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ABSTRACT

One of a series of publications for teachers, consultants, and administrators, the guide offers recommendations for curriculum development and science instruction for gifted students in grades 7-12. Discussed in the introductory chapter is creation of a school environment that fosters skills of interdependence (Communication with other scientists) as well as independent inquiry. Chapter 2 deals with characteristics and identification of gifted secondary students, the teacher's role in stimulating scientific interest, differences between conventional and singular giftedness, and the functions of the lecture and investigative approaches. Among the topics explored in a chapter on curricular strategies are types of curricula (such as the learning activity package or LAP program), a conceptually based curriculum, and instruction in investigative arts. A final chapter focuses on independence training, designing and evaluating LAPs for the junior high curriculum, and a consortium module for senior high curricula. (LH)

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CALIFORNIA STATE DEPARTMENT OF EDUCA
Wilson Riles — Superintendent of Public Instructio

Teaching Gifted Children Science in Grades Seven Through Twelve

Prepared for the

CALIFORNIA STATE DEPARTMENT OF EDUCATION

by

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Foreword

California public schools are making great efforts to provide equal educational opportunities for all children. The schools are accomplishing this by ensuring that every child is given the opportunity to profit to the full extent of his ability. Such an accomplishment becomes possible only when the educational program of the schools is diverse and flexible enough to meet the needs of every individual.

The State Department of Education has conducted a project to develop adequate guides and other instructional materials for teaching mentally gifted students. This publication is one of a series from that project.

Teaching Gifted Children Science in Grades Seven Through Twelve contains information that may be used by consultants, administrators, teachers, and other professional personnel who are working with gifted children.

It is my hope and belief that this publication, designed especially for use in the teaching of the mentally gifted, will be most useful to teachers in their efforts to challenge mentally gifted students in science.

William Riles

Superintendent of Public Instruction

Preface

Teaching Gifted Children Science in Grades Seven Through Twelve was planned and completed as part of a project under provisions of the Elementary and Secondary Education Act, Title V. It is intended to be used as a guide by administrative and consultative personnel.

This project included the development of a series of curriculum materials under the direction of Mary N. Meeker, Associate Professor of Education, and James Magary, Associate Professor of Educational Psychology, both of the University of Southern California.

The federal funds provided by this Title V project also made possible the publication of a series of curriculum guides for use by teachers of the mentally gifted in grades one through three, four through six, seven through nine, and ten through twelve. The guides were prepared under the direction of John C. Gowan, Professor of Education, and Joyce Sonntag, Assistant Professor of Education, both of California State University, Northridge.

The Elementary and Secondary Education Act, Title V, project, "Curriculum Evaluation and Development for Mentally Gifted Minors," was conducted during the 1968-69 fiscal year.

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Chapter 1

Introduction

The gifted are in a sense originals, one and only, the mold made and broken, fulfilling their powers in the pursuit of excellence. They do what they do because they must. When at last they have learned to "stand on the shoulders of others," they may go too far in their private field of excellence so that others may go far enough—far enough in the interests of civilization. And when they have taken upon themselves the variety of the disciplines of science and its methods of intelligence as well, they are still idiosyncratic; it is their powers they must fulfill; their excellence is private.

The concern of this publication is with engineering an environment for the gifted, an environment that encourages diversity in a broad swath of excellence. To be dealt with is the special kind of "liberty and justice" the gifted require, even as they share the varieties of liberty and justice in common with all children, with all the young. The focus of study is on a kind of *liberty in learning,* that idiosyncratic behavior so characteristic of the young who may commit their gifts to science. The study also embodies that human activity known as science, to examine how it enables those with special gifts to meld these gifts with opportunity and destination. To ennoble as well as enable is the goal at hand.

Skills of Interdependence

In developing skills of interdependence, the gifted encounter the curriculum as a means of reducing random experience, without reducing opportunity for the creative act. In this process are involved the factors of instruction, instructed learning, and systematic inquiry that lead to the self-identification and continued development of the gifted. Even though individual, independent creativity is very important, there is no assumption that the gifted are apart from the legacies of science. Scientists know their dependence on and interdependence with scientists now alive and of the past. To exist, science depends on free communication with other scientists; science exists best in an environment in which individuals have the freedom to think, to innovate, to pursue their own excellence in fulfillment of their powers, and to fail intelligently in their search for the hidden likenesses in nature.

The curriculum as platform and matrix, as enhancing the group and the individual, and as a base for creativity is the concern in developing skills of interdependence. In effect, the gifted child must live a kind of apprenticeship before being cast out into the warm but demanding world of independent study, the latter (for primary children at least) under the healing eye of a teacher. To be considered are concepts and content, with the curriculum being viewed as a continuum that makes room for all varieties of excellence. And, of course, the curriculum is viewed out of particular concern with the gifted. These considerations are based on the awareness that the child, beginning in his adolescent years, has already begun to make choices in career.

Nevertheless, the gifted are not to be excluded from the common experience. For, if they are, they may not form a common bond of sympathy so necessary in an open society. The work of the gifted as an adult is supported by all; he must be understood. Further, a fundamental skill of the scholar and the scientist is his uses of interdependence.

But the skills of interdependence are only a base for the true work of the gifted: independent study. For the gifted, the junior- and senior-high-school years may well be the years for personal testing of their ability to maintain independent study and inquiry.

Skills of Independence

In the curricular model to be presented is developed particularly the case of the idiosyncratic child. Dealt with are the fulfillment of fantasy and the encouragement of the probe and the quest.[1] A variety of methods and techniques is designed to create an environment in which the gifted fulfill themselves coming out of the special seeking (concept seeking), which is the art of investigation. Science is a verb masquerading as a noun; it is an active verb, "to science." Gifted children often have individual life-styles in "sciencing."

Over the years of science education in the public schools, the curriculum model seeks to engineer for the gifted a curricular device that will give relative emphasis to interdependence in its meshing with independence (Figure 1).

The curricula for the four grade areas (grades one through three, four through six, seven through eight, and nine through twelve) together offer suggestions for engineering an interlocking and sequential program for the gifted. Taken alone, each curriculum does

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[1]Paul F. Brandwein, *The Gifted Student as Future Scientist: The High School Student and His Commitment to Science.* New York: Harcourt Brace Jovanovich, Inc., 1955, pp. 10-11.

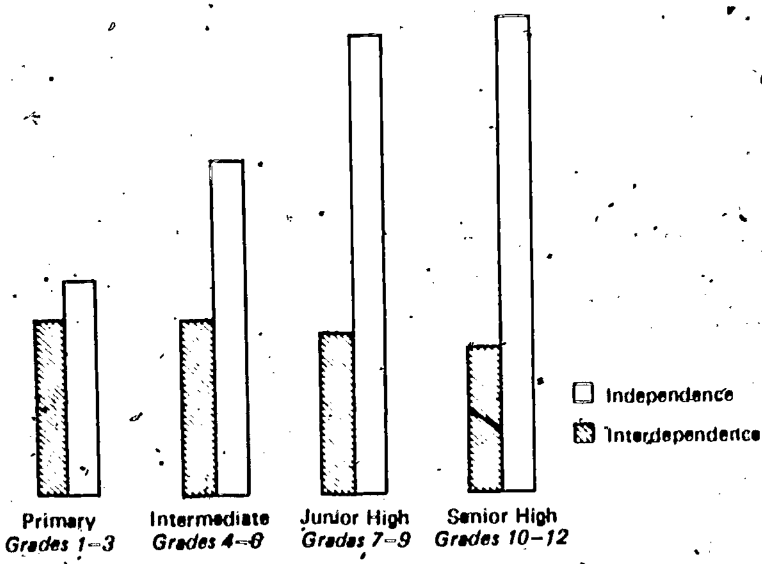

Fig. 1. Relative growth of the gifted in independence and interdependence

not fulfill the purposes of a program for the gifted. A program for the gifted should be continuous and interlocking so that the students will not be lost along the way. The curricular bonds are not coercive, for the teacher of the gifted must be free to develop a program that is effective and idiosyncratic in its own right.

School Environment

Several assumptions should be made relating to the curriculum and the environment of the school as they affect the developed aptitudes of the gifted child. By developed aptitudes is meant the knowledges, skills, and attitudes developed as a result of continued growth in the total educational environment, including home, school, and community. Those developed aptitudes in science of concern are mainly in the area of developing the skills of interdependence that come out of the habits gained in independent study, as well as in developing the skills, attitudes, and knowledges useful in the arts of investigation. Assumptions that should be made regarding the curriculum include the following:

1. Opportunities for early identification of children gifted in science (those who are potential investigators) will occur best in those communities in which the schools make opportunities for independent work early in the school years; that is, in the elementary school. However, this should be an articulated

program continuing through the high school. For this reason, it is well that high-school science teachers should serve as consultants to the elementary school.

2. Where there is a broad approach to the curriculum, the better will be the environment required for the full bloom of the developed aptitudes that characterize potential investigators in science. (Underlying this assumption is the acceptance of still another assumption: that to become an investigator in and a contributor to science requires a certain level of "singular giftedness.")

   A broad approach to curriculum disqualifies the conception of a curriculum as equivalent to the course of study. Thus, a course in physics per se is not the curriculum in physics. The curriculum consists of all the activities in which teachers and students (and, where possible, the community) take part in fulfillment of their purpose. Thus, a science club, individual investigation in a university or hospital under supervision of a recognized authority, a lecture by a visiting scientist, and a science fair (if it is done well) are all part of the curriculum.

3. The more nearly the pattern of the school encourages and rewards individual responsibility for personal behavior and stimulates development of independent study, the greater will be the opportunity for the formation of developed aptitudes of the potential investigator. The pattern of the school is characteristic of the tone of the school. As the result of a long-sustained investigation, the following have been noted as being generally characteristic of a desirable school pattern:

   a. At least one teacher in the department was a scholar in the field; he maintained scholarship through advanced university courses, or work toward a degree, or research, or serious reading. He also had the energy and the desire to work with individual students.
   b. The guidance program tended to give emphasis to individual interviews and, where possible, to individual testing (after group tests have been given). Also, it was generally true that the home-room and science teachers would function as counsellors as well, in the specific area of the course of studies.
   c. There was clear emphasis on intellectual attainment as the prime objective of the school; scholarship did not take second place to sports. But physical fitness was held as one of the prime goals for all.
   d. The curriculum was up to date; experimentation with the "newer" curriculums was going on in at least one "experimental" class.
   e. In the laboratory the leaning was toward individual rather than group work. Demonstrations by the teacher did not rob students of the right to discovery.

f. There was an emphasis on problem-solving in addition to the traditional problem-doing. (Operationally: *Problem-solving* implies that the solution to the problem is deferred over a relatively long period; it may not be in a readily available reference, or it may not yet be published. Problem-solving implies originality. In *problem-doing*, the solution is to be experienced within a reasonable, predicted period, say within a laboratory period or perhaps during the period assigned to homework.)

g. The teaching pattern, the curriculum, the kinds of instructional materials all tended to stress conceptual schemes and concepts rather than memorization and recall-on-demand. Books were chosen for their tendency to organize content around major concepts. The texts that organized their content around an anthology of topics were not in favor.

h. The administration was sympathetic to science and to individual investigation; funds and space were made available without sacrifice of other parts of the program. At the same time, the administrators and supervisors tended not to be laissez-faire in their attitudes towards the science program; they showed active interest and took an active part in planning.[2]

These assumptions imply another assumption: the greatest possible amount of freedom is permitted students, consistent with the ideas of competence and comparison, with health in mind and body, and with insight into the skills of interdependence and independence.

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[2]Paul F. Brandwein and Others, *Teaching High School Biology: A Guide to Working with Potential Biologists.* Biological Sciences Curriculum Study Bulletin No. 2. Washington, D.C.: American Institute of Biological Sciences, 1962, p. 47. Reprinted by permission of the publisher.

Chapter 2

The Gifted in Junior and Senior High School

The gifted child is a questing child. He is the idiosyncratic, perhaps the scientist of the future who travels his own road from organism to person and becomes at last an originator, a contributor, and an innovator, because he must. At ages nine to ten, teachers need not judge who is and who is not gifted. By the junior- and senior-high-school years, the contributors (the singularly gifted) who will add to knowledge will generally have identified themselves.

Characteristics of the Gifted

In junior and senior high school, the children who were identified as gifted in the elementary school years might be said to be more quiet, more reflective, and more inward looking as compared with the norm. They are also characterized by questing, which is discontent with explanations of the way the world of objects and events works, and by a disposition to commitment.[3]

Below is a list of traits characteristic of children gifted in science in elementary school. These traits are also characteristic of gifted children in high school. While no one child possesses all these traits, the possession of several may indicate a potential in science. This is particularly true if their possession correlates with better-than-average number skills and with high physiologic vigor.

A Checklist for Identifying Gifted Children in Science

Interest in science during the pre-school years.
Curiosity as to what makes things work.
Ability to understand abstract ideas at an early age.
Strong imagination in things scientific.
A love of collecting.
Abundance of drive—willingness to work on a science project for long periods of time in the face of difficult obstacles.
Better-than-average ability in reading.
Better-than-average ability in mathematics.
Unusual ability to verbalize ideas about science.
High intelligence, I.Q. of 120 or more.
Tendency to think quantitatively—to use numbers to help express ideas.

[3]Anne Roe, *The Making of a Scientist*. New York: Dodd, Mead and Co., 1953, pp. 237-8.

Willingness to master the names of scientific objects.
Willingness to pass up sports and other games in favor of scientific pursuits.
Tendency to relate stories about science, including the writing of science fiction.
Creativity in science projects, including writing.
Evident discontent with reasons which other children readily accept for things scientific.
Unwillingness to accept explanations about things scientific without proof.
Exceptional memory for details.
Willingness to spend long periods of time working alone.
Ability to generalize from seemingly unrelated details.
Ability to perceive relationship among the various elements in a situation.[4]

As the gifted child approaches the junior-high-school years, the tendency to be open to experience is characteristic of the singularly gifted. In the high-school years, the tendency to be open to experience remains particularly characteristic of the singularly gifted. In studies of high-school students, it has been found that gifted students have a wide variety of interests, an enormously varied repertoire of tools and activities, a tendency to embrace a variety of hobbies, and, above all, an ability to maintain an interest in science (as shown by hobbies, reading, and projects) over the elementary and junior-high-school years. Other boys and girls show interest in science, but this is an interest coming out of the pressure of a culture that is science oriented; these are passing interests that are not sustained.[5]

In the junior- and senior-high-school years, three of the identifying characteristics of the gifted in science are the following:

1. Sustained interest in science as shown by hobbies and continued work
2. Response to invitation to join a science club that meets after school
3. A choice of three or more projects from a list of twenty

Identification of the Gifted

What seems clear is that in the primary years, identification of the gifted in science per se and their selection is a function of their interest in science and their continued activity over a span of years in

[4]J. Stanley Marshall, "Science in the Elementary School," in *Curriculum Planning for the Gifted*, Edited by Louis A. Fliegler. Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1961, p. 137. Reprinted by permission of the publisher.

[5]Paul F. Brandwein, "The Selection and Training of Future Scientists," *The Scientific Monthly*, LXIV (March, 1947), 247-52. See also Paul F. Brandwein, *The Gifted Student as Future Scientist: The High School Student and His Commitment to Science*. New York: Harcourt Brace Jovanovich, Inc., 1955, pp. 54-8.

the area. One may easily defer final identification of the gifted to later years (certainly to grades five and six, if not to the junior-high-school years), if only because the children do remain in school. *The emphasis in the primary and middle years is not so much then on their selection as on the mode and manner of instruction that enable science-prone children to sustain their drive and interest.*

In describing children in the primary (grades one through three) and middle years (grades four through six), the term "science prone" should be used rather than "gifted in science." For the gifted in science are identified not mainly by high IQ (whether 130 or higher), but by their remarkable achievement; that is, by deeds, not by promise. In fact, achievement (usually, but not always, coupled with high IQ) presages promise. In the elementary school, the concern, then, is with the curriculum, methods, and materials (in short, the school environment) that sustain the science prone.

Influence of the Teacher

By the junior-high-school years, and with greater sureness by the junior year of high school, the record of achievement (in the cumulative record) will begin to show whether the child is tending towards conventional or singular giftedness. In the junior-high-school years, the child is beginning to probe into career choice. This becomes a particularly keen search in the high-school years. The teacher, who is the key figure in fostering giftedness, begins to take on increasing significance. It also seems to be observable that children with singular giftedness profit from teachers who prize singular giftedness; i.e., teachers who are not uncomfortable in the face of idiosyncratic behavior.

While the term "conventional giftedness" designates that syndrome of activity that is characterized by high IQ (130 or so), it also indicates that the child depends highly on the teacher's constant advice and approval. The tendency of the child is not to take risks. Projects are done (with a conclusion vouchsafed) rather than experiments (in which there is risk). In conventional giftedness, the child courts success. It is perhaps possible for the teacher to develop such a child's ego strength sufficiently (as shown in independent activity that courts risk) so that the child begins to lean towards activities that characterize singular giftedness.

The child who is singularly gifted usually has high IQ (130 or more) but may not reach that level. However, he or she may be highly innovative and creative and undertake work that is truly experimental in nature. Children who are singularly gifted often take the innovative "leap in the dark." They are the ones of the bold hypothesis. Nevertheless, they are well put together intellectually, physically, and emotionally. Furthermore, they are beginning to give some clues about their idiosyncratic life-style.

With these and other guides, which come out of personal observation of the gifted, the teacher can plan more effectively the kind of program suggested for the intermediate years—a program based on progressively personal and independent work. In the intermediate years (grades four through six), the teacher in such a program takes on more and more the behavior and attitude of a guide, rather than guardian of the archives. The teacher orchestrates what is called a Learning Activity Package.

In this environment, the teacher is the key, for the teaching environment is crucial to the display of the traits of the gifted. Without an environment that sustains the singularly gifted, the child may become that pitiful terror of the school known as a problem. Some of the more frequently noted attitudes and traits of teachers who aid rather than hinder creativity include the following:

1. Realize skills, information, and rich experiences are the texture—the "mulch," the "stuff"—from which creativity develops.
2. Provide a focus on the *search* for answers and do not expect "right answers." In other words, the process of search is valued, welcomed, and rewarded.
3. Help children dare to be themselves through providing a classroom atmosphere free from premature external evaluation of the creator.
4. Are willing to keep "hands off" and are willing not to judge and not to always *teach* with a large T.
5. Are themselves interested in continuing to develop their own creative potentials.[6]

In a study of the characteristics of 82 teachers who had inspired boys and girls to commit themselves to a career in science, it was found that more than 90 percent of the teachers had these characteristics:

1. Competence in the field of science (more than 90 percent had a master's degree in science, in addition to required work in education)
2. Had published at least one paper in science or in education
3. High physiologic vigor
4. Decisive in manner (firm but not coercive or authoritarian)
5. Father or mother surrogate[7]

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[6]Marcella R. Bonsall, "Current School Programs for Developing Creativity," in *Educating the Gifted: A Book of Readings*. Edited by Joseph L. French. New York: Holt, Rinehart and Winston, Inc., 1964, p. 451.

[7]Paul F. Brandwein, *The Gifted Student as Future Scientist: The High School Student and His Commitment to Science*. New York: Harcourt Brace Jovanovich, Inc., 1955, pp. 65-8.

Similar characteristics have been noted of science teachers at the college level.[8] Of course, subject-matter competence is a sine qua non at college, but not all teachers, not even the majority of teachers, with subject-matter competence are found among the key figures who can work with and stimulate the gifted to devote themselves to a career in science.

Investigations of the career commitments of the gifted in science clearly indicate that a key figure was significant in their choice of a career in science. The prime period of influence of this key figure has been found to occur in the early years of the gifted child, in the junior- and senior-high-school years, mainly in the former.[9]

Of course, the experienced observer will note that the preceding is really a description of the characteristics of the good teacher of science. But the term "teacher" describes quite a different person from the term "instructor." An instructor is as large as his subject, and this perhaps is honor enough. But a teacher is not only competent in his subject but is larger than life. His students see him as model and goal. The teacher knows the meanings of both competence and compassion. The teacher not only stimulates his students to go far and deep into the subject, but to go as far as they can in self-fulfillment.[10]

Conventional Versus Singular Giftedness

At one time, the National Manpower Council could maintain that half of the persons with an Army General Classification Test (AGCT) score of 120 or higher do not enter college and that only about one-third with scores 120 or above graduate from college. Further, the Council has declared that, "An AGCT score of 120 is certainly high enough to justify using it as a minimum for estimating the number of individuals capable of college work."[11] In other words, half the number of gifted students enrolled in high school were not sufficiently convinced that they should nurture their gifts. A report

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[8] Robert H. Knapp and Hubert B. Goodrich, *Origins of American Scientists: A Study Made Under the Direction of a Committee of the Faculty of Wesleyan University*. Chicago: University of Chicago Press, 1952, pp. 266-7.

[9] Stephen S. Visher, "Starred Scientists: A Study of Their Ages," *American Scientist*, XXXV (October, 1947), 543. See also Paul F. Brandwein, *The Gifted Student as Future Scientist: The High School Student and His Commitment to Science*. New York: Harcourt Brace Jovanovich, Inc., 1955, pp. 63-4.

[10] Paul F. Brandwein, *Substance, Structure and Style in the Teaching of Science* (Revised edition). New York: Harcourt Brace Jovanovich, Inc., 1968, pp. 28-9.

[11] National Manpower Council, *A Policy for Scientific and Professional Manpower: A Statement by the Council with Facts and Issues Prepared by the Research Staff*. New York: Columbia University Press, 1953, pp. 78-86.

of the Commission on Human Resources and Advanced Training agrees essentially with this.[12] But these studies were in the early fifties, and the situation has changed. There are now programs that attract students with high ability, but perhaps it is still possible to postulate that these programs are developed for the conventionally gifted and not the singularly gifted.

The essential differences between the two types of giftedness may be compared as follows:

1. The conventionally gifted have high IQs (over 130) and conform in general behavior "as expected." These children prefer guidance; they want to please the teacher and generally achieve the "high expectancies" of the teacher.
2. The singularly gifted are one of the following types:
   a. High IQ; conforming in general behavior but creative. These children are well-behaved but also do remarkably inventive things.
   b. Modest IQ; conforming and creative as in (a) but with IQs from 105 to 115.
   c. High IQ; nonconforming and creative.
   d. Modest IQ; nonconforming and creative.

Children of groups (c) and (d) of the singularly gifted are sometimes behavior problems (mostly because of excessive energies and strong innovative tendencies). They cannot "sit and listen" but excel in individually contrived, innovative work requiring periods of high concentration. They do "original" things.

Observations of science education (and other areas) throughout the country indicate the following:

1. Programs for the gifted are presently contrived and organized for the groups that are conventionally gifted.
2. In areas other than science (art, music, athletics, and creative writing), programs have been contrived for the singularly gifted. These areas lend themselves to such innovation, but so does science.
3. Where programs for the singularly gifted have been devised, students do create; that is, they do innovate, invent, and carry out true experimental work, true inquiry. (Inquiry as the term is normally used is not "true inquiry," since the results are known and normally obtained within a predicted period. Inquiry as it is generally carried out in our schools is related to problem doing rather than problem solving.)

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[12] Dael Wolfle, *America's Resources of Specialized Talent. A Current Appraisal and a Look Ahead.* New York: Harper and Row, Publishers, 1954, pp. 269-71.

One major objective of education of the gifted is to meet their idiosyncratic mode. This, in essence, means to stimulate independent study. For the curriculum for the gifted in science, a 12-year program is proposed that increases independent study and that offers instructed learning in interdependent study. The curriculum is devised for all students; the program offers a constructive study of the legacy of science (ordinarily thought of as courses in science, with a system of class attendance, formal lectures, discussion, and formal laboratory work). The independent study refers to the experimental work, true inquiry, as well as to carrying out those studies into the legacy of science independently; that is, without attending formal work.

Lecture in the Gifted Curriculum

Investigations throughout the country have led to some important revelations about science instruction. It has been found that although teachers using the courses developed by the various federally funded committees (BSCS, CHEMS, PSSC, ESCP, and so on)[13] emphasize use of the "inquiry-process approach" in their science teaching, roughly 80 percent of the teachers in grades nine, ten, eleven, and twelve lecture 80 percent of the time. Physics and chemistry teachers lecture approximately 80 to 90 percent of class time. Furthermore, the laboratories are organized in such a manner that students "develop" the correct answers within the stipulated time span of the period. Rarely do students perform a single experiment a year, in the true sense of the term experiment.

This is not to say that administrators, supervisors, and teachers are not honorable in their basic, fundamental, and overarching desires to develop a strategy in which the methods of intelligence (inquiry processes) are used in instruction. Even casual observation would show that it is tactically impossible to teach five classes a day, individualize instruction, and thus plan for the varieties of approaches and equipment characteristic of true experimental inquiry, within the purview of the present facilities and course structures. In fact, it can be hypothesized that given the present facilities and present school requirements, the investigational approach will not flourish. (Hence are suggested Learning Activity Packages and research approaches [see Chapter 4]).

It is estimably clear that gifted students can read and read very well. Therefore, there is little need to lecture on material already in

[13]The committees mentioned are Biological Sciences Curriculum Study (BSCS); Chemistry Education Materials Study (CHEMS); Physical Sciences Study Committee (PSSC); and Earth Science Curriculum Project (ESCP).

books. The lecture is most useful when it brings syntheses of data, or data only, otherwise unavailable to the students. In effect, a program for the gifted in the senior high school should place the student in the position of securing his potential as an independent scholar, this of course being done with the fullest cognizance of his maturational level. The emphasis then is on activity of the student in relation to his gifts, opportunities, and life-style.

There are several kinds of life-styles that can be observed amongst gifted students and that can be related to the kinds of independent study the gifted prefer. Eli Ginzberg and John L. Herma designate life-styles as follows:

1. *Individualistic or autonomous life-style.* The attitudes and behavior towards work of those with an individualistic life-style are characterized by an emphatic desire to design their own activities and to be as free as possible from the pressure or interference of others. More than anything else, they want to work without directional dictation.
2. *Leadership or authoritative life-style.* The attitudes and behavior towards work of those with a leadership life-style are characterized by a strong drive to direct and guide the work of others. They are not mainly concerned with securing autonomy for themselves but rather with securing positions of leadership.
3. *Social or group-oriented life-style.* The attitudes and behavior towards work of persons with a social life-style stand in contrast to those of the individualistic or leadership types. The social or group-oriented type feels good in his membership in a group, is a good member of the "team," and is concerned neither with optimizing his freedom of choice nor with dominating others and aggrandizing his own power. His basic orientation is to gain, hold, and increase acceptance by other members of his work group.
4. *Ideological or idealistic life-style.* The attitudes and behavior towards work of those with an ideological life-style are characterized by dedication to a system of ideals, such as social, religious, political, or scholarly. The ideological type is concerned with relationship within the group, but mainly because he shares the cause for which he is working.[14]

Children in junior high school (twelve through fifteen years of age) are beginning to give clues to their life-styles. Individualistic (autonomous), leadership (authoritative), and social (group-oriented) life-styles begin to show themselves earlier than the ideological

[14]Eli Ginzberg and John L. Herma, *Talent and Performance.* New York: Columbia University Press, 1964, pp. 113-22.

(idealistic). The singularly gifted tend to be more autonomous and idealistic than others. The social and leadership types tend to seek the approval of the teacher and the group more than do the autonomous and idealistic types.

These different life-styles manifest themselves in students' preferences for research work. Thus, the autonomous type prefers a problem "on his own"; he is a loner. The social type many times prefers to work in group research; he likes to be part of a team. The ideologic type tends to want his work to be useful.

These observations of life-styles are tentative and must be considered as clues only. But, if nothing else, the terms are useful in describing the early attitudes and behaviors of gifted children for purposes of guidance. They are not meant to be used as labels, for labels are often libels.

It should be kept in mind that the field of work with the gifted is only at the very beginning of acquisition of hard data. Life-style designations therefore serve merely as one type of clue for identifying and working with the gifted.

Chapter 3

Curricular Strategies

If the basic thesis is accepted that the gifted in science in high school are to be encouraged in as much independent study as they can take, then a gifted program assumes different form and different dimension than that normally found in most of our schools. Under this thesis, the gifted student is to be encouraged to fulfill his giftedness. This does not mean that he is to be cast adrift into pure inquiry, for the life of the scientist is not independent. A scientist is interdependent; he "stands on the shoulders of others." So does the gifted student.

A gifted child does not live alone. He is part of his culture, and he needs an "intellectual umbilical cord" to the community of scholars. He finds this umbilical cord in the curriculum. The curriculum not only gives him the apprentice learnings that furnish the feedback his mental activities require, but also the feedforward his special gifts, his ingenuity, require.

Furthermore, in a completely objective survey of the nature of the scientist's inquiry processes (methods of intelligence) and the nature of scientific contribution, the techniques of interdependence are highly significant. For example, a scientist's report always credits those whose work preceded his, even in the most tentative of ways. A scientist does not rush to the laboratory to begin work; he probably first goes to the library to find clues to his hypotheses, theories, or designs. He reads and analyzes the work of others (his predecessors and peers) as much as he engages in experimental work. A scientist is interdependent with his past and present, and so is a child, gifted or not, and so is a teacher. A scientist does not start with a problem; he starts with his knowns.

Types of Curricula for the Gifted

The suggested curricula for the gifted have at least three parameters, which are the following:

1. The gifted student shall have access to all information, coursework, and the like that will ensure him of opportunities for further study (presumably in college).

2. The gifted student shall have opportunity and access to such types of independent study as will avail him of the work assumed in (1) above ~~and~~ that will moreover give him instruction in the arts of investigation (in true inquiry and research).
3. Within his junior and senior years, the gifted student shall have opportunity to do at least two investigations of a truly original nature. That is, he shall have experience in research and in true problem solving. Through a demonstration of true problem-solving ability, he will demonstrate his talent or high-level ability or developed aptitude in science.

There are three types of organization of high-school curriculum that have been observed that permit the above opportunities. They are described in the first three following models. An additional model, Model IV, is presented as a suggested program for optimal development of gifted students.

Model I. The Traditional Curriculum

The simplest orientation towards meeting the needs of the gifted in science in a majority of schools seems to come out of the presently most-common high-school curriculum (Table 1). In each of the courses in Table 1, the most able students are given opportunity to do project work. This project work often leads to involvement in a science fair or in the Westinghouse Science Talent Search. In many instances, the gifted are the best students in the school (as determined by high IQ, reading score, math score, and achievement).

Table 1

Ordinary High-School Science Curriculum

Grade	Course
9	General science or earth science or physical science or biological science
10	Usually biology
11	Usually chemistry
12	Usually physics

Frequently, the gifted are permitted to take "honor courses," which often are the courses developed by the federally sponsored committees (e.g., PSSC, CHEMS, BSCS, and ESCP).[15] Thus, for the talented or gifted students (usually the conventionally gifted), the course in biology is one of the BSCS courses, usually the blue version;[16] the chemistry course is usually the CHEMS course;[17] and the physics course is PSSC physics.[18] Working on a project, then, is the significant difference in the treatment of the gifted in this type of school.

Model II. The Special School (or Special Honor School Within a School)

In the special school, students with high-level ability (ability to pass a special entrance examination and high IQ, reading score, and mathematics score) are offered a rich science curriculum that uses the BSCS, CHEMS, and PSSC programs. In addition, the students are offered opportunities to do science projects of a complex sort. The other coursework (language arts, social studies, mathematics, music, and art) within the school or within the special honor school are also all honors courses.

Model III. The Tracking Program

A school with tracking modifies its program by offering several curricular paths instead of just one. The tracks are specially designed for different groups (Figure 2). Students who do research (track D in Figure 2) have a sponsor who is a teacher in the school, but their special research problems are determined by consultation with a university scientist, who acts as their consultant. The students in research are required to maintain an average in all areas (whether they are in the normal B track or the mathematically oriented C track) of 85 percent. Those in research are not required to attend the coursework, but they are required to take the examinations.

[15] The committees mentioned are Physical Sciences Study Committee (PSSC); Chemistry Education Materials Study (CHEMS); Biological Sciences Curriculum Study (BSCS); and Earth Science Curriculum Project (ESCP).

[16] BSCS courses were first developed in 1960 and have since been revised several times. For a first high-school biology course, texts were prepared with three different orientations. The blue version (*Biological Science: Molecules to Man* [Third edition]. Boston: Houghton Mifflin Co., 1973) was prepared by biologists with major interests in biochemistry and physiology. The yellow version (*Biological Science: An Inquiry into Life* [Second edition]. New York: Harcourt Brace Jovanovich, Inc., 1963) was prepared by biologists with major interests in development and genetics. The green version (*High School Biology: BSCS Green Version*. Chicago: Rand-McNally and Co., 1963) was prepared by biologists with major interests in ecology and evolution. A text for an advanced, second biology course has also been prepared (*Biological Science: Interaction of Experiments and Ideas* [Second edition]. Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1971).

[17] *Chemistry: An Experimental Science*. Edited by George C. Pimentel. San Francisco: W.H. Freeman and Co., 1963.

[18] Uri Hager-Schaim and Others, *PSSC Physics* (Third edition). Boston: D.C. Heath Co., 1971.

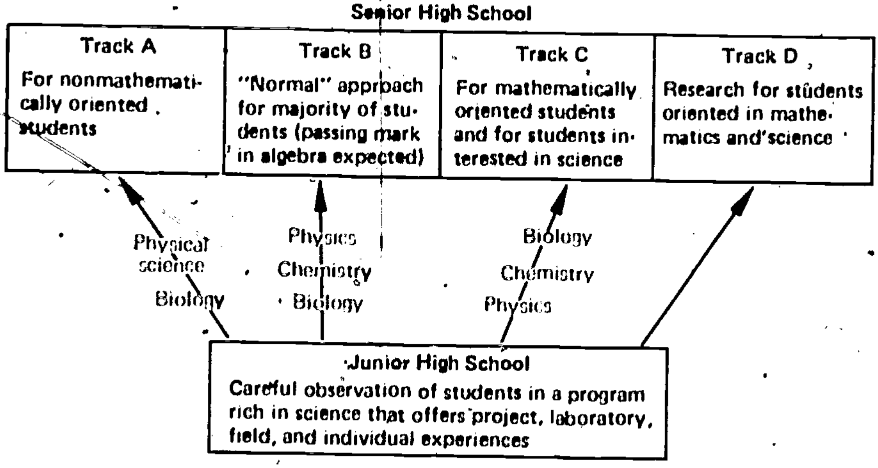

Fig. 2. Diagram of curricular tracking

Model IV. Learning Activity Package Program

The model that portends to provide maximum development of the gifted is based on both Learning Activity Packages and tracking. A synthesis of Model III and LAPs, such a program is suggested for the development of the aptitudes of the gifted in science.

Conceptual Basis for the Curriculum

Whatever the model, the necessary ingredient of all the programs is the opportunity to undertake coursework based on a conceptual rather than a topical orientation and, at the same time, to undertake development in the arts of investigation (inquiry). These arts of investigation include all varieties of investigations, including "true experiment." In other words, the skills of interdependence are to feed the skills of independence.

Science is experience in search of meaning (Albert Einstein's definition).[19] And a curriculum is an orchestration of meanings and the nonrandom experience, the instructed learnings, that seeks out the meanings. Yet, a gifted child scintillates, probes, and scans; he often is given over to sweet, wild, nonregulated thought we call imagination or fantasy. A program for the gifted offers experience in search of meaning and, at the same time, gives rich opportunity for the individual idiosyncratic probe, for the unexpected, for the flash of insight, for the insightful "leap in the dark."

[19] Albert Einstein, "Considerations Concerning the Fundaments of Theoretical Physics," Address given before the Eighth American Scientific Congress, Washington, D.C., May 15, 1940. For a copy of the address, see Albert Einstein, "The Fundaments of Theoretical Physics," in *Ideas and Opinions*, New York: Crown Publishers, Inc., 1954, p. 323.

Science, as Percy Bridgman maintained, means "doing one's damnedest with one's mind, no holds barred."[20] It is precisely this "no holds barred" activity that is especially characteristic of the gifted. The junior-high-school child who is singularly gifted in science can, for example, understand calculus, and he can do original work.

What kind of curricular framework gives solace to all children so that they communicate with common bond and yet gives scope to variety, diversity, and the idiosyncratic mode? What science curriculum is a continuum that makes room for a variety of excellences and also is a home for the idiosyncratic mode that permits a free thrust into the unknown? The answer appears to be a curriculum based on conceptual themes. Such a curriculum reduces random experience and also permits random probes. At the same time that it reduces random experience, it enriches the scope of the gifted child; even as it teaches the skills of interdependence, it enhances the skills of independence. It gives the gifted child access to the legacy of science so he can build on it and contribute to it.

There is at least some agreement on the basic conceptual themes, although there is diversity in their statement. The agreement is inherent in the conceptually based statements developed in newer curricula, whether sponsored by the federal government or private institutions.

The California State Advisory Committee on Science Education has stated the following concerning curriculum:

> The curriculum in science at all levels can be organized around representative conceptual systems, their major supporting concepts, and the processes of science, since concepts and inquiry processes are economical and highly transferable forms of learning.
>
> The sequence of instructional materials from kindergarten through high school can be efficiently organized around (a) the processes of science with continuing growth in meaning and use at successive levels; and (b) the major conceptual systems of science to provide *vertical coherence* [italics added] to the curriculum. Supporting concepts should be introduced at several levels to increase the comprehensiveness and the interpretive power of each concept.[21]

BSCS, CHEMS, CBA, PSSC, and ESCP courses are based generally on a conceptual orientation, not a topical one.[22] The California

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20 Percy W. Bridgman, *Reflections of a Physicist*. New York: Philosophical Library, Inc., 1955, p. 535.

21 *Science Framework for California Public Schools: Kindergarten—Grades One Through Twelve*. Prepared by the California State Advisory Committee on Science Education. Sacramento: California State Department of Education, 1970, p. 16.

22 The full names of the courses are as follows: Biological Sciences Curriculum Study (BSCS); Chemistry Education Materials Study (CHEMS); Chemical Bond Approach (CBA); Physical Sciences Study Committee (PSSC); and Earth Science Curriculum Project (ESCP).

State Advisory Board on Science Education has recommended the development of the following basic conceptual themes in the science curriculum.

A. Most events in nature occur in a predictable way, understandable in terms of a cause-and-effect relationship; natural laws are universal and demonstrable throughout time and space.
B. Frames of reference for size, position, time, and motion in space are relative, not absolute.
C. Matter is composed of particles which are in constant motion.
D. Energy exists in a variety of convertible forms.
E. Matter and energy are manifestations of a single entity; their sum in a closed system is constant.
F. Through classification systems, scientists bring order and unity to apparently dissimilar and diverse natural phenomena.
   1. Matter is organized into units which can be classified into organizational levels.
   2. Living things are highly organized systems of matter and energy.
   3. Structure and function are often interdependent.
G. Units of matter interact.
   1. The bases of all interactions are electromagnetic, gravitational, and nuclear forces whose fields extend beyond the vicinity of their origins.
   2. Interdependence and interaction with the environment are universal relationships.
   3. Interaction and reorganization of units of matter are always associated with changes in energy.

The Committee recognizes that there are other ways of describing these conceptual systems. In this context conceptual systems identify the content of the curriculum; they are learnable but not teachable. Selected concepts, principles, and processes of inquiry provide the subject matter in areas of study. Conceptual systems represent the long-range goals of instruction; it is these that an individual should appreciate at increasing levels of understanding throughout his lifetime. Specific concepts and inquiry skills serve as the more immediate objectives in areas of study or courses. Through an understanding of contributing concepts and relevant processes, a conceptual system acquires meaning for a student.[23]

The courses of the curricula suggested in this publication are full explications of these conceptual themes in their special order. While the order of the conceptual themes is not of special significance, the conceptual themes themselves are significant, for they are "guys to the curricular tent." The concepts are in effect summaries of the work of scientists—the legacy of science.

[23] *Science Framework for California Public Schools: Kindergarten–Grades One Through Twelve.* Prepared by the California State Advisory Committee on Science Education. Sacramento: California State Department of Education, 1970, pp. 34 and 91-108.

Percy Bridgman, referring to concepts as basic to the ordering of understanding, has said, "In general, we mean by any concept nothing more than a set of operations; *the concept is synonymous with the corresponding set of operations.*"[24] For example, a meterstick measures length, not intelligence. The concept of length is synonymous with the experience of using the meterstick. If one uses a meterstick to measure intelligence, one comes out with a useless concept.

Conceptual thinking (concept seeking through reformulation of orderly explanation) is not easy to come by. Children whose concept-seeking experiences are continuous in a curriculum have the opportunity to develop the habitual tracks of association that are the products of concept seeking. Therefore, the hypothesis is that in a conceptually developed curriculum, children improve their ability to think conceptually.

A curriculum is not based on random experience; a curriculum reduces random experience. A conceptually organized curriculum reduces random experience and supports concept seeking, which, of course, is based on inquiry.

Curriculum Development for Junior High School

When the teaching of children is based on concepts that are synonymous with their corresponding operations, children can and do come to fairly accurate conceptualizations or preconcepts. But it is the manner of teaching that orchestrates concept and operation.[25]

Teachers who recognize the distinction between conventional and singular giftedness will come to know that the singularly gifted in science show their giftedness not only in a variety of intellectual behaviors but characteristically in the invention of operations. In the junior high school, the gifted child often invents his own operations, and this is most true of the singularly gifted. The following is an example of an inventive pupil.

> J.L., thirteen years old, in microscope work in class, noted that *Daphnia* (a tiny crustacean) have food tubes that are transparent. He went to his teacher with an experimental design that would enable him to study the food preferences of *Daphnia*. In essence, he wanted to stain with a harmless dye the various organisms *Daphnia* feed upon and then observe food preference.

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[24] Percy W. Bridgman, *The Logic of Modern Physics.* New York: Macmillan Co., 1927, p. 5.

[25] Paul F. Brandwein, *Teaching Gifted Children Science in Grades One Through Six.* Sacramento: California State Department of Education, 1973, pp. 8-10.

He planned to do this in work before school, during his free period, after school, and at home.

Considerations fundamental to the development of a conceptually based curriculum in the junior high school include the following:

1. The curriculum should be developed to fit the stage of development of the knowledges, skills, and abilities (the developed aptitudes) of the boys and girls coming to the junior high school. Particularly for California, where the population is mobile, the school gifted population may be composed of children with widely diverse backgrounds, some rich in science, some very poor.

   Not only must there be adequate information on the children's developed aptitudes (from standard tests), but clues to their achievement in science should also be obtained. It is for this reason that it may be desirable for a faculty to determine where the boys and girls are along the lines of the concept development in the curricular grid in Figure 5 (page 36).

   If nothing else, simple, conceptually oriented tests can be developed to determine the relative positions of students along the grid. Or a period of time, up to two months, at the beginning of level seven might be spent in discussion to determine the class position along the conceptual arrow (the development longitudinally along a conceptual theme). Once this is done, the curriculum for the particular group of gifted under consideration can be planned. But it will be recalled that this curriculum is designed to develop a *base in interdependence.*

2. Once the character of the group is determined, the structure of the curriculum can be developed. It can be devised along a longitudinal structure or in a horizontal structure. The horizontal grid is oriented towards disciplines, but its internal structure is still conceptual. The basis on which this is reasoned is as follows:

   a. Since the boys and girls coming to the school may have had either a conceptually organized curriculum or a sparse program or a topical one, it is well to bring them together in a program that affords equal opportunity to develop the skills of interdependence.

   b. Whatever their origins, children in the junior high schools are beginning to develop career choices. A view of the sciences as disciplines (matter, energy, life, earth, and space) may assist in the career choice. Each horizontal development under the discipline is conceptual.

c. Whether the design is vertical or horizontal, the techniques and procedures for grades one through six still apply. These consist of developing either curricular modules of a sequential type or the curricular module known as a Learning Activity Package, depending on the desires of the faculty.[26]

d. For the junior-high-school years, whether a design in non-graded progression or enrichment is desired, the Learning Activity Package is most desirable. For the junior-high-school program must emphasize independent activity in learning. The lecture is at best to be used only when it alone can fulfill a function.

e. If desired, one can organize a curriculum based on process themes, but observations of the work of scientists indicate that they begin their work with understandings or concepts, not with processes. In practice, once a model based on cognitive themes is developed and the operations that support the concepts are chosen, the processes fall gracefully into the plan.

Instruction in the Arts of Investigation

The teacher of science should create a new environment in the classroom in which the student is encouraged to do the following:

- Explore the material universe.
- Seek orderly explanations (conceptual orderings) of objects and events.
- Test the explanations using the methods of intelligence (inquiry processes) of the scientist.

To explore, to seek, to test, to be active in concept seeking, to be active in learning, to respond, and to inquire: this is what children do as they work in science. "Sciencing" means all these things and more. It means to seek orderly explanations out of the chaos of data. It means value seeking for the values of honest search, honest reporting, and truth seeking. These are the values of the scientist and of science.

A theory of instruction that embraces all children but that does not deny the gifted might be stated as follows: in the classroom, the teacher originates different environments toward which students must respond, thereby gaining new abilities. For all children, this

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[26] Paul F. Brandwein, *Teaching Gifted Children Science in Grades One Through Six.* Sacramento: California State Department of Education, 1973, pp. 13-19 and 51-57.

theory emphasizes activity on the part of the teacher as she develops an environment of nonrandom experience for the children. But, nonrandom or not, the experiences are new and stimulate innovativeness. A curriculum consists of nonrandomized experience, of instructed learning. But within its framework, the random experience coming out of the nonregulated thought, or even fantasy, of the gifted child does have central play.

The emphasis on *new* environments (new experiences) is important, for the gifted child is bored with doing things he has already done or known. Moreover, all children should not waste time with things they have already done. To learn means to be faced with a new environment, for to learn means primarily to learn new things, even though review has its place in fixing skills.

The significant aspect of this theory of instruction is its emphasis on response of the learner. Lecture *tells* the child, but, at the same time, there must be opportunity for the child to do *telling* based on his activity and his experience. In teaching, it is the teacher who creates the nonrandomized, new environment; it is the child who responds by activity in learning. This learning includes all manner of activity: investigation, discussion, demonstration, project, field experience, the rare experiment, library research, and reporting.

If plain, ordinary, garden-variety information is needed, what the child is to learn he can get by reading. The teacher should not under ordinary circumstances "tell," unless it is impossible for the child to aquire the information by direct, individual work. Gifted children do read and read well, and the text can safely be left to them if opportunities are also given them to review their concept seeking and concept forming and to seek advice in prosecuting their original research.

When the lecture is minimized (when it is reduced to less than 50 percent of the class schedule), the gifted are given greater opportunity to do individual laboratory work and original work in true experimentation. At the same time, high standards of scholarship are maintained. For students who are given freedom to carry on their work do so with the understanding that they need fully to understand the fundamental legacy of science basic to their work. The coursework of the models, which is based on the conceptual themes proposed by the California State Advisory Committee on Science Education and similar themes, is such a legacy.

Essentially, a program for the gifted in science orchestrates the skills of interdependence with those of independence. In presenting individual research work, the gifted student not only undertakes to come to terms with the laboratory but with the library as well.

The lesson of inquiry and the lessons taught the researcher indicate that an experienced inquirer starts with the known. The lesson is that mental activity basic to science is not generally directed by problems but by objects and events. If the object or event is not recognized, a problem is not recognized. And if a concept is not available, the problem cannot be clarified. A scientist and a child bring their concepts with them. As did Newton, scientists "stand on the shoulders of others." So does a child.

It is a truism that it would be foolish to disregard what is known, to discover it all anew. The scientist, in "standing on the shoulders of others," is interdependent with other scientists. He starts with the accumulated store of discovery; his is the legacy of all scientists. The student also has this legacy, but he learns to investigate primarily by investigating. A process of investigation, such as illustrated in Figure 3, should emphasize the following:

1. Inquiry is a mix of human activity in search of meaning. Inquiry is not synonymous with laboratory work, not for the scientist nor in the science classroom. A scientist thinks; he consults his resources (books, magazines, and so on); he confers with friends and colleagues; and he attends meetings. The library is as important as the laboratory, but the primary tool is his brain, with the armchair often being a significant locus for scientific activity.
2. Almost always, problem solving and problem doing are based on a body of knowledge. There is no need to have the student rediscover the unknown; this is inefficient even to teach him the arts of investigation. As Robert Gagné has put it, "To be an effective problem solver, the individual must somehow have acquired masses of structurally organized knowledge. Such knowledge is made up of content principles, not heuristic ones."[27] This is not to say that the laboratory work common to BSCS, PSSC, CHEMS, and similar courses should not be done, as they provide for empirical confirmations of knowns. In teaching the essences of science, one should keep in mind (a) the need for accuracy through assessment of error, (b) the empirical base for certain aspects of science, and (c) the nature of problem doing as apprentice investigation.
3. The student in junior high school learns to investigate by investigating. Two aspects of investigation that should be stressed are (a) the need to apprehend the legacy of science (the need to develop skills in the methods of assessing the known) and (b) the techniques of attacking the unknown (the arts of

[27] Robert M. Gagné, *The Conditions of Learning.* New York: Holt, Rinehart and Winston, Inc., 1965, p. 170.

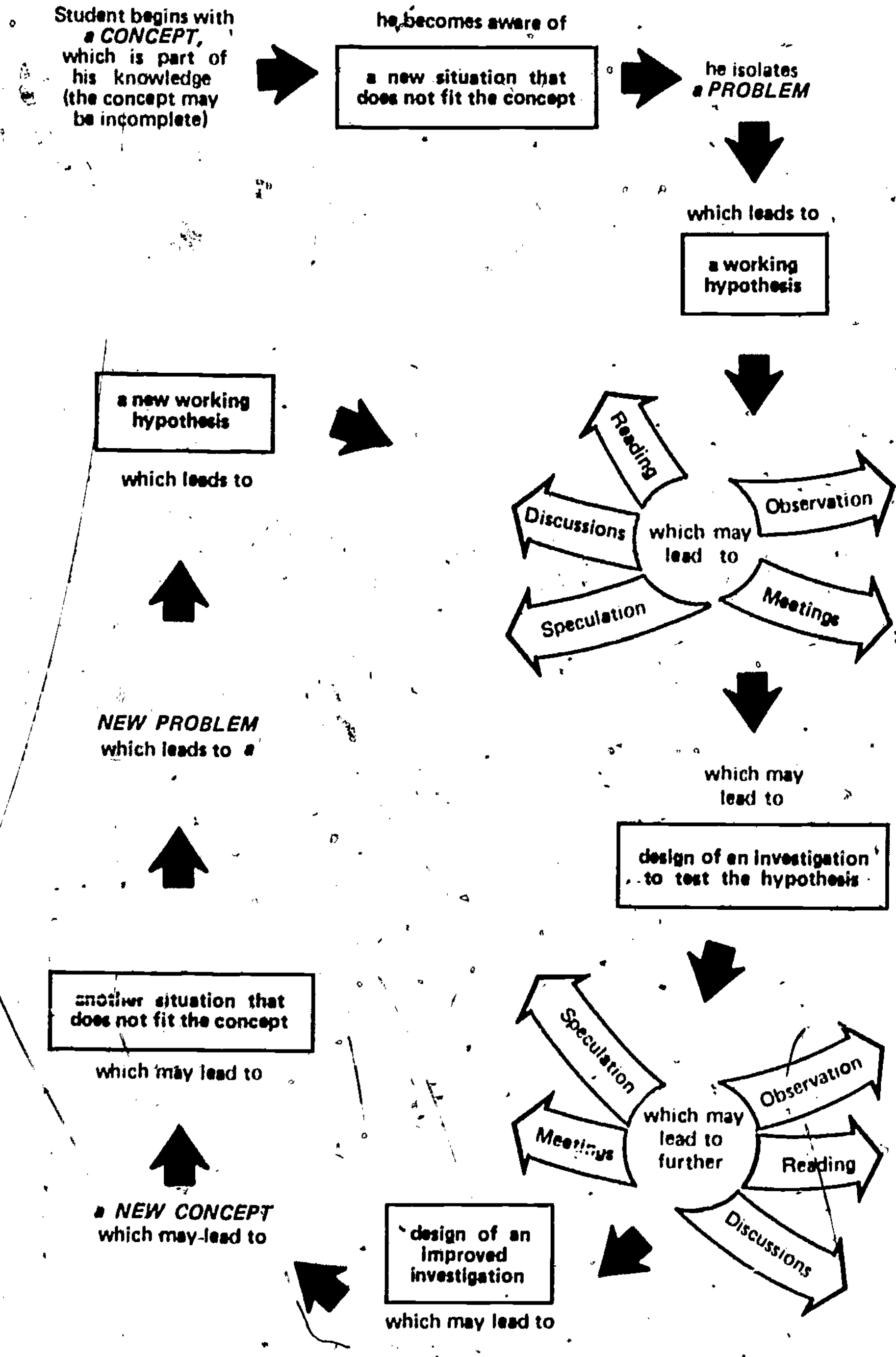

Fig. 3. Schema for investigation

> investigation). Both to apprehend the legacy of science and to attack the unknown, one uses the techniques of inquiry. These simply are all methods of civilized man to find what is known and unknown. The known and the unknown are inextricable; to separate them is to contravene science and the scientist, for both depend on the past to probe the future.[28]

Feedback and feedforward in the gifted are thus one because they are inextricable. Even as the gifted student probes the past, his mind leaps forward. For the brain is one organ; the neurons are interconnected; thus, concepts are the ground for the probe through investigation.

Prototype for a Conceptually Structured Curriculum

What is known can be structured, and, as has been demonstrated, this structure should be conceptually based. The thesis (or hypothesis) of the California State Advisory Committee on Science Education is that if such a structure is developed from the primary years on, the legacy of science will more surely be part of the development of the gifted child. By high school, the legacy will then be assimilated into his fiber of thought.

A curricular structure that is based on the conceptual themes of the State Advisory Committee and that has been developed for use as a guide in curriculum planning is presented in Figures 5 through 7, which appear on pages 36 through 38.[29] Two structures of the Committee's themes are presented: (1) a longitudinal development through levels (Figures 5 and 6); and (2) a horizontal development through grades (Figure 7). Both of these approaches to the curriculum are conceptually based.[30] Methods for implementing the curriculum are explained in Chapter 4.

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[28] James B. Conant, *On Understanding Science: An Historical Approach*. New Haven, Conn.: Yale University Press, 1947, pp. 101-6.

[29] For the curricular grid for the primary school years (grades one through three), see Paul F. Brandwein, *Teaching Gifted Children Science in Grades One Through Six*. Sacramento: California State Department of Education, 1973. p. 12.

[30] For a similarly developed curriculum and a discussion of conceptually based curricular structures, see Paul F. Brandwein, *Substance, Structure, and Style in the Teaching of Science* (Revised edition). New York: Harcourt Brace Jovanovich, Inc., 1968, pp. 6-17.

Chapter 4

Development of Independence

Gifted children must follow their own pace and their own thrust, for it is not only their work but also their work habits that are crucial. Certain gifted children may become the scientists of the future; in fact, all the scientists of the future are or will be in our classrooms. If in the junior and senior high school there is a curricular design in which gifted children can demonstrate their independent style of life and their arts of investigation, the gifted students in science, our future scientists, will not only be identified but their talents will be carefully nourished.

In a horizontal development, an example of such nourishment is teaching advanced mathematical aspects of biology, chemistry, and physics. Gifted children can work and do enjoy the mathematics involved in Mendelian ratios, the Hardy-Weinberg law, quantitative problems in chemistry and physics, and calculus. In a program for the gifted, the tone of the science can be different, as well as its content.

Background for Creativity

Bernice Eiduson has remarked, "As I listened to the scientists' opinions on happiness, I was impressed with two things. Most of the scientists carve out degrees of freedom for themselves with marvelous ingenuity and imaginativeness."[31] A gifted child, particularly one who is to be a scientist, must learn to "carve out degrees of freedom" for himself. This is one of the skills of independence. How is this to be done?

In a study of creativity, Thomas Sprecher discovered that both ideas and work habits (independence to plan own activities) are considered by engineers and psychologists to be essential characteristics of creative individuals. Those who were surveyed rated independence, ability to generate novel ideas, and the liking of problems high on the scale of creativity.[32] Whichever study of creativity is

[31] Bernice T. Eiduson, *Scientists: Their Psychological World.* New York: Basic Books, Inc., 1962, p. 164.

[32] Thomas B. Sprecher, "A Proposal for Identifying the Meaning of Creativity," in *Scientific Creativity: Its Recognition and Development.* Edited by Calvin W. Taylor and Frank Barron. New York: John Wiley and Sons, Inc., 1963, pp. 77-88.

examined, independence is found as a primary virtue of the creative individual. Indeed, it characterizes the vast majority of gifted children, for it is a syndrome trait combining a variety of intellectual and emotional traits.

The function of the school is clear: to develop an environment in which independence can flourish. Related elements that should be fostered are curiosity, courage, individual style, the capacity for hard concentrated work, the ability to make decisions, the skill of isolating problems, and so on.

The alchemy of independence, of individual creative acts, comes out of past experience and comprises the skills achieved from interdependence. Independence stands on a pyramid of the work done in the past; even Newton "stood on the shoulders of giants." Theories are blurted out and are guessed at from rich acquaintance with the data. Creative acts are in effect based on a prior life rich in experience. For this reason, it is crucial in the earliest years to provide an appropriate background for creativity.

Most of the scientists in an in-depth investigation conducted by Anne Roe were found to be firstborn children. A useful explanation seems to be that independence training is part of the life of the firstborn.[33] A similar study by this author had similar results, indicating that gifted science students are independent in their work habits.[34] Contributors in any field are in large part autonomous, and autonomy requires the work habits and personality traits categorized as independence. For this reason, and others, independence training is perhaps as important as any other aspect in the curricular and instructional program for the gifted.

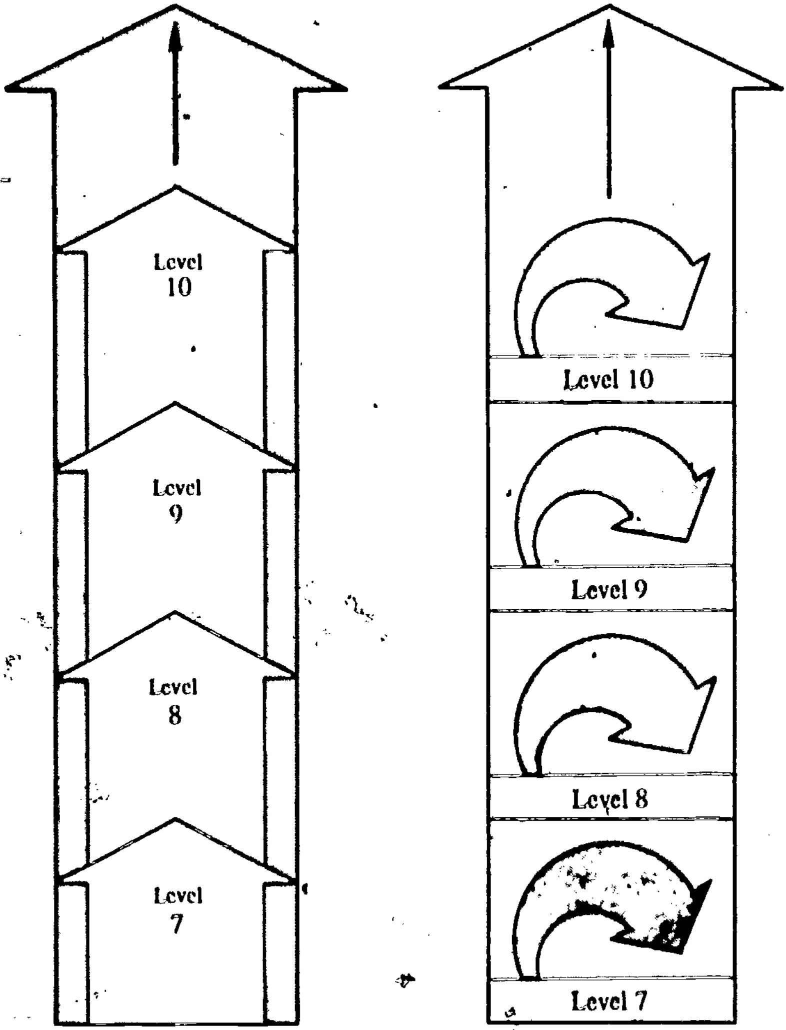
Independence Training in Junior High School

Independence training of children in the junior high school can be accomplished in either of at least two curricular progressions (Figure 4). The two types of progression are the following:

1. *Nongraded progression (continued progress).* Each student progresses as surely and as rapidly as his giftedness permits. At each stage of experience, interviews and demonstrations of his activity determine his growth in concept seeking. For example, a student who has accomplished a Learning Activity Package at

[33] Anne Roe, *The Making of a Scientist.* New York: Dodd, Mead and Co., 1953, pp. 70-4.

[34] Paul F. Brandwein, *The Gifted Student as Future Scientist: The High School Student and His Commitment to Science.* New York: Harcourt Brace Jovanovich, Inc., 1955, pp. 54-60.



Nongraded progression

Enrichment within the grade

The teacher observes the child in activity and guides him to ever more complex activity. As the teacher is satisfied that the child has an adequate grasp on the concept at his level, the child is encouraged to proceed to the next level, or halt and rest and then proceed.

It is entirely possible for a gifted child at what might normally be the chronological age for grade seven to be doing level-ten or even level-eleven work.

The child remains at the grade level consistent with his chronological age (and at a grade level coordinate with his nongifted peers). However, his program is enriched.

Fig. 4. Comparison of independence training in two curricula

Level Seven can advance to Level Eight and undertake the next mini-LAP.

2. *Enrichment within the grade.* Each student is grouped in and progresses by grades. The gifted children are given opportunities to proceed in depth in any module of activity or LAP that is based on a concept. They do not proceed to the next level but probe more deeply into concept seeking at that level.

Which strategy is chosen depends on the school, but the weight of evidence seems to favor continuous progression (nongraded) as the most useful for developing independent activity of the gifted and rewarding it. Advance in learning activity apparently constitutes a major reward for the gifted child. John Goodlad has pressed this point again and again, as have other psychologists.[35]

In essence, what is being suggested for a curriculum and its component instructional devices are (1) activity common to all children that is part of a determined level of learning and (2) independent idiosyncratic activity for those who can profit from it. The latter is of course for the gifted child, who is characterized mainly by his ability for independent, idiosyncratic, innovative, imaginative activity.

In the primary years (grades one through three), in the environment of a rich program combining the skills of interdependence with those of independence, children are beginning to develop their ego strength. As they make their way, they need to hold the hand of the teacher, relinquishing it from time to time. It is assumed that the school staff will fashion its own curricular instrument based on evaluation of the children's background. Nevertheless, there is still available a host of curricula (with concepts, generalizations, principles, and facts) in the same family of curricula as that sponsored by the California State Advisory Committee. In addition to a basic conceptual structure, these curricula have instructional materials adapted to the "norm" and to the gifted.[36]

In the end, the children are to be freed from their dependence on the teacher, and the teacher is to be freed from the burden of assuming that everything children are to learn is to be learned from her. Gifted children should be allowed to learn some things (by high school, most things) without supervision and without direction by the teacher. They can of course ask for direction or supervision, or

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[35] John I. Goodlad and Robert H. Anderson. *The Nongraded Elementary School* (Revised edition). New York: Harcourt Brace Jovanovich, Inc., 1963, pp. 154-5.

[36] A variety of new, conceptually oriented programs are being developed by federal committees and private groups. Many of these programs are now available from publishers.

direction can be provided when it seems indicated for the physical or mental welfare of the child. But generally for the gifted, the less intervention by an adult, the better. In junior high school, intervention of the teacher should be reduced as the student grows in ego strength. But he grows in ego strength as he is given opportunity to do so, and this requires encouragement and reward.

Curriculum for Junior High School

Whether student progress is based on nongraded progression or enrichment, the curricular module in the junior high school should stress and encourage both independent activity and growth in the art of investigation. Towards this end, the curricular module of choice in the junior high school for the gifted student might well be a form of a Learning Activity Package (LAP). LAPs can be developed for each major concept in the vertical and horizontal grids of Figures 5 through 7. To demonstrate how a LAP can be used to instruct gifted in the skills of interdependence and independence and the arts of investigation, the following LAP (see Figure 8) has been devised, based on the State Advisory Committee's theme F-1.[37]

Designing a Learning Activity Package

Assume that the boys and girls entering the junior high school have been assessed for their knowledge and skills as shown in their cumulative records and through interview, tests, discussion, and achievement in the first few months of the year. Assume that a curricular organization (either longitudinal or horizontal) has been developed on the basis of the evaluation results. Assume further that this operational goal is accepted: to create an environment in which the gifted student takes increasing responsibility for his own learning. A curricular module in which this operational goal is realized is the Learning Activity Package (LAP). (For students of any age, a LAP in science requires an adequate library and laboratory. There is little point in developing a program for the gifted in science unless books, equipment, and working space are available.)

The fundamental outlines for developing LAPs are shown in Figures 5 through 7. It should be noted, however, that there are significant differences in LAPs designed for the intermediate years (grades four through six) and those designed for the junior- and

[37] *Science Framework for California Public Schools: Kindergarten Grades One Through Twelve.* Prepared by the California State Advisory Committee on Science Education. Sacramento: California State Department of Education, 1970, pp. 34, 100, and 101.

	OVERARCHING CONCEPTUAL THEME I Matter and energy are manifestations of a single entity: Their sum in a closed system is constant.			OVERARCHING CONCEPTUAL THEME II Units of matter interact.	
	Conceptual Scheme A Energy exists in a variety of convertible forms.	Conceptual Scheme B Matter is composed of particles that are in constant motion.	Conceptual Scheme C Living things are highly organized systems of matter and energy.	Conceptual Scheme D Interdependence and interaction with the environment are universal relationships.	Conceptual Scheme E The bases of all interactions are forces whose fields extend beyond the vicinity of their origin.
Level 8	The sum of matter and energy in a closed system is constant (more advanced mathematical treatment as compared with Level 5).		Combinations and recombinations within the genetic code produce new varieties of organisms.	Modern species are the result of speciation through the ages.	The present Earth (the planet) is the result of continuing change.
Level 7	Changing the nucleus of an atom results in changes in the physical and chemical properties of the atom (formulations and mathematical treatment).		Mutations in the genetic code produce new varieties of organisms.	Organisms fitted by adaptation to the environment survive.	Geologic periods coincide with constructive and destructive changes in landmasses.
Level 6	The behavior of the outer electrons of the atom affects the manner of combination of atoms (formulations and simple mathematics).		Combinations and recombinations in the genetic code affect the characteristics of organisms.	Changes in the environment affect the movement and distribution of organisms.	Constructive and destructive forces affect the movement of landmasses.
Level 5	The sum of matter and energy in a closed system is constant (descriptive and simple mathematics).		The organization of living systems is based primarily on the genetic code.	The environment is and has been in constant change.	The motion and path of microscopic bodies and particles are affected by forces.
Level 4	The amount of energy gotten out of a system does not exceed the amount of energy put into it.	In chemical or physical changes, the total amount of matter remains unchanged.	The cell is the unit of structure and function.	As organisms develop, they convert matter and energy into the species form.	The motion and path of atmospheric masses are affected by forces.

Fig. 5. Curricular grid for the intermediate years and part of junior high school

	Unit A	Unit B	Unit C	Unit D	Unit E	Unit F
Level 9	The motion and direction of electromagnetic waves are a result of forces acting upon them.	Changes in the atomic nucleus are basic to the development of energy resources.	Man as organism affects the resources of the planet.	Mutation is the result of heritable changes in the characteristics of organisms.	Modern species are the result of speciation through the ages.	The present Earth (the planet) is the result of continuing change.
Level 8	The motion and direction of particles are a result of forces acting upon them.	Changes in the nucleus of the atom result in changes in the properties of the atom.	The supply of renewable, nonrenewable, and inexhaustible resources of an area is affected by change in movement of land, sea, and air masses.	Combinations and recombinations within the genetic code produce new varieties of organisms.	Organisms fitted by adaptation to the environment survive.	Geologic periods coincide with constructive and destructive changes in landmasses.
Level 7	The behavior (motion and direction) of objects is a result of forces acting upon them.	The behavior of the outer electrons of the atom affects the manner of combination of atoms.	The behavior of atmospheric masses effects change in the environment.	Combinations and recombinations in the genetic code affect the characteristics of organisms.	Changes in the environment affect the movement and distribution of the organisms.	Constructive and destructive forces affect the movement of landmasses.

Fig. 6. A vertically developed conceptual structure for the junior-high-school curriculum

	Unit A	Unit B	Unit C	Unit D	Unit E	Unit F
Level 9 Energy	The behavior (motion and direction) of objects is the result of forces acting upon them.	The motion and direction of particles are the result of forces acting upon them.	The motion and direction of electromagnetic waves are a result of forces acting upon them.		Mass-energy is conserved.	
Level 8 Matter	The present Earth (the planet) is the result of continuing change.	Constructive and destructive forces affect the movement (change) of landmasses.	The behavior of atmospheric masses effects change in the environment.	Matter—whatever forms it takes—is particulate in nature.	Combinations and recombinations of atoms are the results of the behavior of outer electrons of the atoms. (In chemical change, matter is neither created nor destroyed.)	Changes in the nucleus of the atoms result in changes in the properties of the atoms. (In nuclear change, the sum total of matter and energy is constant.)
Level 7 Life	Organisms are adapted to a variety of environments.	Organisms are adapted by structure and function to their environments.	Organisms interchange matter and energy with each other and with their environments.	Organisms in great variety are distributed in a variety of environments.	The characteristics of organisms are affected by combinations and recombinations in the genetic code.	Modern species of organisms are the result of speciation (change) through the ages.

Fig. 7. A horizontally developed conceptual structure for the junior-high-school curriculum

senior-high-school years. In junior high school, the following elements are emphasized over and above those for the intermediate years:

1. More independent laboratory work (clearly the laboratory is an integral part of the work in the junior high school).
2. More extensive reading and emphasis on the skills of using the library.
3. A variety of projects, providing "routine" projects for the conventionally gifted and truly experimental work for the singularly gifted.
4. A truer attempt at experimental work for the singularly gifted, with all the earmarks of originality; thus, the arts of investigation are learned. (In the senior-high-school years, truly original research can be practiced by the singularly gifted.)

A Sample LAP

The following example of a LAP (Figure 8) for the junior high school consists of extensive directional outlines for one aspect of the State Advisory Committee's theme F-1, which states, "Matter is organized into units which can be classified into organizational levels."[38] The example LAP is in effect a mini-LAP. It is based on the following subconcepts of theme F-1:

- The Earth's atmosphere is organized into particles that can be classified.
  - a-1 The Earth's minerals have characteristic physical properties.
  - a-2 The Earth's minerals have characteristic chemical properties.

Stemming from subconcept a-1 above, the following concept statement has been derived and used as the basis of the example mini-LAP: *the orderly arrangement of atoms, ions, or molecules that make up a crystal determines the form of the crystal.*

In the mini-LAP that follows, directions are for the student. Comments for the teacher are interspersed to aid in developing LAPs for the junior high school. It is of interest to note at this point that a complete LAP for the junior high school is approximately 6,000 words long (about 32 double-spaced pages). The following mini-LAP is not a complete LAP, but it does indicate how a LAP can be developed.

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[38] *Science Framework for California Public Schools: Kindergarten–Grades One Through Twelve.* Prepared by the California State Advisory Committee on Science Education. Sacramento: California State Department of Education, 1970, pp. 34, 100, and 101.

The Crystalline State

(LAP 17, ______________________ School)

Introduction

You are an inhabitant of the planet Earth. You are not a Martian nor an inhabitant of Venus. Could you prove you inhabit Earth? How? (This is an interesting question, and you may want to look into it.)

1. First, what do you know about the Earth? Could you describe it to a Martian if one visited you or you visited him? What would you say? You may want to review your notes for your work in LAP 15 (The Earth) and LAP 16 (The Rocks of the Earth). Or perhaps you would like to review pages____ in your basic text or one of these books:

   [TEACHER—Provide at least three references here.]

   After you are satisfied that you know how to describe your Earth and its major forms—mountains, oceans, seas, rivers, the major rocks—begin to examine what is meant by the "crystalline state."

2. For this study, you will want to grow several kinds of crystals. Plan your work so that as you grow your crystals, you will be reading about the nature of crystals. The growing of a crystal may take two days to a week. Plan your time carefully. A few suggestions may be in order.
   a. Be sure you have your apparatus and materials. For example, you will need jars to grow your crystals and substances such as copper sulfate and potassium aluminum sulfate (alum). You may want to grow sugar crystals.
   b. You may want to plan your work with the help of your consultant. In any event, you are to be able to show your consultant a crystal you have grown and to explain how you grew it. *[TEACHER—The teacher is the consultant.]*
   c. In addition, be certain to do the apprentice investigations on pages____and____of your text.
   d. Some references you may want to consult on the growth of crystals are these:
      1. Pough, Frederick H. *A Field Guide to Rocks and Minerals.* Cambridge, Mass.: Houghton Mifflin Co., 1960.
      2. Holden, Alan, and Phylis Singer. *Crystals and Crystal Growing.* Garden City, N.Y.: Doubleday and Co., Inc., 1960.

      Pough's book is one of the more useful references. (Of course, by now you know that you are to begin all reference work by consulting your basic texts or any other basic reference suggested by your consultant.)

3. When you have grown a crystal and when you have tested your understanding of crystalline structure and growth by taking self-appraisals 19 and 20, go on to step 4. (Be sure you make an appointment with your consultant to take these tests.) *[TEACHER—By this time the students will be quite clear in their understanding that the self-appraisals are for their guidance and that there is no point in slighting*

Fig. 8. An example mini-LAP

an area in which their knowledge is not secure. Many times students go back to review further and ask to take the self-appraisal again.]

4. Now perhaps—if you are interested in doing experimental work with crystals—this section is for you. If not, if you wish to proceed to the next LAP (The Ionic State), arrange with your consultant for an interview on your progress. *[TEACHER—At this point, students working with a LAP may come to the consultant for an interview-appraisal. In one school, the interview-appraisal is conducted as follows. Students have available to them several files of cards with questions (recall, analytical, problems, formulas, item making, reasoning, and concept analysis). A number of the cards contain experimental data and items concerned with methods of intelligence (inquiry processes). These files may be studied at any time. During the interview-appraisal, the student may be asked to select a card at random and answer the question. Thus, concept-seeking and subject-matter competence are under constant scrutiny.]*

For the Investigator

These investigations are on your own. Follow the laboratory procedures in LAP ⌀1, which include developing an experimental design, presenting your experimental design to your consultant, getting approval, ordering equipment, and so forth.

Projects

1. What is the smallest crystal of copper sulfate or potassium aluminum sulfate you can make?
2. Many years ago, crystal radios were made. What is a crystal radio? How does the crystal work?

Experimental designs

You will recall that one of the major advantages of working independently through the Learning Activity Package is planning and prosecuting at least one experiment or original investigation in any year. The arts of investigation are learned through engaging in fairly original investigations.

If you have not already made your selection from the list suggested, you may want to do so now. If you are developing an experimental design with a scientist outside of school, please be certain to inform the chairman of your Investigator's Group and your consultant.

When you are fairly certain of your results, present them to your Investigator's Group. If your investigation holds up to the challenge of the analysis of your group, you may want to present your paper to the Monthly Science Congress. Your consultant will arrange this. *[TEACHER—Each student has the advice of his Investigator's Group (five students). The Science Congress is a meeting of the entire class (or suite) at which the student investigators present papers.]*

With your consultant's approval, you may organize team research over a period of a year or more.

Fig. 8. An example mini-LAP (continued)

Evaluating Student Progress

If children do the learning through the curricular module of a LAP, if it is they who do the responding, and if it is they who are engaged in acquiring the skills of interdependence and independence, then their acts give constant opportunity for evaluation of their growth. In other words, the children "test" themselves each day by their own performance.

In observations of children learning by means of the LAP and similar devices, it has been found that self-evaluation and opportunity for more or less objective evaluation by the teacher is constant. Furthermore, not only is subject-matter competence evaluated, but also growth in the utilization of the methods of intelligence (inquiry processes) is part and parcel of the appraisal. For the student is constantly at work, truly "learning by doing."

Of course, standard tests for comparing achievements may be desirable, and written tests may be useful for helping children determine their own progress. The gifted have prodigious memories and analytical qualities, and grades are reaffirmations of known ability. Gifted students make high grades easily; their base grade is usually A+. If their grade is less, students should not be in a class for the gifted, unless they are potentially gifted children who need time and opportunity to develop background.

Achievement per se is not the sole, nor possibly the most important, element in the development of ego strength and self-esteem. Stanley Coopersmith considers the elements that underlie self-esteem to be the following:

1. Significance—acceptance, attention, and affection of others
2. Power—ability to influence others
3. Virtue—possession of moral and ethical standards
4. Competence—successful performance in meeting the demands for achievement[39]

The kind of program recommended in this publication is based on the mutuality of interdependence and independence and engenders an environment in which competence, power, virture, and significance are nurtured. The building of self-esteem in the gifted is the aim of nourishing their potential in such a program.

To illustrate the inadequacy of grading, the following example of student work is presented. To have to decide on a grade for the student's achievement would be at best an arbitrary and/or perplexing task.

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[39]Stanley Coopersmith, *The Antecedents of Self-esteem*. San Francisco: W. H. Freeman and Co., 1967, p. 38.

R.M. (age 14 years 6 months) noticed a few small beetles in a sack of wheat flour her mother had brought home. She identified them as *Tribolium confusum;* she decided to grow them. She assumed that the flour must be full of the eggs of the beetle or that there were females with eggs. In six months, the meal was rich in the beetles; her assumptions were apparently correct.

On examining the beetles with a hand lens, she found some with abnormalities, e.g., an extra appendage. She tried to produce more abnormalities by various devices, including warmth, cold, light, and agitation. Agitation was most effective.

By consulting with scientists, and through her own well-designed experiments, she hypothesized that when the beetles are disturbed, a gas is produced by the beetles. This gas produces abnormalities. What grade does one give such a student?

Senior-High School Science Curricula

Present curricula in the high school are usually based on a course module; that is, courses such as biology, physics, and chemistry are the basic modules in the curriculum. For the gifted, this may not be the choice curriculum. A curriculum for the gifted might be better based on a consortium module, which has the following basic elements:

1. A consortium of individuals from university, community, and high school to plan for the gifted
2. A curriculum that is the result of the planning of the consortium and that is planned for a particular cadre of gifted
3. A series of learning activities (Learning Activity Packages) and a body of research activities from which research problems are derived

The model Learning Activity Packages developed for the intermediate (grades four through six) and junior-high-school years indicate how a consortium can plan somewhat different course modules.[40] The choice of approach depends on the population of the school and on the life-styles of the teachers, supervisors, administrators, and community. As the California State Advisory Committee on Science Education suggests, it is the teaching staffs that need to decide which variety of curricular modes (or combinations of curricula) and approaches to instruction provides the widest base or orchestration of experiences.

A curricular and instructional mode that fosters the skills of interdependence is, for the gifted at least, nonfunctional unless it

[40] For the model intermediate LAP, see Paul F. Brandwein, *Teaching Gifted Children Science in Grades One Through Six.* Sacramento: California State Department of Education, 1973, pp. 51–7.

also fosters the skills of independence. Furthermore, any curricular mode selected as useful in a program for the gifted should support acceleration and/or enrichment in a variety of administrative forms; i.e., in graded or nongraded (continuous progress) organizations of schools. The gifted can proceed at their own rate, and a nongraded program, where feasible, serves them well.

In the high school, provision needs to be made for both the conventionally gifted and the singularly gifted. This distinction needs making, for the singularly gifted may require greater freedom. The conventionally gifted may be those whose range of accomplishment is highly commendable, but theirs may not ever be original work. They may not ever be contributors of new knowledge. The singularly gifted, on the other hand, are unique. Their work is idiosyncratic, and, if properly nurtured, it is expected they will make original contributions.

Creative or new work is of at least two kinds. It may be new to the individual and to the class and to the community, or it may be new to the world. The work of the conventionally gifted may be remarkable, laudable, and admirable. Nevertheless, their future is generally in new orchestrations of the known. The singularly gifted broach and breach the unknown. Of course, whether work is considered original or not depends on many judgments of the progress in growth the child makes. One may be satisfied with what is considered original (that is, new to the child and the school) but not new to science.

At least two approaches in the uses of the curriculum are possible: (1) acceleration and (2) enrichment. It is probable that in the high school acceleration can presently be provided mainly through the Learning Activity Package rather than nongraded instruction per se.

The curricula that are the orchestrations of legacy and adventure are hierarchies of concept-seeking patterns. For gifted children, hierarchies and intellectual orchestrations break down. Even the most explicit curricula and hierarchies are in truth milieus in which the gifted child roams and jumps predictable sequences. For the gifted child, a curriculum of concept-seeking patterns is mainly and merely a taxonomy of cognitive tools. It is a map that enables the teacher to plan a course, but, in the end, it also is a tool through which the teacher and the gifted child's peers communicate with him and understand him.

A concept cannot be divorced from the processes that give it life. A concept cannot be told to children. It comes out of their activity, some of which is inquiry oriented. But all activity in the classroom is not, and cannot be, inquiry process in the sense of experimental inquiry. Concept seeking is inquiry. Recall that Bridgman, a Nobel laureate in physics, insists that a "concept is synonymous with the corresponding set of operations."[41] Clearly, then, one should not separate concepts and inquiry processes; they are two sides of the same coin, two faces of unified activity in thought, a single result of "sciencing."

What the gifted need is to acquire a life-style in their own thinking and work, a life-style that from the viewpoint of the intellect embodies the overwhelming desire to defeat one's own hypothesis. This is recognized to be a behavioral objective of instruction for all children, but it is critical for the gifted, whose hypothesis may be central to the advance of knowledge. It is for this reason that in the high school, part of a curriculum for the gifted should encourage research in the truest sense; gifted students should do a bona fide experiment or original investigation. This research can be accomplished in either of two curriculum modules, a course module or a consortium module.

The Course Module

In the high school, the traditional curricular module, even for the gifted student, is the course. As has been indicated, in recent years, federally funded committees have developed course structures in biology, chemistry, geology (earth science), and physics along conceptual lines. The traditional course sequence is still biology in grade ten, chemistry in grade eleven, and physics in grade twelve. In other sequences, biology and/or earth science are given in grades nine and ten, followed by chemistry and physics.

Usually, for the gifted, the biology course is Biological Sciences Curriculum Study (BSCS) biology.[42] Chemistry is the course developed by the Chemistry Education Materials Study (CHEMS).[43] (There are very few Chemical Bond Approach [CBA] courses given.) Physics is the course of the Physical Sciences Study Committee (PSSC).[44] The overall structure of BSCS biology is based in part on the following conceptual themes, which are related to the California science framework:

1. Organisms are interdependent with each other and with their environment (theme G-2).

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[41] Percy W. Bridgman, *The Logic of Modern Physics.* New York: Macmillan Co., 1927, p. 5.

[42] See footnote 16 concerning BSCS biology courses.

[43] *Chemistry: An Experimental Science.* Edited by George C. Pimentel. San Francisco: W. H. Freeman and Co., 1963.

[44] Uri Haber-Schaim and Others, *PSSC Physics* (Third edition). Boston: D.C. Heath Co., 1971.

2. Organisms are the product of their heredity and environment (themes F-1, F-2, and F-3).
3. Modern organisms are the result of development over past ages (themes F-1, F-2, and F-3).
4. Structure and function are often interdependent (theme F-3).[45]

The overall structure of CHEMS chemistry is based in part on the following conceptual themes:

1. Matter is composed of particles which are in constant motion (theme C).
2. Units of matter interact (theme G).
3. Matter and energy are manifestations of a single entity: their sum in a closed system is constant (theme E).[46]

The overall structure of PSSC physics is based in part on the following conceptual themes:

1. Matter and energy are manifestations of a single entity: their sum in a closed system is constant (theme E).
2. The bases of all interactions are electromagnetic, gravitational, and nuclear forces whose fields extend beyond the vicinity of their origins (theme G-1).[47]

Laboratory work (rich in potential for individual effort), field work (rich in individual research problems), and mathematical analysis (rich in potential for synthesis of concepts) are pervasive through the courses.

In current practice, most courses are centered on the teacher's efforts, rather than on the student's. The teacher synthesizes, presents, and clarifies; the student is often passive. In other words, the teacher essentially lectures. Whether the course module or the consortium module is used in the high school, emphasis should be put on the skills of independence. The method that appears most useful is the Learning Activity Package (LAP).

Gifted students in science (who are usually gifted in mathematics as well) can take a sequence of physics, chemistry, and biology,

[45] *Science Framework for California Public Schools: Kindergarten Grades One Through Twelve.* Prepared by the California State Advisory Committee on Science Education. Sacramento: California State Department of Education, 1970, pp. 34 and 99-106.

[46] *Ibid.*, pp. 34, 94-99, and 102-108.

[47] *Ibid.*, pp. 34, 97-99, and 103-104.

rather than the usual sequence of biology, chemistry, and physics (Table 2). It seems reasonably clear that chemistry uses concepts basic in physics, while biology uses concepts basic in physics and chemistry. Further, it is expected that high-school work for the gifted will be closely articulated and based on work in the areas of life (biology), matter (geology and chemistry), and energy (physics), and that the courses will receive mathematical treatment.

Table 2
Suggested Course Sequence for the Science Curriculum

Grade	Course Sequence: Gifted	Course Sequence: Other students
10	Physics—highly mathematical treatment	Biology
11	Chemistry—based on physics, with concomitant mathematics	Chemistry
12	Biology—based on physics and chemistry, with concomitant mathematics	Physics

NOTES: Required mathematics can be given concomitantly with the physics course for gifted. Preparatory mathematical work can begin in grade seven. In grade ten, gifted students can do calculus.

Students in the "other students" category often do not complete the entire course sequence. The majority do not take chemistry and physics.

The Consortium Module

The course module is the curricular device most commonly in operation in the United States, even for gifted and slow students. The advantages of the consortium module are that it makes optimum use of resources of the community and is more facile for planning for the idiosyncratic nature of the gifted. As observed in operation in one locale, the community resources of the consortium included the following:

1. University and college representatives from physics, chemistry, biology, geology, psychology, and education departments
2. Community representatives from engineering, medicine, and industry
3. High school science and mathematics staffs
4. Assistant principal and/or curriculum director
5. Assistant superintendent of instruction and members of the Board of Education
6. Members of the press

The responsibilities and functions of the consortium organization in the example being cited were the following:

1. High school staffs
   a. To develop assistance of other members of the consortium
   b. To develop general curricular and methodological policy, including (1) structure of the curriculum, (2) nature of instruction, (3) nature of evaluation, and (4) special methods of instruction for individual students
   c. To design special facilities and, when necessary, develop instructional materials
2. College and community component
   a. To make available special facilities and equipment such as hospital, college, and industry laboratories and libraries
   b. To make special guidance available to gifted students

After a series of meetings over a six-month span, the consortium organization made the following decisions:

1. The biological science course was to be basically the BSCS blue version (with strong emphasis on molecular biology). The biology course was to be mathematically oriented and based on Learning Activity Packages.
2. A two-year physical science course combining physics, chemistry, and geological physics should be given in grades eleven and twelve. This course should be based on Learning Activity Packages. At least three of the Learning Activity Packages should include aspects of biochemistry and biophysics (these "biological" LAPs deal with inquiry systems, photosynthesis, and molecular biology).
3. At least one experiment, preferably two, was to be designed by each student in research science. Research science was to be open to any student with a B average in all subject areas and with a percentile score above 90 in a standard test in verbal and mathematical reasoning. Other students could enter research science (whatever their records of achievement or scores on tests) upon recommendation of a panel of science and mathematics teachers (including a guidance counsellor). The research problems in biology were to be based on the BSCS publication *Research Problems in Biology*.[48] Problems in physics and chemistry were to be developed in consultation with the university and college members of the consortium.

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[48] Biological Sciences Curriculum Study, *Research Problems in Biology: Investigations for Students*. Garden City, N.Y.: Doubleday and Co., Inc., 1963.

The consortium did not base LAPs on preexisting courses but synthesized its physical science course. For example, while PSSC and CHEMS courses were used, some LAPs were also based on Harvard Project Physics.[49] Further, the consortium was able to convince the administration (including the Board of Education) to institute modular scheduling—permitting a variety of time schedules for instruction. Thus, there could be lectures (50 minutes), double laboratory periods (120 minutes), discussions (45 minutes), planning periods (30 minutes), and so forth.

The consortium was able to raise funds through industry to advance the library fund, the fund for audiovisual aids, and for equipment.

The consortium provided special seminars in which gifted students met scientists at work. Thus, students had greater opportunity to meet the surrogate figure, the key figure who is so important to the potential scientist. The gifted students were also able to develop insight into the ways of the scientist, into the character and commitment of those who probe the universe.

[49] G. Holton and Others, *The Project Physics Course*, New York: Holt, Rinehart and Winston, Inc., 1970.

Epilogue

Scientists have a commitment similar to that of teachers. They are, in a sense, immortal because their work is eternal. Just as a teacher lives in the students who have accepted his life as mode and model, so the work of the scientist lives on in the continuity of the work of those who come after him. Moreover, science, like teaching, like the ministries of scholarship, does not fatigue those who are committed to it. Science, like teaching, is an act of conscience. And like teaching, it is supremely a moral response to the questions of life. The gifted student, once scientist, has not only informed his conscience but informed the world.

For this purpose, it is not enough to develop a curricular scope and sequence that promotes intellectual development confined to normal expectancy and that is graded in the usual way. What is needed is a curriculum that promotes and catalyzes the *independent activity* of children. Cumulative records describing kinds of activities of gifted students are significant; in them, the present grading systems are found to be totally inadequate. For the aim for the gifted is superordinate: to develop independence of grading and appraisal by others and to stimulate self-appraisal and the development of self-esteem through independent, idiosyncratic activity.

However, once independent activity is encouraged, instructional problems may occur since children engaged in independent activity probe their own personalities to the limit. Even as they are idiosyncratic, original, and independent, the gifted must be taught to "suffer" intellectual constraints and restraints. The gifted, having chosen their parents properly, tend not to suffer restraint gladly. But the child needs to learn humility and to learn it through example; what the teacher does speaks so loudly, the children cannot hear what she says.

The teacher needs to play the role written in the single behavioral objective, which undergirds the methods of intelligence. The behavioral objective is this: *between impulse and action, to interpose evidence, reason, and judgment.*[50] This is the prime objective of

[50] Paul F. Brandwein, *The Permanent Agenda of Man: The Humanities.* New York: Harcourt Brace Jovanovich, Inc., 1971, p. 49.

science teaching. It has relevance and power and meaning for human endeavor.

Imagine a world in which evidence, reason, and judgment could be the tribunal to which personal behavior is brought. Imagine individuals reducing compulsiveness and the reflexive action of prejudice and hate and substituting compassion in their place. Imagine the children coming out of our schools interposing evidence between impluse and action. What a reasonable world this would be. And a compassionate one.

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