrew.[270] Arthur Jensen's arguments justifying racism have been convincingly refuted;[271] the "culture of poverty" thesis advanced by Oscar Lewis and others has been

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[269] Jones, Hope Factor, pp. 1-19.

[270] Thomas Pettigrew, "Racially Separate or Together," Journal of Social Science Vol. 25, no. 1 (1969), pp. 43-69.

[271] Carolyn C. Peelle, "Myths and Issues in Urban Education," (Amherst, Mass.: Center for Urban Education, 1972), pp. 17-19.

demolished.[272] The time for debate about whether classism, racism and sexism are harmful in education is over; the time for taking decisive action to eliminate discriminatory action in these areas has come.

Chapter IV has already delineated why, given our probable futures, the biases inherent in present systems of testing and grading hamper the development of excellence in the secondary science curriculum. Before discussing why our present chronological forms of elitism are harmful and why requiring early specialization in science is a dysfunctional form of elitism, one major problem intrinsic within <u>any</u> system of elitism must be brought forward.

A little discussed but very fundamental issue underlying elitism is the problem of the self-fulfilling prophecy. Psychologically, human beings seem to be so constructed that:

1) if a person believes he is not able to do something, he will act in ways which reinforce that belief.
2) if a person is denied the opportunity to learn, he will rapidly become less capable of learning.

For instance: by a mistake in measurement or by malice or for some reason extraneous to his abilities, Joe is labeled as a "slow learner." However, Joe does not realize that this is not correct--he believes that he is "truly slow," that the ideas he is exposed to are all that he is capable of grasping. As a result, Joe does not try to prove that his

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[272] Charles A. Valentine, <u>Culture and Poverty</u> (Chicago, Ill.: University of Chicago Press, 1968).

status is unjust--he learns what "slow learners" are supposed to learn and in a year or so his knowledge is less than that of the "average" student.

Even if Joe believes that his abilities were incorrectly assessed, he still must convince his teacher and his guidance counselor of this fact. Given the attitudes of many teachers and guidance counselors associated with "slow learners," this is no easy task. Overall, then, attempts to determine whether Joe was correctly placed according to his abilities will tend not to detect errors because:

1) The same biases which resulted in incorrect placement originally may still be operative.
2) The persons who surround "slow learners" tend to have negative expectations for the student.
3) Joe will fall behind "average" students as soon as any appreciable amount of time has passed.

Discouragingly, there is a great deal of evidence which indicates that many students are in Joe's position. The Jones and Clark study on teachers' expectations in Harlem schools,[273] the research by Rosenthal and Jacobson on the self-fulfilling prophecy and teacher expectations,[274] the observations of Eleanor Leacock in Teaching and Learning in City Schools,[275] and Walter Borg's study of ability grouping

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[273]Ryan, Blaming the Victim, pp. 53-56.

[274]Rosenthal and Jacobson, Pygmalion.

[275]Eleanor Leacock, Teaching and Learning in City Schools (New York, Basic Books, 1969).

in the public schools[276] all reinforce the statements just made. Any elitist system pays for flaws in its instruments for assessing students' abilities by the loss of potentially able persons who were told that they were "disadvantaged," "less gifted," or "dumb."

An interesting corollary to these findings might be that:

- if a person believes that he is able, he will act in ways which reinforce that belief, and
- if a person is given many opportunities to learn, he will rapidly become more capable of learning.

In other words, if all students were expected to be "gifted"--even if they were taught in different ways depending on their individual needs--the proportion of "gifted" graduates might rise.

Any system of elitism, then, necessarily reinforces its own expectations of what percentage of students will be able, what percentage will not. Segregating students by age, by IQ, by grades, or by any other factor will intrinsically be dysfunctional to the extent that the student's (or teacher's) image of the student's abilities is lowered.

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[276] Walter R. Borg, Ability Grouping in the Public Schools, (Madison, Wisc.: Dembar Educational Services, Inc., 1966).

The Decreasing Role of Chronological Elitism and Early Specialization in This Country's Future

Our present practice of separating students into different age-based groups even though each group is learning science at a "secondary" level of difficulty was once a viable approach to education. Earlier, the cultural and economic assumptions underlying chronological elitism were delineated; at one time, there was a great deal of evidence to support these assumptions. When our rate of cultural change was slow, older people were a valuable source of wisdom to the young. At that time, the future was sufficiently pre-determined so that a singly fifteen year chunk of education could suffice for the next forty years.

In the late 1800's, puberty occurred three or four years later in life, and young people did not attain their full cognitive/affective potential until about the end of high school. Mixing students of differing ages did retard group learning at one time because cherished cultural taboos were trampled and because people who had widely differing amounts of experience were treated as similar. When our economy was laissez faire, it was strongly tied to full employment; separating students by age to keep young people off the job market was functional then.

Now, the probable futures in Chapter III suggest that none of these factors will continue to be important in the next thirty to fifty years. Our rate of cultural change has quickened and is steadily increasing[277]--we are moving to a pre-figurative period in which the young are as viable a source of wisdom as the old.[278] As discussed in Chapter III, preparing students for life forty years from now becomes almost impossible with this rapid rate of change; many widely different alternative futures are probable, and the student must be prepared for all of them. With the age of puberty steadily decreasing and with the early childhood experience of each youngster growing richer and more varied, students attain their full cognitive and affective potential long before finishing high school.

Mixing students of widely differing ages is no longer an issue, as cultural beliefs demanding intrinsic respect for age have almost disappeared and as young people--through the vehicles of modern media and advanced transportation systems--have gained as wide an experiential background as older persons. As our economy steadily moves towards socialism,[279] a guaranteed annual income,[280] and capacities for production largely independent of manpower, "full employment" will become less and less an index of national

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[277]Alvin Toffler, Future Shock (New York, N.Y.: Random House, 1970), pp. 20-31.

[278]Mead, Culture and Commitment, pp. 51-76.

[279]Robert L. Heilbroner, The Future As History (New York, N.Y.: Harper Torchbooks, 1959), pp. 173-211.

[280]Theobald, America II, pp. 34-37.

prosperity. These evidences that the cultural and economic assumptions underlying chronological elitism in education are no longer valid indicate that our system of separating students by age no longer is serving a useful function.

The changes in our cultural and economic dynamics discussed above also undercut another elitist part of science education: pressures on secondary students interested in science to specialize early. Now that our rate of cultural and technological change is swift, now that the useful "half-life" of information in the scientific professions ranges from five to twenty years, even very specialized areas of knowledge must be continually re-learned rather than mastered once while young and utilized thereafter. The rate of change of conceptual frameworks within disciplines is increasing[281]--no longer can a student learn at the feet of an "expert" with the expectation of his new-found expertise lasting for many years. The economic value of specializing also has deteriorated--an "expert" may enjoy high earnings if few share his knowledge and his knowledge is in demand, but inevitably a plethora of "experts" emerges and the forefront of science moves elsewhere.

The strong link that has existed between expertise and age is now disintegrating because of these dual pressures on chronological and intellectual elitism. No longer is half a lifetime needed to become an "expert"--knowledge is

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[281] Schwab, "Teaching of Science," pg. 40.

changing too quickly. In fact, a scientist of twenty-five may well have more areas of expertise than a scientist of fifty...the younger scientist has just completed an exhaustive education, the older has forgotten much of what he has learned. In the absence of any evidence that specializing early in the sciences ultimately produces a better scientist, the insistence of secondary science on commitment to the sciences while very young seems no longer functional.

This section has thus far argued that chronological elitism and expertise-oriented elitism in science education are out of date in our modern technological society. Equally cogent arguments can be made for why our probable futures render these forms of elitism not only obsolete, but dysfunctional. In Chapter III, a key distinction was made between "conventional" and "transformational" organizing images of the future. "Conventional" forecasts presuppose that our present problem-solving methods are adequate to deal with the crises emerging in our future; "transformational" forecasts see these problem-solving methods as an intrinsic part of these crises, and emphasize that totally new frameworks for problem-solving must be developed. Since chronological elitism and a concomitant emphasis on expertise are intrinsic to our society's present approaches to problem-solving, both these forms of elitism are directly dysfunctional to the extent that "transformational" forecasts are correct.

Three major problems which are listed in several of the "transformational" forecasts in Chapter III are 1) the collapse of hierarchical authority,[282] 2) the emergence of severe schisms in our present system of representative democracy,[283] and 3) the increasing dysfunctionality of the "technological imperative."[284] Each of these problems is closely connected with expertise and chronological elitism. For example, hierarchical systems of authority tend to have a high proportion of older people at the top, a high proportion of younger at the bottom. Promotions often are given as much on the basis of years of service as on merit. The specialist becomes very important in hierarchical structures because each decision-maker tends to accumulate his own staff of different experts beneath him who can give him the "right answers."

As hierarchical systems of authority become less and less functional, as "noetic" authority[285] and similar collegial, knowledge-based systems come into use, education's orientation towards chronological elitism and early specialization will become a handicap to students. In these new systems of authority, a person's age will be less important, and a premium will be placed on individuals who can work well in a group composed of persons of widely differing ages.

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[282]Theobald, America II, pg. 71.

[283]Platt, "What We Must Do," pg. 1117.

[284]Harman, Alternative Futures, pg. 25.

[285]James D. Carroll, "Noetic Authority," Public Administration Review (Sept.-Oct., 1969), pp. 492-500.

Specialization and expertise will be less valuable than the ability to evolve solutions by group interaction, to synthesize new ideas using knowledge from a variety of different fields. This is not to say that the expert will have no place, but expertise per se will be de-emphasized and will assume a subsidiary position to more synergetic skills.

Similarly, the emergence of severe schisms in our present system of representative democracy will result in chronological elitism and early disciplinary specialization becoming much less viable. The young, the poor, and minority groups all feel unrepresented in our present system of government; pressures by these groups for political reform may well cause major structural changes in our governmental processes in the next ten years. Certain to be included in these changes are 1) more youthful representation in the legislative, judicial, and possibly even executive branches of government; and 2) greater governmental reliance on the advice of representative community leaders rather than on academic "experts" in economics, integration, or domestic management. Education utilizing age-based divisions and encouraging early disciplinary specialization will not prepare students for the challenges of living in such a society.

The increasing dysfunctionality of the "technological imperative" provides another reason why these elitist practices in education are no longer viable. As long as every possible technology continues to be developed if it promises to show an economic profit, our society will need hordes of technological experts and will find it desirable to segment the advertising public into the old (Geritol), the middle-aged (Sears), young adults (psychedelia), and children (Frankenberry). As our country's natural resources begin to dwindle, however, America's emphasis on constant economic growth as a means of guaranteeing prosperity will be forced to change. As this occurs, our society's need for technological experts and for massive agglomeration of the public into peer groups will decrease, and early specialization and chronological elitism in education will serve no useful purpose. Overall, John Dewey's emphasis on the popularization of public education seems well justified.[286]

The more formal education moves away from separating students by age, the more that early specialization in a discipline is discouraged, the better prepared this country will be to face its probable futures. A democracy can only survive if it is composed of citizens with sufficiently recent knowledge to make decisions based upon the present rather than the past.

Alternatives to Elitism in Secondary Science Education

Individualization Without Expectations

One alternative to intellectual and chronological elitism is to make no distinctions at all between persons.

[286]Cremin, Genius of American Education, pp. 49-57.

Education would be designed for a "composite" individual; and young and old, wise and foolish would have to fit within this mold. This alternative does not seem feasible for three reasons: first, education needs to convey to students that the human race is composed of a variety of different individuals rather than a single stereotype. Second, educational research has clearly shown that students learn more quickly when the material they are presented is individualized to fit their needs.[287] Third, the history of civilization indicates that human beings have always tended to error on the side of perceiving a great many differences between themselves and others rather than on the side of perceiving very few. So any educational system built around a refusal to acknowledge differences probably would not work.

An alternative which seems much more feasible is to individualize education without building in biased expectations. While difficult to implement, this alternative has the advantage of eliminating many of the weaknesses of elitism while retaining the capacity to treat each student according to his personal needs. Some of the primary areas in which educational expectations would have to be changed are time-use, purposiveness, and deportment. That is, educators would have to stop assuming:

1) that a student who learns quickly is more able than a student who learns slowly,

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[287] Silberman, <u>Crisis</u>, pp. 217-218.

2) that a student who has a firm career in mind is more likely to succeed in life than a student who has diverse and unformulated interests, and

3) that a student's race, willingness to obey the teacher, scholarly vocabulary, etc. correlate with his ability.

Of course, this is not to imply that educators should have no expectations for students, no goals for the curriculum. One of the primary functions of formal education in our culture is socialization; students must gain a sense of what behavioral expectations they will encounter within our society, what skills they will need to earn a living. However, the picture of themselves and society that students presently receive from formal education is biased by all the forms of elitism discussed earlier; these biases must be removed so that students can gain a true picture of the world they will be living in for the next fifty years.

The educational expectations which presently link time and ability must be abandoned.[288] Achievement and IQ tests, quizzes, and other instruments which purport to measure ability also measure the speed with which a student can answer questions. The faster the student can give the right answer, the more able the student is assumed to be--even though after a student graduates he may never operate under

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[288]For a good discussion of this point, see Patricia Dede, "Patterns of Child-Directed Time-Use in the Open Elementary Classroom" (unpublished thesis proposal, University of Massachusetts, 1972).

similar constraints. Instead of assuming that students who work slowly are "less gifted," educators could convey to students a more realistic expectation of what skills our society expects of its citizens.

This point about the interrelationship of time and ability also holds for many other implicit expectations built into achievement tests, IQ tests, and similar ways of classifying students. As discussed in Chapter IV, these testing instruments do not adequately reflect the richness and complexity of the challenges students will face in the next fifty years. By expanding our techniques for measuring students' progress to a much wider range of skills, a much broader variety of instruments, the narrow expectations educators now have for what constitutes "ability" can become less biased.

The ultimate goal of these changes would be to bring about an attitude in education that a student's "progress" does not reflect his "ability." Student "progress" can be defined in terms of mastery of behavioral objectives, although care must be taken to ensure that this does not become a process of mass production, of "grinding out" skill upon skill. Progress, when defined in this way, becomes a method of recording a student's accomplishments over time--but a much longer time period is involved than in a test, and hence the premiums educators now put on problem-solving speed is greatly diminished.

By classifying students according to their "progress" in a subject rather than their "ability," educators can individualize their treatment of each student without biasing this treatment by inculcating the student with faulty notions of his "giftedness." This will not be easy: instruments for measuring progress in secondary science would have to be carefully designed to avoid the forms of elitism described earlier, and educators would have to be carefully indoctrinated to divorce a student's accomplishments on these instruments from judgments about his ability. However, the positive impact on student self-esteem and the reduction of educational elitism that would occur from this shift seem well worth the effort involved in the transition.

Present educational conceptions of guidance and the use in schools of "special" courses and tracking systems must also change if instruction is to be individualized without bias. As long as a student with firm career goals is treated as more "gifted" than a student who wants to be a "Jack-of-all-trades-and-master-of-none," students will be discouraged from developing a broad cognitive base. Now that any student who wishes to enter a profession must complete at least a bachelor's degree to be properly certified, a student can wait to make a career choice until the end of his freshman year in college without incurring any disadvantage.

Special courses for "science-oriented" students and special tracks for "gifted" and "disadvantaged" students would not exist in this individualized system. To satisfy his need for additional learning in science, a "science-oriented" student could take extra courses and could help the instructor teach the "basic" science course. The instructors of such a student would certainly encourage him to continue work in the sciences--the purpose of individualization without elitism is not to pull each person's self-image down to some "average," but to encourage each person to his utmost as an individual with unique abilities.

A student whose progress was slower than that of his peers would not be put in "special" courses (which tend to make such students feel "dumb"). If a student fell far behind or felt intimidated, he might take an additional course designed to help him catch up enough to master the rudimentary knowledge needed by every citizen before he graduated. Under no circumstances would this student be taught "less challenging" material, or made to feel less "gifted."

To complete the process of eliminating elitism, instructional materials must be designed which are not sexually, racially, or culturally biased. Naturally, it is desirable for those students who wish to become scientists to master the sort of written style required by technical journals. There is no reason, however, why most students should have to step outside their cultural orientation to develop a scholarly vocabulary or a great deal of written proficiency in styles peculiar to the sciences. Along the same lines, the instructor may have definite biases about his students' hair style, dress, or willingness to obey his instructions; but these opinions should not prejudice his assessments of their abilities or his willingness to consider them as potential future professionals. The combined system of "credit/no credit" and "contract" grading discussed in Chapter IV would be one possible system which could be used for recording students' progress without bias.

Overall, this system of individualization would be difficult to implement, but it does have many advantages over the biased elitism which is presently part of secondary science education. By abandoning an emphasis on speed as a measure of ability, by not forcing students into early specialization, the science curriculum can give students a more realistic picture of the expectations society has for them. By grouping students with their peers rather than using tracking systems, by measuring students' progress rather than their abilities, secondary science education can encourage all students to make the most of their potential.

Education as the Center of Societal Interaction

Thomas Green has argued that formal education is expected to perform at least five major societal functions:

1) training people for occupations, 2) screening people for occupations, 3) screening people for further schooling, 4) training for social roles other than occupations, and 5) training for the preservation of the status quo.[289,290] In the past, public education has attempted to discharge all five of these functions by working only with the young, segregating these students into age-based groups, and isolating these groups away from the community in schools. One alternative to this process is the concept of a "deschooled" society (different variations have been described by Ivan Illich,[291] Dwight Allen,[292] and others).

The central change involved in "deschooling" is the movement of formal education from its present position outside of society to the center of societal interaction. Whether schools physically cease to exist is unimportant--but schools must be reoriented so that they no longer serve as a retreat from the "real world." By mixing persons of

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289 Thomas Green, "Some Social Functions of the Public School System," (Syracuse, N.Y.: Educational Policy Research Center, 1967 [mimeo]).

290 For a further discussion of this point, see C. Dede and K. Hoagland, "Alternative Futures in which Formal Education Plays A Major Role In Cultural Change," (Preconference Volume of the Cultural Futuristics Symposium of the American Anthropological Association, Minneapolis, Minn.: University of Minnesota, 1972).

291 Ivan Illich, DeSchooling Society (New York, N.Y.: Harper and Row, 1970).

292 Dwight Allen, "The Future of Education," Education and the Future (New York, N.Y.: Goodyear Publishing Co., 1972).

different ages, by allowing students to study directly the problems they must face as citizens, "deschooled" education can transcend the dysfunctions of chronological elitism through becoming a platform for testing out differing viewpoints about what future our society should create for itself.

In the past, science education has been confined to the school for good reasons. It is not realistic to expect that working scientists would have either the time or the willingness to admit secondary students to their laboratories to work as apprentices, nor would working scientists necessarily be very good instructors for secondary level students. For the non-disciplinary aspects of science education, however, moving secondary science instruction outside of the school becomes not only possible, but highly desirable. The examples in Chapters III and IV of the future-oriented scientific skills citizens will need clearly illustrate that many of the interactions of science and society can best be understood by first hand observation and participation. What better way is there to understand the difficulties of attempting to reduce pollution, for example, than to experience, via a "field trip" project, the frustrations of attempting to design advanced technology capable of cutting back pollutants and yet viable economically?

The increased student participation in societal affairs generated by defocusing education spatially is an important aspect of orienting secondary science education toward the future, but a more important priority is making secondary science education part of the experience of people of all ages. This might be accomplished by creating three types of formal secondary level science education:

Type A: young persons (ages fourteen to eighteen) would be given secondary science courses focusing both on the disciplinary aspects of science and on the long-term (forty years) future-oriented aspects of science and technology

Type B: all persons within the society would be encouraged to participate in semi-formal group experiences oriented around the short-term (ten years) future-oriented aspects of science and technology

Type C: a small group would act to diffuse information through the media about the impacts of science and technology on the future of our society

Type A science education has already been described at length in the last three chapters. Type B science education is one alternative way of getting past the problem of having to orient science education towards all the futures probable forty years from now. Citizens of all ages can meet, be presented with some science-based issues that seem likely to be of major importance in the next ten years, and discuss their beliefs about these issues. For example, a group of twenty people of all ages might meet three times (one evening a week for three weeks) to discuss the issue of biological manipulation of human beings. The coordinator might invite as speakers one researcher in the area plus someone opposed to this research to set up a dialectic. If such groups were viewed as an educational mechanism of major national importance, the federal government could take the initiative (through moral suasion, tax credits, and so on) in encouraging citizens to attend these meetings.

Type C education would be designed to reach citizens who would not attend group meetings. A fairly small staff of scientists, technologists, educators, media specialists, and futurists could have a major impact on the amount of science-based, future-oriented information contained in network television, radio programs, newspapers, etc. This group would not only produce "specials" and "documentaries" (which reach only one type of audience), but also--for example--would help write an occasional episode of "All in the Family," "The Mary Tyler Moore Show," "Night Gallery," and so on. By utilizing these shows as an educational vehicle, audiences could be reached who would not dream of watching an adult "Sesame Street" exposition on science, society, and the future. A more detailed description of how a "deschooled" society might work is contained in an article by Dwight Allen entitled "Education and the Future."[293] Clearly, the overall impact of implementing these three

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[293] Ibid.

types of secondary science education would be very great. Education would have a major impact on short-term decisions in our society as citizens learned about and debated the long-range implications of these decisions. Young people and older people would be more able to communicate and to work together as artificial chronological distinctions were removed. The healthier society that would result from these changes seems well worth the truly enormous effort that this major discontinuity in educational practice would involve.

CHAPTER VI

CONCLUSIONS AND CONJECTURES ABOUT THE FUTURE OF SECONDARY SCIENCE EDUCATION

The Strengths and Weaknesses of Current Directions in Secondary Science Education

The first generation reforms have provided the central themes around which current curriculum development in secondary science education is based. The focus on disciplinary concepts and discovery learning that characterized these reforms has been modified somewhat in the second generation materials towards the needs of the learner, but much of the contents of the latest curricula in secondary science are predicated on similar assumptions to those made by PSSC in 1956.

The strengths of the first generation reforms were that:

1) scholars in the scientific disciplines again became involved with the pre-college curriculum.
2) secondary science curricula were developed which provided alternative ways of learning the same material.
3) more attention was focused on the plight of the science teacher in the secondary schools.

4) students were challenged intellectually by the new science courses.

5) a more accurate picture of the scientific disciplines was presented than in traditional science courses.

The weaknesses of these curricula were that:

Overall Approach

1) the reformers adopted a traditional, passive approach to the science/society problems confronting America: courses were developed to be taught in schools to persons of the appropriate ages.

2) the reformers ignored the lessons in curriculum design and implementation that could have been learned from the failures of the Progressive movement in education.

3) the first generation courses were developed for only a small segment (fifteen to seventeen years old) of the population which could have benefited from science instruction at this level of difficulty.

4) the first generation reforms were designed to fit the existing organization of the school curriculum; no attempt was made to modify these arrangements to a structure more suited to the teaching of secondary science.

5) the first generation reformers created only isolated components to fit within the present cur-

riculum rather than working to produce a curriculum integrated either horizontally (with other subjects taught at the same grade level) or vertically (across grade levels).

6) the first generation courses were intellectually biased against non-white, female, and lower-class students, as well as students who did not test well or who did not wish to specialize in science at the secondary level.

7) the limitations of standardized testing and of grades were ignored by the reformers.

Content

1) the first generation reforms were so oriented toward single disciplines as to omit significant interdisciplinary and transdisciplinary problems.

2) the first generation reforms paid no attention to developing curricula designed to prepare young people for their future roles in shaping and responding to society's future needs.

3) the interactions of science and technology, science and society were omitted from these courses.

4) no specific educational objectives for student performance were given in the first generation courses.

Implementation

1) the reforms did not pay sufficient attention to

the difficulties involved in training teachers to use the reform courses properly.

2) the reform courses were too difficult and too oriented to the future scientist for the majority of secondary students.

3) little room for teacher and pupil spontaneity was left in the comprehensive materials packages utilized by the reforms.

4) school districts were given no guidelines to use in choosing among the different secondary reform courses.

The second generation reforms have retained all of the strengths of the first generation curricula while making progress on some of their weaknesses. All of the second generation courses have been designed to appeal more to the "average" student and the non-science student than the first generation courses (although these reforms are still heavily biased along certain lines, as described in Chapter V.) The proposed ACS reforms take a more innovative, active approach to the science/society problems confronting America than earlier curricula; the target population of the ACS reforms includes many other groups besides high school students, and alternative vehicles besides courses are to be used by these reforms in communicating knowledge about science to this target population.

The ECCP course is the first modern secondary course to be based on technology rather than on one of the scientific disciplines; and all of the second generation courses include some material on science, technology, and society. Educational objectives for student performance have been specified in all of the second generation materials. More care has been taken by the later reformers to build in flexibility and to ensure that teachers and administrators will be interested in implementing these new curricula. As discussed earlier, however, many of the weaknesses of the first generation courses remain as major problems in current curriculum development in secondary science education.

An Alternative Conception of Secondary Science Education

The intent of this thesis has been to suggest new assumptions to replace those which have been the cornerstones of recent reforms without discarding the contributions to science education that these reforms have made. The process envisioned is similar to that described in Thomas Kuhn's *The Structure of Scientific Revolutions*, which delineates the manner in which radically new scientific perspectives emerge from and build upon existing theories, yet change the fundamental ways in which science approaches reality.

In brief, the changes which have been suggested are:

1) So that the secondary science curriculum can prepare students for their future roles in shaping and responding to society's future needs,

a future-oriented analysis should be made of what skills secondary science education should attempt to convey. A rudimentary version of such an analysis has been delineated in Chapter III.

2) Once these future-oriented skills have been derived, a vehicle sufficient for teaching both future-oriented skills and discipline-based skills must be found. This vehicle must have the following characteristics:

   a) it must be capable of including non-disciplinary knowledge,

   b) it must include some conceptual framework which the average secondary student can use to integrate disciplinary and non-disciplinary knowledge,

   c) it cannot be predicated on the assumption that the disciplines are man's highest accomplishment and his sole intellectual resource, and

   d) it must be viable beyond the traditional constraints and assumptions of the school.

3) This vehicle can then be used as an "empty form" for creating new secondary science curricula. These new curricula would be of three types:

   a) young persons (ages fourteen to eighteen) would be given secondary science courses focusing both on the disciplinary aspects of science and on the long-term (forty years) future-oriented aspects of science and technology.

b) all persons within the society would be encouraged to participate in semi-formal group experiences oriented around the short-term (ten years) future-oriented aspects of science and technology.

c) a small group would act to diffuse information through the media about the impacts of science and technology on the future of our society.

4) The history of curriculum design and implementation would be carefully studied before creating these three types of curricula so that past mistakes can serve as examples of what not to do.

5) Taking into account the obstacles to easy implementation raised by designing these new curricula around new organizational structures for the school curriculum, alternative organizational structures within which these new curricula could be taught would be considered. Some compromise would be evolved that would consider which structures are best suited for teaching science, which best suited to the needs of the learner, and which best suited to the present structures of the school.

6) All of these new secondary science curricula would be designed to be integrated both horizontally and vertically within the total school curriculum. That is, specialists in fields other than the sciences would be consulted to help in creating curricula which incorporate materials relevant to science/society issues from these other fields and to aid in ensuring that the science curriculum and other curricula at the same grade level form an integrated whole. At the same time, all three types of curricula at all grade levels would be designed to be an integrated progression of knowledge.

7) The materials of these new secondary science curricula would be created so that students can learn about science and technology according to their individual needs without being subjected to biased expectations of their ability. Achievement tests, IQ tests, and similar instruments which purport to measure ability would be de-emphasized in favor of a broader variety of instruments which measure a wider range of skills and which reflect more adequately the richness and complexity of the challenges students will face in the next fifty years. Students' progress would be recorded rather than their ability; students who work slowly

or who have vague career goals would not be treated as less "gifted" than other persons. The use of tracking systems with different basic courses for each track would be discontinued. All materials would be designed to combat sexual, racial, and social class biases.

8) Present systems of standardized testing and grading would be replaced in these new curricula by evaluation based on the combination of "credit/ no credit" and "contract" grading discussed in Chapter IV. Emphasis would be placed on developing those student skills which cannot easily be measured as well as on developing those skills which can.

As new secondary science curricula which include these changes are designed, one major constraint must be kept in mind: the difficulties inherent in implementing discontinuities in educational practices in the schools. Since these difficulties should not dictate the fundamental goals of a curriculum, the changes outlined above are valid even though derived without considering problems of implementation to any great extent. However, as more concrete and specific formulations of the ideas above are evolved, the sources of resistance to change in the scientific professions and in the schools must be carefully considered. The specific forms that new curricula take may well be largely determined--

at least initially--by considerations of what will be accepted.[294]

The statements above are especially true for those of the changes which alter the "culture" of the school (as defined by Sarason).[295] A new set of materials, a focus on the future rather than on the disciplines, a set of curricula integrated both horizontally and vertically will be accepted in the schools far more easily than a de-emphasis of chronological elitism, of testing and grading, of sexual bias. The former changes primarily affect content--and while teachers and administrators may not relish such alterations, they can be implemented far more easily than the revisions in process that the latter changes will require. Implementation strategies will have to be designed very carefully for process-oriented changes so that more than just another set of content-based changes is instituted in the secondary science curriculum.

This thesis has demonstrated that--in theory--the secondary science curricula now being used are inadequate.

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[294]Some of the best references in this area are: Seymour B. Sarason, The Culture of the School and the Problem of Change (Boston, Mass.: Allyn and Bacon, Inc., 1971). Ronald G. Havelock, Planning for Innovation (Ann Arbor, Mich.: Institute for Social Research, 1971). Arthur W. Eve, Variables of Institutional Change at the Elementary and Secondary School Levels (Amherst, Mass.: University of Massachusetts, 1971). Ronald G. Havelock, A Guide to Innovation in Education (Ann Arbor, Mich.: Institute for Social Research, 1972).

[295]Sarason, Culture of the School, pp. 15-28.

Any curriculum can be shown to have weaknesses, however; the challenge that remains is to develop an alternative curriculum which is so much better than the present curriculum that a transition to the alternative seems justified. The first step in developing this alternative has taken place with the proposed changes listed above.

The next steps are to produce a draft of each of the three new types of secondary science curricula and to demonstrate that these new curricula can be implemented as part of American education. A moderate grant would fund a feasibility study of this sort; after such a study, the determination of whether to start a national project to develop and implement final versions of these alternative curricula could be made. Hopefully, this thesis has convinced the reader that, given the weaknesses of the present curriculum and the alternatives available, such a feasibility study would be extremely worthwhile.

Probable Futures for Secondary Science Education in the Next Ten Years

No future-oriented exposition can be complete without some attempt to assess the probably futures of the area being discussed. The major variables which affect the dynamics of the secondary science curriculum are (in no particular ranking):

1) the science education budget of the National Science Foundation (NSF)
2) the federal government's budget for pure research
3) the level of funding available to the public schools
4) the type and intensity of criticism formal education is receiving from the public
5) the type and intensity of criticism science and technology are receiving from the public
6) the policies of the officials of NSF in charge of educational funding
7) the policies of the education officers of the scientific professional societies
8) the attitudes of science teachers in the secondary schools
9) the attitudes of students in the secondary schools

The secondary schools are more likely to implement an alternative curriculum such as that discussed in this chapter when:

- the NSF science education budget is high
- the federal government's budget for pure research is low[296]

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[296] The lack of funding for science in recent years has prompted far more self-searching by scientists than occurred when federal funding for science was high.

- the level of funding available to the public schools is low[297]
- public criticism of education centers on the obsolescence of current practices and on fiscal shortages
- public criticism of science and technology centers on malfunctions in science/societal interactions
- the officials in NSF allow large budgets for science curriculum development projects[298]
- the education officers of the scientific professional societies are willing to give major roles in science curriculum development to members of other professional societies and to professional educators
- science teachers are dissatisfied with students' responses to the present science curriculum

The secondary schools are less likely to implement an alternative science curriculum such as that described in this chapter when the opposites of these statements are true.

In the next ten years, some of the major events likely to have a high impact on these eight variables are:

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[297] Fiscal shortages tend to cause the public schools to be more willing to consider innovations (especially inexpensive innovations).

[298] For Fiscal Year 1972, the estimated federal expenditure on development of alternative elementary and secondary science materials is only 3.8 million dollars (out of an NSF science education support budget of 99.3 million dollars). c.f. Anna Harrison, "Science Education and the National Science Foundation Budget FY 1973," (unpublished paper distributed at the American Chemical Society Conference, April 4-10, 1972: Boston, Mass.).

1) which political party wins the Presidential elections
2) which political party (if any) controls Congress
3) the "cold war" with Russia and China
4) public reaction to the biomedical control of human potential that science will probably attain within this period
5) the success of higher anti-pollution standards in stabilizing the ecology
6) the resolution of the Serrano decision[299]

The alternative curricula discussed earlier are most likely to come into existence during a period in which the President of the United States is a Democrat and the Democratic Party controls both Houses of Congress (the level of educational funding will tend to be higher). An entente in relations with Russia and China would decrease the prospects of this alternative science curriculum (fears about national defense strengthen the status of discipline-based courses such as PSSC). A fearful public reaction to biomedical advances or the failure of higher anti-pollution standards to stabilize the ecology would aid the chances of a new curriculum. Should the Serrano decision be affirmed, the shifts in educational funding that this would cause would also tend to increase the prospects of a new science curriculum (because

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[299] The Serrano vs. Priest decision in California established that present systems of school finance via property taxes unconstitutionally discriminated against certain districts.

of resultant lower funding levels for suburban schools). Overall, to the extent that America moves towards the domestic problems predicted in transformational futures (such as Theobald's Platt's, and Meadow's forecasts) while remaining relatively stable internationally, an alternative secondary science curriculum will become more likely.

A Meta-Perspective: The Nature of All Reforms

Near the end of each novel by Vladimir Nabokov (Lolita, Pale Fire, Ada, etc.), the stylistic haze lifts and for an instant the author is dimly seen behind his characters... creator, controller. Similarly, after countless sentences resolutely cast to omit the first person singular, in this the final section of the final chapter, I will step forward and converse in a more colloquial tone.

Thomas Kuhn's magnificent book The Structure of Scientific Revolutions and Norwood Hanson's complementary volume Patterns of Discovery both argue that each scientific theory is truthful only in the relative context of the perceptions of reality which provide its base. The phlogiston hypothesis was as scientific and as based on concrete experimental evidence in its day as our hypotheses of oxidation are now. Einstein's space-time continuum is closer to Aristotle's conceptions of the universe than to Newton's. Science does progress to make better and better predictions of natural phenomena, but the theories which underlie these predictions do not converge to ultimate truth.

Similarly, each conception of education is valid only within the relative context of the society it serves. Each successive reform in education hopefully results in better and better service to the clientele of education, but the assumptions which underlie these reforms will never converge to the ideal. The educational ideas in this thesis provide a better way to approach our society's needs than what we are doing now, but after twenty to forty years this set of reforms may also become obsolete and may require a new approach.

Even though any set of reforms can only be a transient solution to the problems of education, each successive set of reforms must be implemented in an act of affirmation and faith. Kuhn's book argues that a "scientific revolution" (the acceptance of a new paradigm which invalidates the established paradigm) ultimately requires an act of faith on the part of the scientific community. Each scientist must individually decide on the basis of his values about the nature of science whether the new view of reality is "better" than the old. In education also, acceptance of a particular reform is an act of faith; individuals must personally decide whether present educational practices seem inadequate and which theoretical formulation seems to offer the best ideas to implement. Within the limitations of the required style for dissertations, I have tried to write in a way which conveys my personal belief in the ideas presented here; I hope that this thesis will serve as an adequate vehicle for communicating this faith.

WE MUST CHANGE SECONDARY SCIENCE EDUCATION DRASTICALLY.

WE MUST CHANGE IT NOW.

APPENDIX A

Obviously, for reasons of space these forecasts must be greatly condensed, and inevitably some misinterpretation of the complexities of the originals may occur. Therefore, these brief descriptions should not be construed as a valid representation of the ideas of these futurists, but as a set of basic alternative primary forecasts derived from more sophisticated sources. Any minor losses of accuracy should not greatly affect the validity of this analysis.

A) the "surprise-free" projections for America from The Year 2000

The central assumption underlying these "surprise-free" projections for America is that there is a "Basic, Long-Term, Multifold Trend" towards:

1. Increasingly Sensate (empirical, this-worldly, secular, humanistic, pragmatic, utilitarian, contractual, epicurean or hedonistic, and the like) cultures
2. Bourgeois, bureaucratic, 'meritocratic,' democratic (and nationalistic?) elites
3. Accumulation of scientific and technological knowledge
4. Institutionalization of change, especially research, development, innovation, and diffusion
5. World-wide industrialization and modernization

6. Increasing affluence and (recently) leisure
7. Population growth
8. Urbanization and (soon) the growth of megalopolises
9. Decreasing importance of primary and (recently) secondary occupations
10. Literacy and education
11. Increasing capability for mass destruction
12. Increasing tempo of change
13. Increasing universality of the multifold trend [300]

By extending this trend for the next thirty to fifty years and by assuming no discontinuities, Kahn and Wiener describe a "surprise-free" world. The most important points of this forecast are:

a) the authors expect major advances in the field of nuclear power; the art of strategic warfare; the areas of electronics, computers, information processing, and automation; the field of holography; the work on lasers; and the biological manipulation of man.[301]

b) quantitatively, the authors project:

> World population in the twenty years ending in 2020 is assumed to grow about as fast as in 1965-2000, to reach 9.0 billion. One-half will live in Asia; only one-fifth will live in Europe and North America as compared with the present three-tenths. In the same period, Gross World Product will rise five percent per year. The share of Asia will reach one-fourth of the total as compared with the present one-eighth share, largely because of the 7.5 percent GNP growth rate assumed for Japan.
>
> Per capita world output will nearly double in the twenty years ending in 2020, reaching

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[300] Kahn and Wiener, Year 2000, pg. 7.

[301] *Ibid.*, pg. 66.

then about five times the world 1965 figure. Japan leads with $33 thousand (compared with only $3.6 thousand for the United States in 1965). The United States and West Germany follow with $19 and $18 thousand, respectively. As in the year 2000, the Soviet Union, with $9.7 thousand, trails the major developed countries.

Presumably, an even greater range of uncertainty pervade the long-term projections for the last two major, but less-developed countries, Mainland China and India. The area of per capita GNP possibilities is so broad, particularly in the area of China, that specific projections become unusually arbitrary. At best...China would exceed only the Soviet Union and that only if the Soviet Union performs at its low growth rate. 302

United States population was projected at 421 million persons in 2020 with the labor force at 179 million; hours worked per year per employed person were assumed to be 1370. GNP was judged to fall between $4.0 and $8.9 trillion, contingent upon the same alternative rates of annual increase in GNP per man-hour as were used for the period 1965-2000. Growth rates of GNP for 2020 versus 1965 are, respectively, 3.3 percent and 4.8 percent.

Personal consumption expenditures would range from $2.7 to $5.7 trillion, in comparison with $432 billion in 1965. Per capita personal consumption is projected to be from $6400 to $13600 in 2020, versus $2220 in 1965. Thus, the United States standard of living would rise to between three and six times its 1965 level, and this increase would be accompanied by an increase in leisure time....By 2000, twenty-seven percent of all consumer units will attain incomes of $25000 or over before income taxes; by 2020 this will amount to about fifty-eight percent. 303

c) the authors picture America as a "post-industrial society having the following characteristics:

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[302] _Ibid._, pp. 140-141.

[303] _Ibid._, pg. 184.

1. Per capita income about fifty times the preindustrial
2. Most "economic" activities are tertiary and quaternary (service-oriented) rather than primary or secondary (production-oriented)
3. Business firms no longer the major source of innovation
4. There may be more "consentives" (vs. "marketives")
5. Effective floor on income and welfare
6. "Efficiency" no longer primary
7. Market plays a reduced role compared to public sector and "social accounts"
8. Widespread "cybernation"
9. "Small world"
10. Typical "doubling time" between three and thirty years
11. Learning society
12. Rapid improvement in educational institutions and techniques
13. Erosion (in middle class) of work-oriented, achievement-oriented, advancement-oriented values
14. Erosion of "national interest" values?
15. Sensate, secular, humanist, perhaps self-indulgent criteria become central [304]

d) the authors project that the international scene is dominated by co-existence, but that detente still exists between the United States and the Soviet Union.

Kahn and Wiener also describe three categories of "Canonical Variations" of this "surprise-free" world:

1) More "Integrated" Worlds are "relatively peaceful, relatively prosperous, relatively arms-controlled with a high degree of cooperation among nations..."

2) More "Inward-Looking Worlds are "almost as

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[304] Ibid., pg. 186.

peaceful and prosperous, but with little arms-control or general coordination"

3) Greater "Disarray" Worlds are "relatively troubled and violent worlds, but ones in which no large central wars have occurred." [305]

"Inward-Looking" and "Disarray" Worlds are seen as likely if the Communist movement declines, the democratic movement (United States) declines, or if Europe or Japan become exceptionally dynamic powers. For example, the authors see the decline of the democratic movement coupled with the collapse of NATO as causing a "Disarray" World, whereas the decline of the democratic movement without such events as a collapse of NATO might result in an "Inward-Looking" World.

This primary forecast with its Canonical Variations results in a United States very much like that desired in the normative forecast. The standard of living in the United States is three to six times as high as in 1965; leisure time has increased; "service-oriented" activities predominate; the society is quite democratic and "sensate;" and the United States occupies a relatively secure position politically, militarily, and economically. The primary technique that this forecast is based

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[305] Ibid., pg. 9.

upon is trend extrapolation.

* B) the forecast for the world from The Next Ninety Years

The Next Ninety Years, published in 1967, represents the first revision of a forecast published ten years earlier by the same authors entitled The Next Hundred Years. In this earlier forecast, Brown, Bonner, and Weir projected a future world much like that envisioned in The Year 2000; the one major problem which they feared might disrupt this favorable future was a severe shortage of technical manpower. In the ten years intervening between their two forecasts, the authors revised their projections considerably; the major changes in world trends which prompted this revision were:

a) the rate of world population growth increased much more than expected--so much so that the authors state: "we are now experiencing rates of population growth which greatly exceed those which were imagined by even the gloomiest pessimist ten years ago;"
b) the costs of nuclear power decreased much more swiftly than anticipated;
c) agricultural production in the "underdeveloped" countries increased far less rapidly than

hoped; and

d) economic development in Latin America, Asia, and Africa took place much more slowly than projected.[306]

As a result of these major changes in world trends, The Next Ninety Years projects a much more gloomy world future than did The Next Hundred Years (or The Year 2000). Six major problems blocking the occurrence of a favorable world future are forecast:

1) World population may be much too large--between fifteen and twenty-five billion in the year 2057. United States population may be between six and seven hundred million at this time.[307]

2) The economic gap between "developed" countries (such as the United States) and "underdeveloped" countries (such as India) may widen to the point of doubling every twenty-two years.[308]

3) If this economic gap is somehow closed and all seven and one half billion people in the year 2000 live at the United States present standard of living, the earth's high grade mineral resources may be almost exhausted by

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[306] Industrial Associates, Next Ninety Years, pp. 5-6.

[307] Ibid., pp. 8-9.

[308] Ibid., pg. 12.

this affluence (although the authors do forecast that, with a sufficiently high level of technology, up to ten billion persons could be supported indefinitely at this standard of living using the world's total resources).[309]

4) By 1980, if present policies continue, two permanent world cultures may exist: the permanently rich and the permanently poor. By 2057, massive starvation and perhaps extermination of the world's poor may occur.[310]

5) By 2057, only one-half of the United States needs (let alone the world's needs) for trained technical manpower may be filled.[311]

6) In the next ninety years, environmental overload in the United States may cause severe problems of fresh water depletion, waste disposal, and disposal of the excess heat of urban populations.[312]

Given these problems, the authors' primary forecast for the world in 2057 differs from that in The Year 2000 in that:

- world population will be massive, and possibly

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[309]Ibid., pg. 17.

[310]Ibid., pg. 40.

[311]Ibid., pg. 56.

[312]Ibid., pp. 108-110.

still growing; and

- a large permanent disparity between a few "developed" countries and many "underdeveloped" countries in food and income per capita will cause political destabilization, massive starvation, and possible extermination of the "have-nots" by the "haves."

The authors project an America very different from the normative forecast:

- the population will be quite large,
- the position of the United States (and all the "developed" countries) in the world community will be very insecure, and
- the standard of living in America will be disrupted by severe environmental problems and a lack of trained technical manpower.

This primary forecast, like that from The Year 2000, is based primarily on trend extrapolation.

C) the projections for the world from the World 3 Model of the Systems Dynamics Group at MIT

The World 3 Model is a computer simulation based on a complex, highly interrelated set of assumptions about the dynamics of world civilization. Given the present levels of about thirty different variables, the simulation yields predicted future world levels of eight major variables (population, industrial output per capita, food per capita, pollution, nonrenewable resources, crude birth rate, and services per capita).[313] Typical of the assumptions underlying this model are the following:

- birth and death rates depend on population size, food, pollution, crowding, and the material standard of living
- capital generation and the nonrenewable resources usage rate depend on population and the material standard of living
- the rate of pollution generation depends on the level of pollution already present and on the rate of capital investment
- the fraction of capital devoted to agriculture depends on the amount of food available to each person and the total amount of capital investment.[314]

From the predicted future levels of nonrenewable resources, pollution, population, industrial output per capita, and food per capita derived from the World 3 Model, Dennis Meadows and his colleagues at MIT have forecast a set of different primary world futures, each based on slightly different initial conditions:

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313 Meadows, Limits, pg. 123.

314 Ibid., pp. 102-103.

if: nonrenewable resources such as coal, oil, and high grade metal ores continue to be depleted at present rates, and technology can find no adequate substitutes,

then:
- nonrenewable resources will fall steadily to about one-half their present level by 2020
- world population will rise to about four times its present level (2050) and then decline steadily from lack of resources to maintain an adequate standard of living
- industrial output per capita will rise to about two and one-half times its present value by 2010, and then will decline for lack of resources
- pollution will rise to about nine times present levels by 2040, and then decline

if: "unlimited" nuclear power doubles the resource reserves that can be exploited and makes possible extensive programs of recycling and substitution that cut present rates of resource depletion by three-quarters,

then:
- non-renewable resources will fall to about three-quarters of present levels by 2060

- industrial output per capita will rise to two and three-quarters times present levels by 2040, and then decline as
- pollution rises to twenty-five times present levels by 2050
- world population will grow to two and three-quarters its present level in 2040, then decline to below its present level by 2070 due to pollution

if: to forestall the previous prediction, "unlimited" nuclear power is coupled with a reduction in pollution generation per unit of output to one-quarter present values,

then:
- nonrenewable resources will fall to four-sevenths present levels by 2100
- pollution will climb to three times present levels by 2050, then fall as
- industrial output per capita rises to three and one-half times present levels by 2050, then falls as capital is diverted to food production because
- food per capita climbs to twice present levels by 2020, then falls steadily due to lack of arable land
- world population will rise to four times

present levels by 2070, then fall off rapidly due to lack of food

if: "unlimited" nuclear power, pollution controls, doubled agricultural productivity, and perfect birth control are all achieved,

then:
- nonrenewable resources will fall to one-half present levels by 2100
- food per capita will rise to over four times present levels by 2060, then will fall drastically due to erosion from land overuse
- world industrial output per capita will rise almost to present United States levels by 2050, then will decline as pollution climbs to twenty times present levels by 2050
- world population will stabilize at under twice present levels by 2020, then will fall slowly after 2080 due to pollution, lack of food[315]

This set of different primary world forecasts can be combined into a single primary world forecast:

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[315]*Ibid.*, pp. 124, 132, 136, 140.

- nonrenewable resources will fall to 50-90 percent of their present levels by 2020
- industrial output per capita will rise from two and one-half to ten times present levels between 2010 and 2050, then fall
- pollution will rise to between three and twenty-five times present levels by 2050
- world population will rise to between two and four times present levels between 2020 and 2070, then decline

This primary forecast differs considerably from the normative forecast in two ways:

- lack of resources, pollution, or lack of food will limit America's growth and standard of living
- the world tension generated by the pressures on population this forecast indicates will create an international situation conducive to global warfare

This primary forecast is based on an explicit model for world dynamics embodied in a computer simulation.

D) the forecast for America from <u>An Alternative Future for America II</u>

The major assumption of this primary forecast is that the present socioeconomic system in the United States is based on an obsolete and dysfunctional view of the nature of man. Robert Theobald argues that as American society moves into a "post-industrial" period, a major transformation must take place as the important industries become those based upon information, rather than production or transportation. This shift implies to him that

- processes will become more important than goals
- authority by knowledge will become more functional than authority by hierarchical position
- attempts to build social institutions on a Skinnerean view of human motivation will become completely dysfunctional
- extrapolation of trends will fail as a viable means of anticipating the future

His primary forecast is that America's economic system, its system of national defense, its familial structures, its urban centers, its educational systems, and its total reliance on technology to solve societal problems will all become dangerously outmoded within the next five years. The following societal areas will become especially unstable:

- the reliance of our economy on constant growth
- the basing of our advertising system on Skinnerean psychology
- the policy of a restrictive welfare system for the poor
- the use of education as a means of certification and as a way to keep the young off the job market
- the reliance of our international policies on military deterrence
- the continuation of urbanization
- the use of the nuclear family as a child-raising device
- the delineation between work and leisure in daily life
- the de-individualization of institutions
- the reliance on deductive thinking as a problem-solving tool
- the urge of those dissatisfied to work for revolution rather than evolution

As a result, Theobald projects that American culture will become profoundly unstable with respect to its internal and external psychosocial environments. This instability will lead to extreme cultural paranoia, and within twenty years

America will deviate from the normative forecast to become a fascist police state domestically, and a dangerously defensive nuclear power internationally. The primary technique used in this forecast is an intuitive model of the impact of a "post-industrial" transformation on present societal structures.

E) the analysis of the future in "What We Must Do"

The major assumption in John Platt's projections is that technological advances in the "developed" countries in the last hundred years have created a "crisis of transformation." The technological advances of the last century which he argues have created a profoundly destabilized future are:

- increases in communication speed of ten million times
- increases in travel speed of one hundred times
- increases in data handling speed of ten thousand times
- increases in usable energy resources of one thousand times
- increases in power of weapons by one million times
- increases in disease control by one hundred times
- increases in rate of population growth by one thousand times what it was a few thousand

years ago[316]

As a result, Platt projects eight crises which will disrupt a favorable world future. These are:

In the Next Twenty Years

1) a crisis in nuclear or radiological-chemical-biological warfare that carries the risk of total annihilation

2) a crisis in the earth's ecological balance that carries the risk of great physical devastation

3) a crisis of many groups feeling inadequately represented by the present American political system that may destroy our present system of participatory democracy

4) a crisis of widespread world famine resulting in a confrontation between "have" and "have-not" countries that could precipitate world racial war

5) a crisis in the lack of effective techniques of administrative management that may cause widespread chaos, confusion, and tension

In the Next Fifty Years

1) a crisis in finding viable ways to integrate economic structures and political theories that may result in widespread social disruption

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[316]Platt, "What We Must Do," pg. 1115.

2) a crisis in reconciling population growth with world resources and world ecology that may cause great changes in existing life styles

3) a crisis in implementing universal education and communication that may bring about major world divisiveness[317]

In the light of these on-coming crises, Platt forecasts the probable end of civilization as we know it by 2020 unless most of these problems are solved. He projects a very different future for America from the normative forecast:

> In the next five years, the United States faces nuclear escalation, racial conflict, problems of severe urban poverty, some difficulties in maintaining a system of participatory democracy, and a collapse of effective techniques for administration
>
> In the next twenty years, the United States faces nuclear escalation, severe difficulties in maintaining a system of participatory democracy, disruption in its ecological balance, and increasing problems of recalcitrant poverty

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[317] Ibid., pp. 1117-1119.

> In the next fifty years, the United States faces difficulties with overpopulation, and drastic problems with reconciling its political theory with its economic structure[318]

This primary forecast is based on an intuitive model of the effects of technological advance on society.

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[318] *Ibid*., pg. 1118.

APPENDIX B

Measurement of the performance of individual students is not new: written descriptions of student competencies were compiled by teachers as early as the mid-nineteenth century, and grades began to be used in the secondary schools about a century ago. Oscillations between different grading and percentage systems for reporting student achievement have continued to the present.[319]

After World War II, a variety of specialized instruments for specifying different types of student performance appeared. In 1956 and 1964, the first two handbooks of a Taxonomy of Educational Objectives, Benjamin S. Bloom, editor, were published.[320] The first of these handbooks delineated a hierarchy of educational goals in the cognitive domain, thus:

Knowledge

1.00 Knowledge
  1.10 Knowledge of Specifics
    1.11 Knowledge of Terminology
    1.12 Knowledge of Specific Facts

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[319] For a historical discussion, see Howard Kirschenbaum, Sidney B. Simon, and Rodney W. Napier, Wad-Ja-Get?: The Grading Game in American Education (New York, N.Y.: Hart Publishing Co., 1971), pp. 50-70.

[320] Benjamin S. Bloom, ed., Taxonomy of Educational Objectives Handbook I: Cognitive Domain and Handbook II: Affective Domain (New York, N.Y.: David McKay Co., Inc., 1956, 1964).

1.20 Knowledge of Ways and Means of Dealing with Specifics
1.21 Knowledge of Conventions
1.22 Knowledge of Trends and Sequences
1.23 Knowledge of Classifications and Categories
1.24 Knowledge of Criteria
1.25 Knowledge of Methodology
1.30 Knowledge of the Universals and Abstractions in a Field
1.31 Knowledge of Principles and Generalizations
1.32 Knowledge of Theories and Structures

Intellectual Abilities and Skills

2.00 Comprehension
2.10 Translation
2.20 Interpretation
2.30 Extrapolation
3.00 Application
4.00 Analysis
4.10 Analysis of Elements
4.20 Analysis of Relationships
4.30 Analysis of Organizational Principles
5.00 Synthesis
5.10 Production of a Unique Communication
5.20 Production of a Plan, or Proposed Set of Operations
5.30 Derivation of a Set of Abstract Relations
6.00 Evaluation
6.10 Judgements in Terms of Internal Evidence
6.20 Judgements in Terms of External Criteria [321]

Bloom justified the development of knowledge as a cognitive educational goal by citing these arguments:

1) with an increase in knowledge or information there is a development of one's acquaintance with reality,

2) knowledge is basic to all the other ends and purposes of education,

3) our culture places emphasis on knowledge as an

[321] Bloom, Cognitive Taxonomy, pp. 201-207.

important characteristic of the individual, and

4) knowledge is simple to teach and simple to evaluate.[322]

The development of intellectual abilities and skills was justified on the grounds that:

1) in a changing and unpredictable culture, intellectual abilities and skills are a very important asset,

2) the ability to attack problems independently is a sign of maturity and self-sufficiency important in a democracy,

3) intellectual abilities and skills are more widely applicable than knowledge, and

4) intellectual abilities and skills are better remembered than knowledge.[323]

W. D. Hedges has compiled an excellent overview of how this cognitive taxonomy can be used in classifying science objectives.[324]

The second handbook edited by Bloom delineated a hierarchy of educational goals in the affective domain:

1.0 Receiving (Attending)
  1.1 Awareness
  1.2 Willingness to Receive
  1.3 Controlled or Selected Attention

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[322] *Ibid.*, pp. 32-34.

[323] *Ibid.*, pp. 39-42.

[324] William D. Hedges, *Testing and Evaluation for the Sciences* (Belmont, Calif.: Wadsworth Publishing Co., 1966), pp. 26-88.

2.0 Responding
  2.1 Acquiescence in Responding
  2.2 Willingness to Respond
  2.3 Satisfaction in Response
3.0 Valuing
  3.1 Acceptance of a Value
  3.2 Preference for a Value
  3.3 Commitment
4.0 Organization
  4.1 Conceptualization of a Value
  4.2 Organization of a Value System
5.0 Characterization by a Value or Value Complex
  5.1 Generalized Set
  5.2 Characterization 325

Bloom defined "affective" as emphasizing a feeling tone, an emotion, or a degree of acceptance or rejection. Examples of science objectives which would be classified as affective are:

1) The student should develop an attitude of faith in the power of reason and in the methods of experimentation and discussion.

2) The student should become interested in science.[326]

The ECCP curriculum has developed a set of sixteen such affective objectives for students in the course.[327]

These two taxonomies offer one way of hierarchically classifying different types of student performance. One alternative to these taxonomies which has been developed is exemplified by Robert Glaser's Individually Prescribed In-

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[325] Bloom, Affective Taxonomy, pp. 176-185.

[326] Ibid., pp. 7, 21-22.

[327] Engineering Concepts Curriculum Project, The Man-Made World-Teacher's Manual (New York, N.Y.: McGraw-Hill Book Co., 1972), pp. xiv-xvi.

struction (IPI) approach, which consists of two key operations:

> 1) the analysis and definition of educational objectives which are used as guidelines for setting up each student's program of study; and
> 2) the evaluation and diagnosis of student performance so that amount and kind of instruction can be adapted to his particular requirements. 328

By delineating "well-defined sequences of progressive, behaviorally defined objectives"[329] in an area of study, IPI specifies what types of student performance are important.

Behavioral objectives such as IPI uses are based around the question: "What do I want my students to be able to do after taking my course that they couldn't do before enrolling in it?" In other words, "don't ask yourself 'what will they know?' but do ask 'what will they be able to do?'"[330] A behavioral objective typically contains three elements: "terms describing the testing situation, measurable performance terms, and qualifying terms which describe the level of sophistication needed for acceptable performance."

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[328]Robert Glaser, "An Individualized System," Readings in Science Education for the Secondary School, ed. by Hans O. Anderson (New York, N.Y.: Macmillan Co., 1969), pg. 146.

[329]Silberman, Crisis in the Classroom, pg. 197.

[330]Edwin B. Kurtz, Jr., "Help Stamp Out Non-Behavioral Objectives," Science Teacher (Jan., 1965), pg. 31.

For example:

Situation:	Given a diagram of a mature, living plant cell,
Performance Term:	the student should be able to label its major structures.
Qualifying Terms:	Acceptable performance should include labeling the cell wall, chloroplast, nucleus, cell membrane, and mitochondria. 331

Behavioral objectives, then, delineate various types of student performance by specifying the student's behaviors, rather than his knowledge or thought processes.[332]

Since World War II, methods of specifying achievements by students which connote probable future scientific prowess have also been developed. Some of the dimensions of student achievement which have been subjected to multivariate analysis in the search for gifted science students are described by William Cooley in his article "National Welfare and Science Education"[333] and by Morris Parloff in his research at NIH.[334] Brandwein developed two instruments for predicting

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[331]Hans O. Anderson, "Preparing Performance Objectives," Readings in Science Education for the Secondary School, ed. by Hans O. Anderson (New York, N.Y.: Macmillan Co., 1969), pg. 156.

[332]For a good overview of the use of behavioral objectives in science education, see Smith, "Curriculum Development," pp. 400-401.

[333]Cooley, "National Welfare," pp. 41-53.

[334]Morris B. Parloff, et al., Personality Characteristics which Differentiate Creative Male Adolescents and Adults (Bethesda, Md.: National Institute of Mental Health, 1970).

potential future student success in the scientific professions.[335] One of these instruments is a Man-to-Man Rating Scale which has eleven possible ratings--the instructor assigns a rating by matching one of a set of semi-fictional descriptions of behavior to the behavior of the student in question:

For example, the highest rating on the scale corresponds to a student with approximately the following characteristics:

- Splendid attendance record (4 days total absence in high school career)
- IQ 153, reading score 16+ (9th year), arithmetic score 12+ (9th year) (Henmon-Nelson)
- Scholastic average 95.6
- Intends to take science, math, and languages all four years in high school
- Plans to attend Harvard, MIT, or Princeton
- Extracurricular activities: Engineering Club, Research Club, Social Studies Honor Society, Science Math Honor Society, Fencing, School Newspaper
- Ambition: Research Physicist
- President of general recitation classes and one club
- Hobbies: Chess, Piano, Reading, Hiking (Boy Scouts), Woodworking
- Works weekends

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[335] Paul F. Brandwein, The Gifted Student as Future Scientist (New York, N.Y.: Harcourt, Brace, and World, 1955).

- Pleasant yet hurried, never thinks of himself, cannot say no, takes on activities on own initiative, always bemoaning lack of time, refuses to pity himself for any misfortune, high ambitions for public service, high sense of responsibility and integrity, a leader in scholarship, respected by his classmates, shy, great affection for father, learning to accept himself and his environment.[336]

A middle (average) rating on the scale corresponds to a student with:

- good attendance record (4 days absence per year)
- IQ 151, Reading 16+ (9th year), Math 12+ (9th year)
- Scholastic average 89.6
- Intends to take science, math, languages four years
- Plans on Harvard, Michigan, Cornell
- Extracurricular activities: Tropical Fish Club, Research Club, School Newspaper
- Hobbies: Baseball, Basketball, Social Club, Orchestra, Tennis
- Does not work after school. Often does not do homework. (says he knows his "subjects" without doing it)
- Ambition: Dentistry, Medicine, or Science Writing
- Pleasant, loquacious, likes to pass time of day, willing to serve but has to be asked, popular with students and teachers, a great organizer of parties,

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[336] Ibid., pg. 89.

group activities (almost always takes on collection of dues, etc.), makes friends easily.[337]

The other instrument developed by Brandwein to measure potential future student success in science is an Inventory of Predisposing Factors (IPF). The student is ranked on continua which measure:

1) days absent due to colds, illness
2) number of hours per week spent in science hobby work outside of school (outside of assigned work)
3) number of projects chosen from a list of 25 (designed to illustrate width of scientific interests)
4) number of projects selected after commitment to one chosen because of interest
5) time spent in laboratory in advanced science
6) GPA in all areas through seventh term (includes 3 1/2 years science, math, English, and language)
7) nature of reading outside of school
8) amount of drive, ability to accept disappointment
9) tendency to ask questions[338]

These two instruments provide one way of specifying the types of student performance most indicative of future scientific success.

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[337] _Ibid._, pg. 90.

[338] _Ibid._, pp. 91-93.

Both with Brandwein's instruments and with many behavioral objectives approaches, direct observation by the teacher can be used to measure the student performances specified. More general categorizations of student achievement, such as Bloom's Taxonomy, have prompted the development of a host of different written tests for measuring particular types of student performance. So much literature is available on IQ tests, the CEEB (College Entrance Examination Board) examinations, Graduate Records Exams, Advanced Placement tests and the like that no effort will be made to describe each here.[339] A brief overview of the general characteristics of all written tests follows:

First, any test should reflect an accurate sample of the material the student is being tested on, weighted in direct proportion to the relative importance of different subsets of that material. The type of test questions used (essay, multiple choice, matching-type, true-false, completion-type) should depend on what type of performance is being measured, as each type of question has certain innate biases. For example, essay questions can assess higher mental processes (ability to outline and organize, ability to select important ideas and interrelate them) than objective-type questions, but the essay question is more subject to subjective evaluation and greatly restricts the number of items on which

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[339] The classic source in this area is O. Buros, Mental Measurements Yearbook (First through Seventh Editions, New Jersey: Gryphon Press, Seventh Edition 1970).

a student is tested. The multiple choice question is versatile, allows a test to cover a great many items, and is unambiguous; but construction of these questions with enough plausible alternative answers is difficult.[340]

Three important criteria for judging any test are its predictive validity, its reliability, and its relative difficulty. Predictive validity reflects whether a test measures the performances it is supposed to measure. For example, a test which asks for the recall of one hundred scientific facts may well be more valid as an indicator of a good memory than as a predictor of future scientific ability. Reliability is a measure of how consistent and stable a test is, how great the fluctuation in test scores will be on repeated examinations. Relative difficulty assesses how well a test differentiates between the students who take the test: if the test is too easy, most scores will cluster at the top and many students who are not actually equal in ability will receive perfect scores.[341] It has been suggested that the best difficulty distribution on a test is;

• items which can be passed by 85-100% of the test-taking population	15%
• items which can be passed by 50-85%	35%
• items which can be passed by 15-50%	35%
• items which can be passed by 0-15%	15%[342]

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[340]Hedges, Testing and Evaluation, pp. 89-112, 113-131.

[341]Ibid., pg. 20-23.

[342]Henry E. Garret, Testing for Teachers (New York, N.Y.: American Book Co., 1959), pp. 216-217.

Tests also are subject to cultural biases, sexual biases, and biases of the person grading the test. There are at least three types of grading bias: the "halo" effect, teacher mood, and the grading sequence. The "halo" effect reflects the fact that neatly dressed, obedient, respectful students are more likely to receive high evaluations than sloppy, disobedient, disrespectful students--even if work quality is the same. Similarly, a teacher in a good mood is likely to give higher scores than a teacher who has had a difficult day. The sequence in which tests are graded is also important--after grading a few bad tests in a row, a teacher is likely to give an average test a better than average grade.[343] The implications for secondary science courses of the predictive validities and the biases of tests such as the SAT and CEEB Achievement Tests in Science has been discussed in Chapter IV.

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[343]Hedges, Testing and Evaluation, pg. 203.

"Eliot stayed contritely sober for two days after that, then disappeared for a week. Among other things, he crashed a convention of science-fiction writers in a motel in Milford, Pennsylvania....

"'I love you sons of bitches,' Eliot said in Milford. 'You're all I read any more. You're the only ones who'll talk about the <u>really</u> terrific changes going on, the only ones crazy enough to know that life is a space voyage, and not a short one, either, but one that'll last for billions of years. You're the only ones with guts enough to <u>really</u> care about the future, who <u>really</u> notice what machines do to us, what wars do to us, what cities do to us, what big, simple ideas do to us, what tremendous misunderstandings, mistakes, accidents, and catastrophes do to us. You're the only ones zany enough to agonize over time and distances without limit, over mysteries that will never die, over the fact that we are right now determining whether the space voyage for the next billion years or so is going to be Heaven or Hell.'"

"Eliot admitted later that science-fiction writers couldn't write for sour apples, but he declared that it didn't matter. He said they were poets just the same, since they were more sensitive to important changes than anyone who was writing well. 'The hell with talented sparrow-farts who write delicately of one small piece of one mere lifetime, when the issues are galaxies, eons, and trillions of souls yet to be born.'"

From <u>God Bless You, Mr. Rosewater</u>
Kurt Vonnegut, Jr.
pp. 17-18

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