

INDIVIDUALIZED SCIENCE IN FOCUS

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Individualized Science is an elementary-school science education program that is relevant. It is relevant to the child and it is relevant to the social circumstances of the day. The program has been under development since 1964 at the Learning Research and Development Center, University of Pittsburgh, in cooperation with the Oakleaf School, a public elementary school in the Baldwin-Whitehall School District. In this paper, I would like to discuss the concerns that underlie the design of *Individualized Science* and to describe the main features of the program's organization and operation which represent our response to these considerations.

In designing a school science program, we must think first about the child. This does not suggest a maudlin, hand-wringing concern about the child, but a realistic appraisal of the child's need for orientation in the world. We know that the world which the child faces daily shows itself to him as a buzzing, booming confusion filled with contradictions. How can the study of science help the child to unravel some of these contradictions and to make some sense out of his world? The young child in the elementary school, if he is thoughtful, —and what child is not thoughtful in his own way? — is probably most concerned with the functions of his own body and with what transpires in his immediate surroundings. It doesn't seem unreasonable, then, that the child's experiences early in his science program should try to help him to unpuzzle things in those areas. The child has many other pushes and tugs, — differing curiosities, questions, interests. These vary widely from one child to another due to differences in background, capacities,

and as-yet-unfathomed aspects of personality. It is therefore apparent that the study of science should seek to give each child some methods and skills for attacking the questions which tug at him and some useful frameworks in which to fit the answers. Perhaps what an elementary-school science program really can accomplish is to make the child's world appear less contradictory to him, so he may feel safe in it.

Our second concern in designing a science program is that the subject-matter content should be relevant to the social circumstances of today and the foreseeable future. All of us are aware of the problems and issues raised by the unbridled growth of human population, the pollution of our natural environment, the everyday hazards of living in a technological age. To understand and seek solutions to these and other problems of contemporary society, the individual should have a firm grasp of the essential scientific ideas related to these problems. Since the life of the elementary-school student is and will be mightily affected by how these problems are resolved, and he may even be a participant in solving them, what better place is there for him to begin to develop understanding of the relevant scientific ideas than in his study of science? Five groups of current and imminent social problems contain a sizeable science component, a subject-matter pool from which the science content in most of the instructional units of *Individualized Science* is drawn. The units are organized around the science content, not around the social problems. The five problems and their science components are:

Problem 1. Overpopulation and its consequences: air pollution (industrial, private, chemical pollutants); water pollution (industrial, private, chemical pollutants, radioactive pollutants); strain on ecological balance; strain on resources (water, clean air, food, space); and quality of life in cities (overcrowding and aggression, noise, sanitation). The relevant science content is: human reproductive system, birth, growth, development, death, reproduction, contraception; atmosphere, composition, movement, weather, climate; conversion of energy in living things, oxidation (respiration and combustion), sun as energy source, photosynthesis; chemistry and physics of certain industrial processes, water and solutions; physiological effects of chemicals and radioactivity on plants, animals, and man; micro-organisms, decomposers of wastes, carriers of disease, transmittal of disease; the ecosystem, ecological niches, diversity of species, natural selection; cycles, carbon dioxide, oxygen, nitrogen; food chains, predator-prey relationships; man's requirements for good health, nutrition (essential elements, sources, substitutions), growth, nurture and selective breeding of food animals; conservation of natural resources, water, mineral, plant, and animals; psychological and physiological effects of noise; and social behavior of animals, aggression.

Problem 2. Everyday hazards of technological life; automobiles, electrical gadgets and tools, household chemicals, and household gadgets. The relevant science content is: physics principles (momentum, expansion, moments, levers); electrical circuits; electrical units; physiological effects of chemical agents; and, acids and bases, neutralization.

Problem 3. Biological engineering: transplants; eugenics and genetic manipulation, and drugs. The relevant

science content is: human anatomy and physiology (including circulatory, digestive, nervous, reproductive, endocrine, and immunological systems); cell physiology; and genetics and genetic code.

Problem 4. Extraterrestrial exploration: feasibility and extent; necessity and costs. The relevant science content is: Newtonian physics; propulsion of space vehicles (chemical fuels, nuclear energy); geography of solar system; biological needs of man in space.

Problem 5. War and disarmament: massive nuclear assaults; detection and surveillance; chemical and biological weapons. The relevant science content is: nuclear physics; physiological effects of radiation and radioactive isotopes; electronic systems; effects of chemical and biological agents on physiology of plants, animals, and man.

The content of a few units does not appear on this list. These are the units in the early part of the program which deal with the process skills of observing and measuring. There is something quite interesting about the science content list. At least half of the topics listed are related to topics which the child most frequently asks questions about. This suggests that most of the science content selected for inclusion in the program has relevance both to the social circumstances of today and to the interests of the individual child.

Our third concern stems from one of the consequences of living in a technological age where change is rapid. The continued advent of new technologies has brought about an alteration in the traditional pattern of occupations and careers. No longer does a person choose a career specialty as a youth, train for it in school, and pursue it throughout his life. Rather, the career of a young man

or woman starting to work in the 1980's is likely to include several major occupational shifts, as specific occupations are made obsolescent by technological change. Even within a line of work, there will be few jobs that are not periodically affected by innovations. These characteristics of occupations and careers will require that the individual often learn new skills and tasks and acquire new knowledge. He will be a learner for much of his life, not only during the years of formal schooling. For this situation, the best preparation the school can offer is to help the child become an effective independent learner. Consequently, a science program which is relevant to contemporary social circumstances must make provisions for the student to learn how to learn. This can be done by including in the program's goals not only the customary objectives which pertain to achievement in science subject-matter content and in scientific inquiry, but also objectives for developing the student's skills in self-direction and self-evaluation. While the development of these skills should be a commitment of all school programs in these times, it is altogether fitting to stress self-direction and self-evaluation in a school science program. In science itself, the investigator is obliged to direct his own work and to judge its worth. Self-direction and self-evaluation are a part of inquiry in science. By stressing these same qualities in a science program, we are doing no less than emulating the scientific enterprise, and thereby providing the student with a perspective of scientific inquiry.

On the basis of the three concerns I have just reviewed, we have delineated a set of five goals for the *Individualized Science* program.

- I. Student self-direction goal. The student views the learning pro-

cess as primarily self-directed and self-initiated.

- II. Student co-evaluation goal. The student plays a major role in evaluating the quality, extent and rapidity of his learning.

- III. Affective goal. The student displays positive attitudes toward his study of science, scientific inquiry, and the scientific enterprise.

- IV. Inquiry goal. The student is skillful in using the processes of scientific inquiry and is able to carry out inquiries.

- V. Scientific literacy goal. The student acquires a foundation of scientific literacy.

Some comments on our perception of scientific literacy may be appropriate at this point. Four components are encompassed in the notion of scientific literacy. First is the behavioral component implied by the common literal meaning of literacy, that the student can describe his observations and experiences with terms drawn from his basic vocabulary of science words. A more fundamental component of scientific literacy is the student's understanding of certain important concepts, principles, and conceptual schemes of science. We consider a scientific idea important if it is relevant to the child in orienting himself to the world, both the natural world and contemporary society. A third component of scientific literacy concerns the student's realization that scientific ideas change over time and his understanding of other key ideas related to the nature of scientific inquiry. The fourth component, last in this list but not the least important component of scientific literacy, is the student's understanding of significant ideas related to the social aspects of science. We believe that a

foundation of scientific literacy encompasses all four of the foregoing components.

The goals listed above represent a kind of composite description of a student near the end of his *Individualized Science* program. The student's attainment of any or all of these goals is, of course, a developmental process. We assume that there are identifiable levels in the student's development toward the attainment of the desired goals. We also assume that it is possible to specify most of the student's behaviors related to these five goals at each developmental level in terms of competencies he has attained. In *Individualized Science*, there are ten levels of student development, Levels A through J. The approximate current school grades which correspond to these ten development levels are: A, K-2; B, K-3; C, 1-4; D, 2-5; E, 3-6; F, 4-7; G, 5-8; H, 6-8; I, 6-8; and J, 7-8. Since the student's progress in the program is an individual matter, there is no exact correspondence between the number of years he has spent in school, i.e., school grades, and his developmental level in *Individualized Science*. In the first three levels, A through C, the child is introduced to various processes of scientific inquiry, and he has many opportunities to sharpen his skills in using these processes as he explores in several different areas of science. In the next four levels, corresponding approximately to the intermediate grades, the main focus is on the child's application of his process skills in problem solving and on his accumulation of knowledge and understanding about himself and his environment. In the last three levels, H through J, the child carries out genuine investigations, i.e., inquiries where the answers are not known. He utilizes his process skills and existing knowledge to acquire new concepts, principles, and insights.

A significant element in promoting the student's ability to direct his own learning is the opportunity to make choices. Moreover, an individualized program must make many alternatives available to the student, because different students have different interests. In designing a school program, however, a conflict arises between giving the individual free choice in what he will study and assuring that his needs are met in developing certain recognized skills and understandings. Our resolution of this conflict has been to provide a Mainstream in *Individualized Science* and, at the same time, to offer the student numerous Alternative Pathways. The Mainstream includes a common core of science learnings in which every student is expected to achieve mastery. Units of study on the Mainstream are arranged in a sequence. For example, the Mainstream organization for Levels E and F of *Individualized Science* begins with Voit and continues sequentially through Joule, Beaumont, Powell, and Harvey. Each unit is identified by the name of a scientist who made some contribution to the field of science that the particular unit concerns itself with. Thus, the Voit Unit is concerned with human nutrition, the Joule Unit with the concept of energy, the Beaumont Unit with the processes of digestion, the Powell Unit with the role of water in natural systems, and the Harvey Unit with the circulation of blood in man.

A student may choose to interrupt the continuum of these five Mainstream units at any time by selecting one or several of the activities in the Alternative Pathways. There are various possible Alternative Pathways activities available to students working in the E and F levels. They are: Linnaeus, Copernicus, Archimedes, Volta, Watt, Kepler, Audubon, Drew, and Arrhenius.

Whole units of study, such as the Watt Unit, which is concerned with the expansion and contraction of materials with changes in temperature, or the Linnaeus Unit dealing with the growth of plants from seeds, are available. Each of these Alternative Pathways units arises from possible points of curiosity on the student's part or his desire to know more about topics taken up in the Mainstream units. Other Alternative Pathways activities give the student opportunities to investigate science concepts which may or may not be related to

the subject-matter content of the Mainstream units.

The notion of Mainstream and Alternative Pathways is used, not only at Levels E and F as illustrated, but throughout *Individualized Science*. As the student progresses, he has continually increasing opportunities to select learning experiences in diverse and meaningful Alternative Pathways. Within the units themselves, choices are also offered to the student. In each unit, there is generally a common core of learnings, developed through a sequence of indi-

TABLE 1.—Learning Resources of *Individualized Science*.

LEARNING RESOURCES		Contribute to the attainment of				
		Student Self- Direction Goal	Student Co- Evaluation Goal	Affective Goal	Inquiry Goal	Scientific Literacy Goal
Individual Lesson	(IL)		X		X	X
Individual Taped Lessons	(ITL)				X	X
Men & Ideas Filmstrip	(M&I)			X		X
Mini-Exploration	(MEX)	X	X	X	X	X
Mini-Investigation	(INV)	X	X	X	X	X
Directed Readings in Science	(DRS)		X	X		X
Directed Group Activity	(DGA)			X	X	X
Student Seminar	(SEM)		X	X	X	X
Student Activity	(SA)	X	X	X	X	X
Invitation to Investigate	(ITI)	X	X	X	X	X
Self-Initiated Independent Activity	(SIIA)	X	X	X	X	X
Science Learning Game	(SLG)			X	X	X
Science Books (selected readings)	(BKS)	X	X	X		X
Individual Science Journal (student publication)	(JOUR)				X	X
Guidance and Selection System	(GSS)	X	X			X
Individual Prescription	(IP)	X	X			

vidual lessons, laboratory exercises and investigations, readings, and small group discussions. In addition to the common core, a Mainstream in miniature, various alternative and additional investigations, activities, and readings are available for the student to choose from. In the units also, the student receives instruction in how to manage his learning in *Individualized Science*, through what we call a "Guidance and Selection System." This system makes it possible for the student to practice self-direction within the program. Having experienced and practiced self-direction in *Individualized Science*, the student may well become confident about directing his own learning in many other situations.

I should like to emphasize that we are committed to the realization of all five goals of *Individualized Science*. We seek to give approximately equal attention to each goal. Throughout the program, we do not intend to neglect, for example, the student's development in self-direction or inquiry in favor of promoting scientific literacy. To make possible the realization of all five goals, our principal strategy is to make available a large variety of learning resources for the student's use in the program. These learning resources are listed in Table 1. In some of the learning resources, student behaviors are emphasized that contribute to the attainment of certain goals, while other learning resources emphasize behaviors that contribute to attaining other goals.

This strategy may be illustrated by looking at some of the learning resources available in one unit from Level D of *Individualized Science*. Students working in Level D usually are either third or fourth graders. The Lavoisier Unit in Level D uses these eleven types of learning resources: Individual Lesson, Individual Taped Lesson, Men & Ideas Filmstrip, Mini-

Exploration, Directed Readings in Science, Directed Group Activity, Student Seminar, Student Activity, Self-Initiated Independent Activity, Science Learning Game, Guidance and Selection System.

All of these resources make some contribution to the attainment of the Scientific Literacy Goal. The four components encompassed in our notion of scientific literacy were previously discussed. The science subject-matter of the Lavoisier Unit relates directly to the first two components, *viz.*, building a vocabulary of science words and developing an understanding of science concepts. The Lavoisier Unit deals with the concept of burning and the scientific description of burning. The unit takes advantage of the child's natural curiosity about fire to lead into a consideration of how a candle burns and how various fuels burn in air. Fuels combine with oxygen, producing carbon dioxide and water vapor, and energy in the form of heat and light is released. The content and organization of the Lavoisier Unit are indicated on a student's Planning and Recording sheet for the unit.

Contributing to the attainment of the Student Self-Direction and Co-Evaluation Goals are the GSS (Guidance and Selection System) lessons of the Lavoisier Unit. The GSS lessons, in conjunction with the Planning and Recording sheet, guide the student in choosing his learning activities and in planning for and evaluating his own learning. In the series of three GSS lessons of the Lavoisier Unit, the student takes a placement test to demonstrate what prior knowledge he has of the unit's content; he scores his placement test; he decides whether or not he has achieved mastery of the content of each of the unit's Individual Lessons; he prescribes for himself the Individual Lessons he hasn't mastered; he

decides whether or not he wants to take the mastered Individual Lessons; he chooses which of the Mini-Explorations he wants to do; and he selects other elective activities available in the unit. The plan which the student has made to direct his own learning is discussed in a teacher conference, and the student can revise his original plan as he proceeds through the Lavoisier Unit.

Fifteen Mini-Explorations in the Lavoisier Unit contribute to the attainment of the Inquiry Goal. Each Mini-Exploration (MEX) presents a problem in the form of a question and a photograph on the cover of the MEX booklet. The student seeks an answer to the problem either by proceeding in his own way or by using the procedural hints and photographs on the inside pages of the MEX booklet. The procedural hints provide models which the student can imitate to develop inquiry process skills, such as observing, recording, and measuring. Some MEX's in the Lavoisier Unit are primarily concerned with these process skills, e.g., MEX-2: "When does the candle in the can go out?" Some MEX's are primarily concerned with problem-solving, e.g., MEX-13: "How can you put out a fire?" Most of the MEX's are open-ended; they include one or several questions on a related follow-up problem. The titles of the remaining MEX's in the Lavoisier Unit are: MEX-1, "How do you light a candle? How can you put it out?"; MEX-3, "Does the capacity of the jar make a difference?"; MEX-4, "Candles in a Jar."; MEX-5, "The Long and Short of It."; MEX-6, "Candle Making."; MEX-7, "How do things change when you heat them?"; MEX-8, "Flame Shadows and Rings."; MEX-9, "Flame Jumps."; MEX-10, "What's a wick?"; MEX-11, "Spirit flames and oil flames."; MEX-12, "How does wood

burn?"; MEX-14, "Novelite Candle."; and MEX-15, "Angel Chimes."

In one of the six Individual Lessons of the Lavoisier Unit, the student views and listens to a sound filmstrip from our "Men and Ideas" series. The name of the six IL's in the Lavoisier Unit are: IL-1, "What makes a candle?"; IL-2, "About the Wax."; IL-3, "Lavoisier Filmstrip."; IL-4, "The invisible subsystems, Part I."; IL-5, "The invisible subsystems, Part II."; and IL-6, "Matter and Energy." These filmstrips are designed to contribute to the Affective Goal and to the components of scientific literacy concerned with the nature of scientific inquiry and with the social aspects of science. We are interested in developing informed attitudes toward science, scientists, and scientific inquiry. And, we are interested in providing an enjoyable, aesthetically-appealing learning experience. In the "Men and Ideas" filmstrip in this unit, we have depicted some events in Lavoisier's personal and scientific life. In doing so, we are able to explain why a unit on burning is called the Lavoisier Unit and to illustrate some ideas concerning the nature of scientific inquiry and the social aspects of science. In the Lavoisier filmstrip, the ideas illustrated include:

1. the interconnections between observations, experiments, and scientific explanation;
2. the distinction between science and practical applications of science;
3. the importance of communication among scientists through publications and meetings; and,
4. the contributions of scientists both to science and society.

Three Directed Group Activities are included in the Lavoisier Unit: DGA-

1, "The Vapor Burns."; DGA-2, "When Things Burn."; and DGA-3, "Energy.". Thus, even within one unit, we are able to give attention in various learning resources to some portion of all the goals of *Individualized Science*.

The individual student has been placed at the focus in planning, designing, and developing the *Individualized Science* program, and we have been mindful of the social circumstances in which the student lives and

will live. Our overriding aim is to offer a program of elementary-school science education that is relevant, meaningful, and of greatest benefit to the individual. We shall know that this aim has been achieved when we see that the student in *Individualized Science* develops positive feelings about science and about himself through his active involvement in self-directed, self-fulfilling, satisfying science learning.

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