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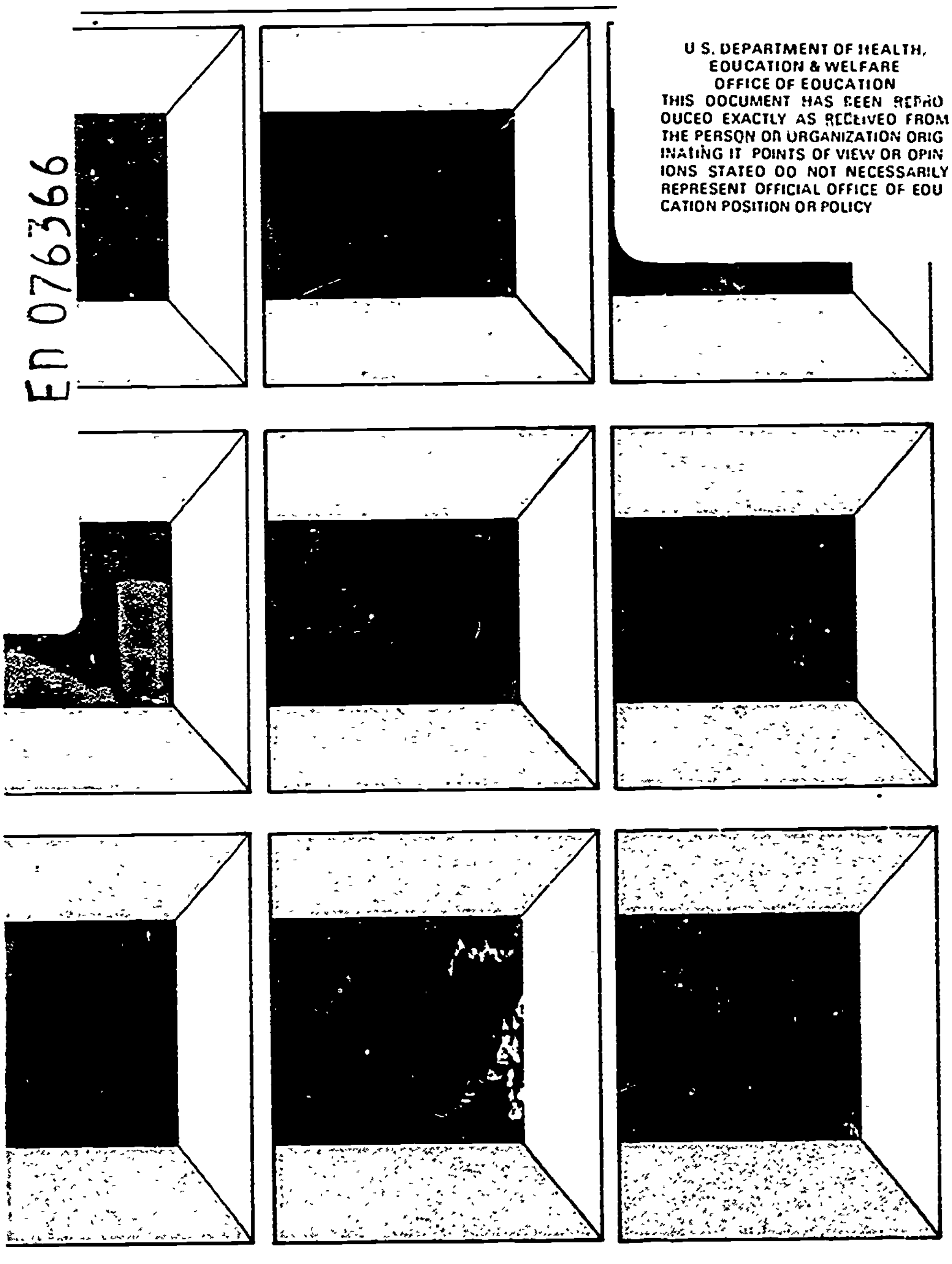
ABSTRACT

Seven articles concerning individualized science education are compiled in this publication which begins with a brief introduction to the concept of individual differences. Representative projects on both elementary and secondary school levels are included to illustrate differerc degrees of structure and styles of individualization. D.scussions of the individualized learning approaches are grouped under these headings: Audio-Tutorial Techniques, The Intermediate Science Curriculum Study, Open Learning Environments: The Ultimate Individualization, PACE - Personalizod Adventures in Chemical Education, Audio-Tutorial Learning, and Individualizing Your Own Classroom. Emphases are placed on analyses of variables such as learner's selection of direction, sources, paces, and evaluation. Differences between independent and individualized learning are emphasized in an article entitled: "Individuals Learn." Included in the appendices are two bibliographies. One is concerned with research studies related to open humane education and the other with humanistically-oriented education. (CC)



INDIVIDUALIZED SCIENCE · like it is ·

Edited by HENRY J. TRIEZENBERG

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• like it is •

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PREFACE

If you are an experienced teacher, very likely you are sensitive to the individual differences among your students. You probably also wish to correlate these differences with varied learning experiences and may even have tried to do so. If you are making such attempts, you may be frustrated by the amount of software you must prepare and skeptical about the management of individualized science in real classrooms. Whereas group instruction is designed so that you, the teacher, can function, individualized science must be designed so that your learners can. Given the teacher-student ratios of modern schools, many science educators are rightly skeptical about whether individualized science can really happen in the classroom.

The projects described in this publication were chosen primarily because they are happening. After reading about them, you may be motivated to see them in action for yourself, and to apply your own criteria for success. They were chosen also to illustrate different degrees of structure and styles of individualization. Therefore, only a representative sampling is included of all the individualized science projects presently in existence.

We hope this publication stimulates the production of more software for individualized science and better schemes for managing individualized programs. Given the educational milieu described here, and the ways open for you to get involved, progress is inevitable. The NSTA will welcome continuing reports of efforts to individualize science programs.

Henry J. Triezenberg

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A CURRICULAR FABLE

or, The Concept of Individual Differences

Once upon a time the animals had a school. The curriculum consisted of running, climbing, flying, and swimming, and *all* the animals took *all* the subjects.

The duck was good in swimming; better, in fact, than his instructor. He made passing grades in flying, but he was particularly hopeless in running. Because he was low in this subject, he was made to stay in after school and drop his swimming class in order to practice running. He kept this up until he was only average in swimming. But, average was acceptable, so nobody worried about that except the duck.

The eagle was considered a problem pupil and was severely disciplined because, although he beat all the others to the top of the tree in the climbing class, he insisted on using his own method.

The rabbit started out at the top of the class in running, but he had a nervous breakdown and had to drop out of school because of so much makeup work in swimming.

The squirrel led the class in climbing, but his flying teacher made him start his flying lessons from the ground up instead of from the top of the tree down. He developed charley horses from overexertion at the take-off and began getting C's in climbing and D's in running.

The practical prairie dogs apprenticed their offspring to the badger when the school authorities refused to add digging to the curriculum.

At the end of the year, an abnormal eel that could swim well, run, climb, and fly a little was made valedictorian. ■

Original Source Unknown

1

INDIVIDUALS LEARN

Henry J. Triezenberg and Richard J. McLeod

Students are different from each other. They know different facts and ideas. They can verbalize those facts and ideas to varying extents. Some can manipulate a set of objects well; others operate poorly with that set of objects, but well with a different set. They like different things and want to learn different things. They will learn at varying rates, and the student who proceeds most quickly toward one objective will often proceed slowly toward another. They vary in their ability to learn from different media. They appear to learn more when they commit themselves to a course of learning actions by choosing the course themselves from among alternative possibilities.

Individualized education is an attempt to accommodate instruction to the unique abilities, goals, and learning rates of each student. It is an attempt to personalize the learning process, allowing it to be more relevant or meaningful to the individual student, as well as to his society. Individuals, not groups, learn. In the past, many educators have considered various ways of grouping students and various methods of teaching those groups. Individuals have learned in spite of group methods; the big idea here is that some educators have found methods to facilitate learning by individuals and as individuals. As students participate in an individualized learning process, they appreciate their differences and become more different instead

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of more like each other. They mature as unique individuals and independent learners.

Independent Learning

Since independent learning has often been confused with individualized learning, some distinctions must be clarified. Independent and individualized learning are practiced in varying degrees, and they are usually more or less mixed in any course of study. Each can be said to exist on a continuum. At the opposite extreme of the continuum from independent study is teacher-dependent study; at the opposite end of the continuum from individualized study is group study, with all students marching along together and accomplishing precisely the same objectives at the same time. Few classrooms can be characterized by any of these extremes. However, all courses of study can be characterized by some degree of independent and of individualized study.

Varying degrees of independent learning allow the student corresponding degrees of choice in what he is to learn, in how he is to learn it, in the time he takes to learn it, and in determining when he has learned it. Independent study, in its extreme, is individualized because the student makes his choices only for himself. An independent learner does not depend on a teacher —he learns without a teacher. Educators generally hope that each student will be an independent learner at the end of his formal education, and they generally increase the amount of independence as students progress in the educational process. In some notable exceptions, learners are independent very early in the educational process; and these exceptions should be apparent in this volume. Away from extremes, as independent study often exists in higher education, it is possible for all students in a group to accomplish roughly the same objectives at the same rate. It is possible here to allow considerable study independent of a teacher without allowing much individual variance.

Individualized Learning

In individualized learning, the goals and the rates of learning are different for each student. To the extent that learning is individualized, it approaches the "one teacher–one student" relation. But this relation might be extremely teacher dependent. The teacher might plan the whole program for each student and set the deadlines for its completion. Ideally this prescription

would be a unique program for each student; but since the teacher is only human, the programs that he plans for different students will have elements of commonality. The probability of greater variety for individuals increases with computerized prescriptions, but common elements still exist. Such elements of commonality are minimized when each student plans his own program independently. Hence, in its extreme form, individualized study would also be independent—planned and executed by a student for himself only and this with minimum commonality among students. In practice, there are varying degrees of independence among individualized learning situations, with teachers providing more direction to some students than to others. Ideally in individualized learning situations, the degree of independence is individualized, too, and thus is only one parameter among many that contribute to individualized learning.

Generally, teachers plan the individualized learning environment and provide a core of commonality with a variety of options. They help students choose their direction in selecting objectives from the options. They individualize the degree of independence by consulting with independent learners and prescribing for dependent ones. They allow each student to pace himself but they might set deadlines, thereby limiting an individual student's degree of choice. They advise students about different sources of learning available to them and allow varying degrees of discretion in selecting a source from different media for learning ("real world" outside, books, audiovisual materials) and different modes of presentation (lecture, lab, library). They encourage students to evaluate their own progress and set limits by imposing periodic examinations. The relative freedom of teacher and students to choose objectives, sources, paces, and evaluations is also a function of school resources. This publication describes available options and existing school situations in which a conscious attempt is being made to provide a different school program for each student.

The degree of independence in an individualized learning situation can often be identified by the medical terminology used to describe it. In some individualized approaches, the teacher utilizes a test to "diagnose" a learner's needs. Self-evaluation and self-diagnosis by a student represent an independent approach. Some teachers then "prescribe" a course of learning actions. Here the learner becomes very dependent on the teacher. Other teachers "consult" with the student or "ad-

vise" him about the courses of learning action available and the one he might take. In the consultation, the teacher varies the amount of independence according to the needs of the individual. The completely independent learner "self-selects" when, what, how, and how well he learns. Here we will describe many real learning situations designed for individualization—and this independence will be one variable described in each situation.

Individualized learning variables can be classified in four processes, with independence one of the variables in each. These four processes are selecting one's direction (what he learns), source (how he learns), pace (when he learns), and evaluation (how well he learns).

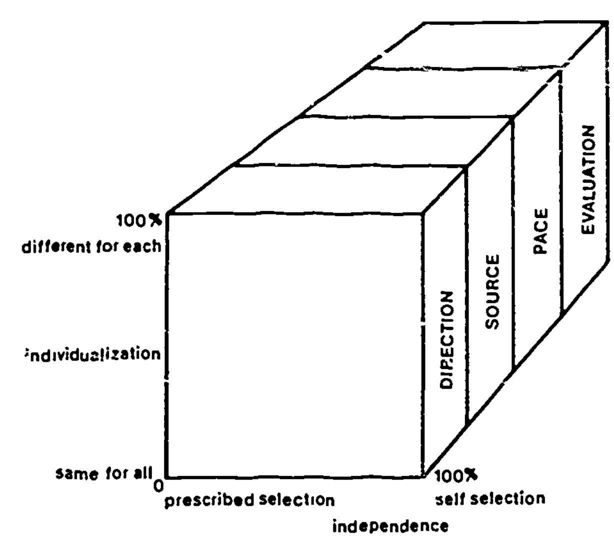

Figure 1. Parameters of individualized learning.

Direction

In individualized situations, the objectives toward which students work vary among individuals. The curriculum direction is individualized by branching student pathways of learning. Learning elements common for all students are called core

materials. Many schools require performance of a given percentage of the core for passage into the next grade level. Branches from the core are available for enrichment learnings —remedial, general interest, or extensions. Limits of student choice, at most, are the variety of learnings available to the school system. The independence of selection may be described by prescription, consultation, or self-direction.

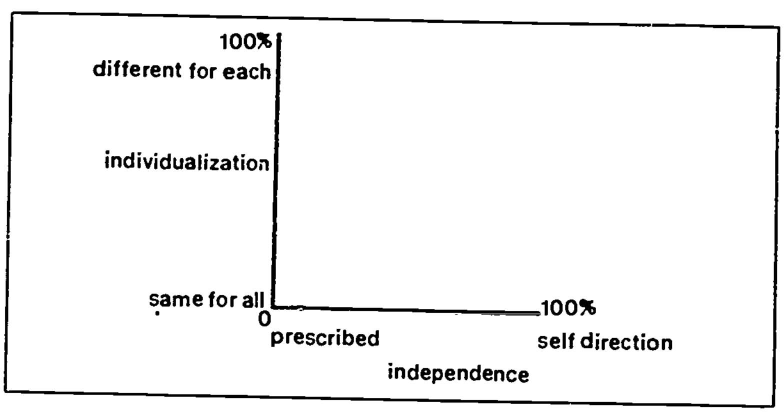

Figure 2. Direction for learning.

Source

The variety of instructional resources being made available for learning is increasing so rapidly that it is becoming possible to select media and modes of presentation appropriate for each child. Books have been common media for hundreds of years, and students have often had a high degree of independence in selecting a book to reach an instructional objective. The increasing availability of natural materials in laboratories and outdoor areas provides a "real world" instructional resource. A cornucopia of audiovisual material provides a degree of communication intermediate between natural materials and books. Once the objective is selected, a decision can be made on the medium desired to attain it. And the media are more or less suited to varying modes of presentation: lecture, library, media center, audio-tutorial center, laboratory, field trip, and others. Because the variety of media and modes is increasing, students can be given greater independence in their selections. Once it is decided where to go, a decision can be made on how to get there.

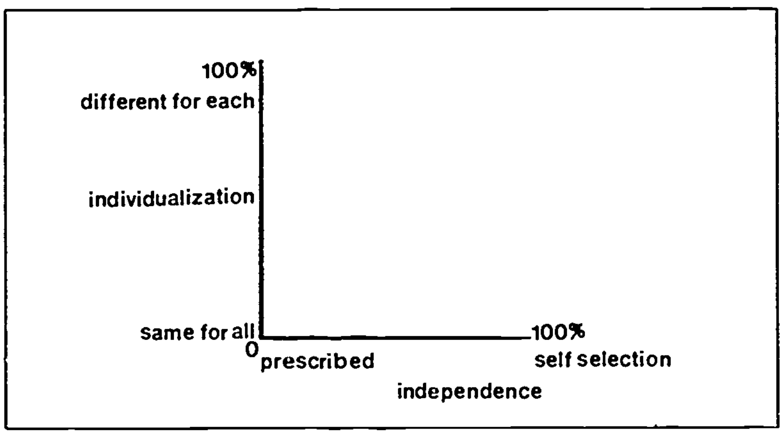

Figure 3. Sources for learning.

Pace

Individualized pacing is characterized by variable repetition and size of learning activity. In some schools, a student can repeat a unit of learning activity as many times as he wishes until he can pass a test. The learning activity might be based on reading a chapter from a book, memorizing a set of words, performing laboratory operations, viewing a film, or any combination of such activities. Allowing repetition is a common way to individualize learning—probably because it is so easy to allow and does not often require additional resources. The size of the learning activity is somewhat more difficult to arrange; nonetheless almost any student can learn almost anything if it is broken down into small enough units. But most students would be bored with such learning units because they can learn larger chunks of subject matter and, therefore, proceed more rapidly. They should not be restricted to the pace of the slowest learner in the group. An independent learner is self-pacing.

Evaluation

Evaluation is an especially critical process in individualized learning because decisions about learning paths, sources, and paces are based on evaluation. Usually a variety of evaluation devices are available, both objective and subjective. A recent development is the use of criterion instruments referenced to specific objectives of a learning unit. This relation to objective

criteria can be described for many individualized approaches. Diagnoses for future learnings are based on such test devices and affect direction, source, and pace variables. A diagnosis and prescription can be made in terms of each variable. Degrees of independence can be described as degrees of self-evaluation.

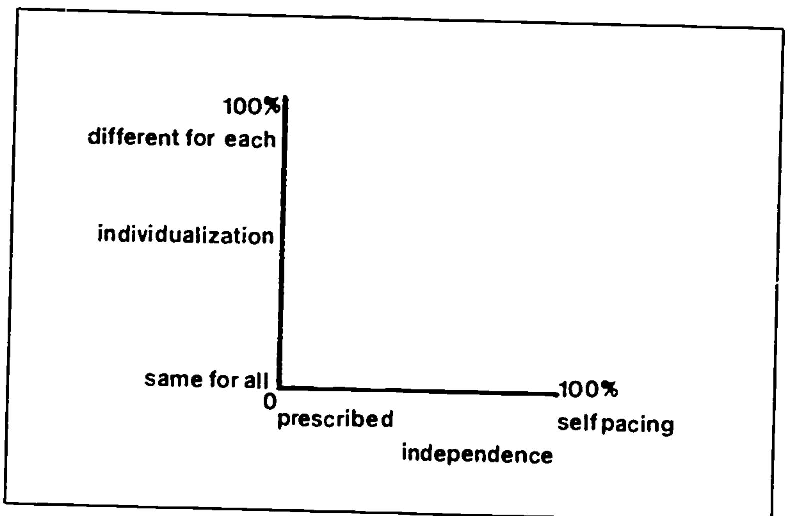

Figure 4. Pace of learning.

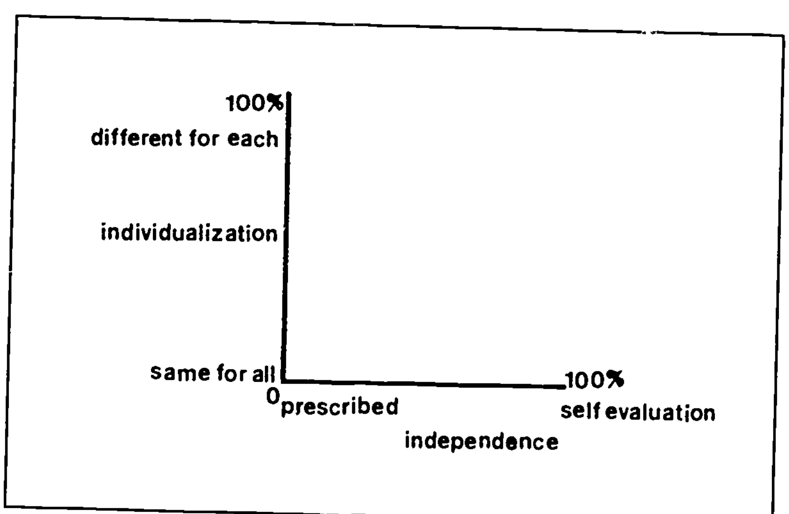

Figure 5. Evaluation of learning.

Summary

Since learning is done by individuals, not groups, educators can facilitate learning by considering and implementing methods of individualized learning rather than by continuing to spend energy on methods of group learning.

Four variable processes of individualized learning are selecting direction, sources, paces, and evaluation with a parameter of independence included for each process. Existing individualized learning approaches are described in the remaining chapters of this publication in terms of these variables. These descriptions should help you compare various approaches and decide which approach is most appropriate for you in designing your own individualized curriculum. ■

2

AUDIO-TUTORIAL TECHNIQUES

for Individualized Science Instruction in the Elementary School

Joseph D. Novak

The audio-tutorial method was first developed in 1961 by Professor Samuel Postlethwait at Purdue University. In his continuing search for better ways to instruct students in a college botany course, Professor Postlethwait began using audio-tape to guide students through observations with botanical materials, as well as to present some necessary background information. The use of staff tutors working in a specially equipped room with tape recorders and carrel units evolved into a highly effective approach for teaching botany. In 1965, this approach was adapted for use in elementary schools. Figure 1 shows a child working with an early audio-tutorial lesson on plant growth. Since the early 1960s, many schools and colleges have developed audio-tutorial courses, and almost all subject fields are now taught at some school with this method of instruction. A detailed description of the audio-tutorial approach is available in the *Audio-Tutorial Approach to Learning*. [11]

Audio-tutorial methods make it possible to offer students a wide range of experience, largely on an individual schedule. In addition to the work with the audio-tape guided lessons, supplemental activities in various forms (some with audio-tape guidance as well) can be incorporated into the curriculum structure. Moreover, teacher-directed or small-group activities can emerge from experiences in the audio-tutorial lessons. The full range of instructional approaches, including some inquiry or discovery activity, can complement audio-tutorial instruction at the elementary school level.

JOSEPH D. NOVAK is professor and chairman, Science Education, Cornell University, Ithaca, New York.

Figure 1. A first-grade student studies germinating bean seeds in an audio-tutorial program.

Planning the Elementary School Science Curriculum

In our elementary school science project we have found that learning theory plays an important role, partly in the design of individual lessons and also in planning the overall science curriculum. Another useful source of information has been the curriculum theory developed by Mauritz Johnson. Figure 2 shows a simplified model of curriculum as proposed by Johnson. [6] Johnson distinguishes the process of curriculum planning from the process of instruction. In his view, the output of the curriculum planning system is used to design specific instruction, drawing on the available repertoire of teaching behaviors. Audio-tutorial methods allow for the introduction of additional teaching options, thus permitting instruction in some areas that might otherwise be curtailed by the available teacher skills.

In elementary school science, one of the continuing problems in curriculum planning is consideration of what kinds of knowledge and skills are available in the teacher population.

While audio-tutorial methods do not eliminate this problem, they substantially enhance the potential for presenting knowledge directly to students. Consequently, some constraints on selecting and sequencing content that operate in conventional instruction are not limitations in audio-tutorial approaches. For example, some of our elementary science lessons present concepts of energy flow in biotic communities which are generally not familiar to elementary school teachers. However, we have found that children can learn these concepts when they are presented through appropriate audio-tutorial lessons. Moreover, teachers can acquire this knowledge together with their pupils, thus enhancing their own science backgrounds in a form of "in classroom" teacher education.

With the additional potential for displaying learning material through the use of audio-tutorial methods, the important task becomes deciding what concepts or what information should be included in the program. In addition, there is a need to explore various forms in *instrumental content*, which Johnson describes as the specific examples or exemplars invoked to teach the concepts or principles selected in the curriculum plan. For example, if we plan to present the idea that energy is required when changes are to be made in physical systems, we find an almost infinite number of possible examples to illustrate this concept.

The selection of instrumental content requires extensive work with children in the schools. Very frequently we are told that a certain concept cannot be taught. It would be an error to accept this dictum too readily, for alternative approaches to presenting the content, using different instrumental content, frequently do result in successful learning. Moreover, children's failure to acquire a concept may be an indication that the concept was inappropriately positioned in a sequence of concepts or that the pace with which elements of the concept were presented may have been too fast. Determination of instructional sequences and modification of the pace at which new concepts are introduced require extensive field testing, with revisions necessitated in an entire learning sequence as substantial modifications are made at any point in that sequence.

The task of determining the major conceptual structure to be presented in an audio-tutorial program is not an easy one. The long-term goal of our elementary science project at Cornell University is to design a curriculum sequence, employing audio-tutorial instructional methods, that will introduce the major

CURRICULUM—INSTRUCTION MODEL

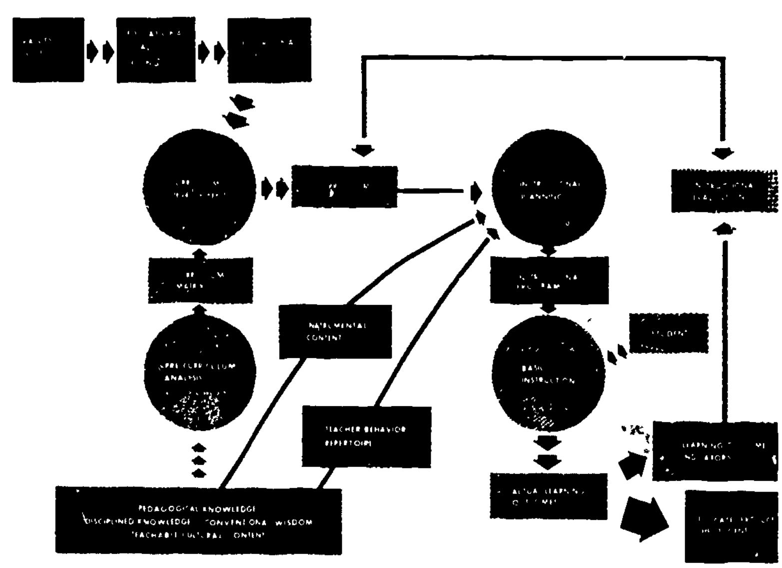

Figure 2. A model showing various activities involved in planning curriculum and instruction. (After Johnson, 1971 [6]).

concepts of science to youngsters over a three- to six-year period. Rather than pursue the task anew, we used a concept matrix developed earlier, namely The *World of Science* [9], a series of elementary science textbooks developed during 1961-1966. In the conceptual structure underlying the series, five major concepts constituted the basic framework of the instructional program with subconcepts organized under each of the large generalizations. The five concepts developed were:

1. Matter in the universe is organized into units which vary in size and complexity; the larger units encompass the properties of the subunits and possess additional properties of their own.
2. Units of matter interact; the different kinds of forces involved in the interactions are few in number.
3. When units of matter interact, energy may be exchanged, but the sum of energy always remains constant. Matter can be changed into energy and vice versa, but the sum of matter and energy involved does not change.

4. The behavior of matter can be described on a statistical basis only. The interaction of units of matter occurs in such a manner that the results must be described only in terms of what is likely to happen.
5. Interaction among units of matter occur in time and space and result in changes which take place at different rates and in different patterns.[1]

For curriculum-building purposes, it is useful to limit the number of major concepts or conceptual schemes to a number small enough so that the curriculum developer can keep each of these concepts in mind as he proceeds in lesson development. We have found that the selection of instrumental content, or exemplars for specific concepts, can be guided by the major conceptual schemes. We try to choose examples that will illustrate a specific concept being taught but that will also contribute in some way to one or more of the major conceptual schemes. In this way, lesson content is more than a dissociated set of examples but becomes a conceptual whole as individual lessons are completed in a large instruction sequence. Moreover, the language used to describe a phenomenon or to explain an event that a student might observe not only is based on the vocabulary limitations of the children but is also determined by the contribution that words and phrases will make to understanding the larger conceptual schemes. This means that a lesson writer must be familiar not only with the specific content in the area in which he is working but also with the total conceptual structure we are trying to present to students.

Curriculum considerations have not been our only concern in lesson planning. We have also been guided by the psychological theory of David Ausubel. Although the work of several cognitive learning theorists has value for elementary science lesson planning, we have found that Ausubel's theoretical formulations encompass, in the most parsimonious manner, most of the considerations we find important. His theoretical structure embodies many of the ideas developed by Robert Gagné [4], Jean Piaget, and other workers.

[1] The conceptual structure as developed for the *World of Science Series* was similar to the set of conceptual schemes developed by the National Science Teachers Association. [8] It also bears some similarity to the conceptual structure incorporated in Brandwein's text series, *Concepts in Science*. [2] The similarities of these three curriculum efforts may be in part fortuitous; however, the similarities may also represent the fact that science does have a coherent structure.

In Ausubel's most definitive work, *Educational Psychology; a Cognitive View* [1], an important distinction is made between rote learning and meaningful learning. Ausubel describes meaningful learning as the acquisition of information by association with concepts already in cognitive structure. As a child grows and matures, the stores of information in his brain lead to the development of neuro-assemblies that are known psychologically as concepts or as organized segments of cognitive structure. Concepts in cognitive structure may be relatively simple, such as the recognition of the letter "a" in various forms, or they may be extremely complex, such as the concept of evolution. In Ausubel's view, whenever new information can be associated to some relevant concept in cognitive structure, that information can be acquired *meaningfully*. In contrast, if the cognitive structure offers no concepts that can be related to some information to be presented, that information must be learned *rotely*. Since a concept may be highly elaborated, such as a chemist's concept of molecule, or may be comparatively primitive, such as a child's concept of air, the dichotomy between rote and meaningful learning is not simple. There are obvious degrees of meaningfulness for new information presented to learners, depending on the extent to which relevant concepts have been differentiated in their cognitive structures.

Figure 3 illustrates the differences between meaningful and rote learning. When information can be associated to a relevant concept in cognitive structure, meaningful learning of that information can occur. Another important event also occurs: The concept itself is enhanced by the addition of new information and now will serve as a more powerful vehicle for acquisition of additional relevant information. In other words, when meaningful learning occurs, the capacity for additional, similar meaningful learning is enhanced. This is an important distinction between meaningful and rote learning.

The alternative to rote learning is to allow students to explore a variety of natural phenomena in comparatively undirected fashion. In this approach to teaching science, it is possible for a youngster to acquire information relative to how batteries, wires, and bulbs can be brought together to light the bulb or effect some other action, and any information acquired is necessarily *meaningful* to the student. Knowledge acquired through discovery methods (assuming the teacher is patient enough not to intervene and "tell" the student the answer) is likely to be meaningful learning. The primary difficulty with

this approach is that a substantial percentage of students do not acquire important concepts, and those students who do, require much more time in their exploration than is otherwise needed. To be sure, the acquisition of meaningful information through discovery methods may have a high positive affective result. We do not advocate that discovery methods should be eliminated, but we do hold that they are not the only avenue to meaningful learning. This argument is carefully developed by Ausubel. [1, Chapter 14]

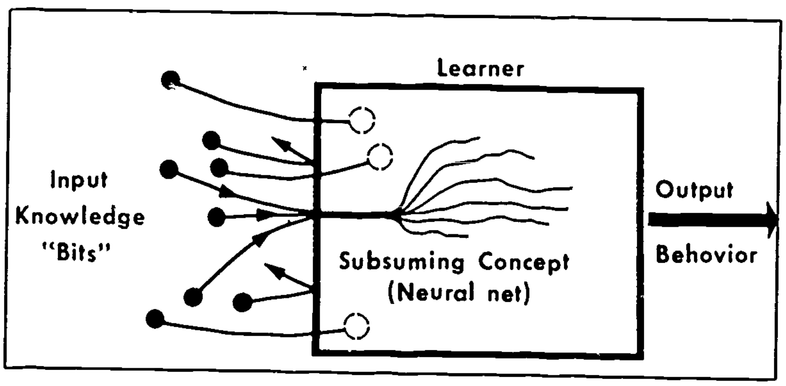

Figure 3. Diagram showing meaningful learning as acquisition of new knowledge by association with a concept in cognitive structure and rote learning as isolated storage of knowledge bits (open circles). (After Ausubel, 1968. [1]).

To summarize our position: Up to this point, we see the process of curriculum building utilizing audio-tutorial methods as allowing additional display opportunities for student learning and thus widening the range of knowledge that can be presented to the learner. Using the theoretical constructs from Ausubel, it is possible to design a sequence of lessons that can progressively develop important conceptual structures needed for meaningful learning of scientific information. Our curriculum planning efforts are based on the assumption that the number of major conceptual structures needed for facilitating meaningful learning in science is relatively small; we believe that five or seven major concepts, as they begin to take on meaning to the student, can guide and facilitate meaningful learning of almost an infinite variety of scientific information. At present this position is in part an assumption, although we

have designed long-term research programs to test this assumption. If students can learn science in such a way as to develop major cognitive structures that allow a wide variety of scientific information to be learned meaningfully in subsequent years, this should be evident as they progress from elementary to intermediate and secondary school science classes. A first requisite for this skill in subsequent grades is to demonstrate that students do acquire basic concepts of science through audio-tutorial instructional methods in the elementary school. This has been the primary focus of our research for the past four years.

The Design of Audio-Tutorial Lessons

Planning a new A-T lesson is a complex process. First, consideration is given as to what major concept (or concepts) are to be extended by the lesson. The next step usually involves planning an appropriate activity through which the concept may be illustrated. This step may take days or weeks. Very early in the planning we discuss with children the concepts or activities we are considering for a lesson. The need for interaction with children at all stages of lesson development is absolutely critical. Sometimes we design a new piece of apparatus, such as that shown in Figure 4, which was designed for lesson 6 in our first-grade lesson series. With it a child observes how addition of "energy producing units" (i.e., dry cells) increases the amount of change, such as the speed of the motor or the brightness of the light bulb. Here we are extending the child's concept that changes in matter just don't "happen," but rather that energy exchanges are involved in changes. To be sure, no one lesson or even a series of lessons will establish clear, fully assimilated concepts of energy or the relation between energy and change. However, these experiences will be remembered. The ordered sequence of experience, together with appropriate language development, has been shown to develop substantial, stable concepts in the children we have studied.

Once the content and activities for a lesson are selected, a program is written and then recorded. Next, we try out this new program with four or five children at the appropriate age and experience level and observe them as they are guided by the audio-tape. Immediately, it becomes apparent that some major or minor changes are needed. Sometimes the children fail to manipulate the apparatus in the proper way. If stopping the tape and showing children how to perform the manipula-

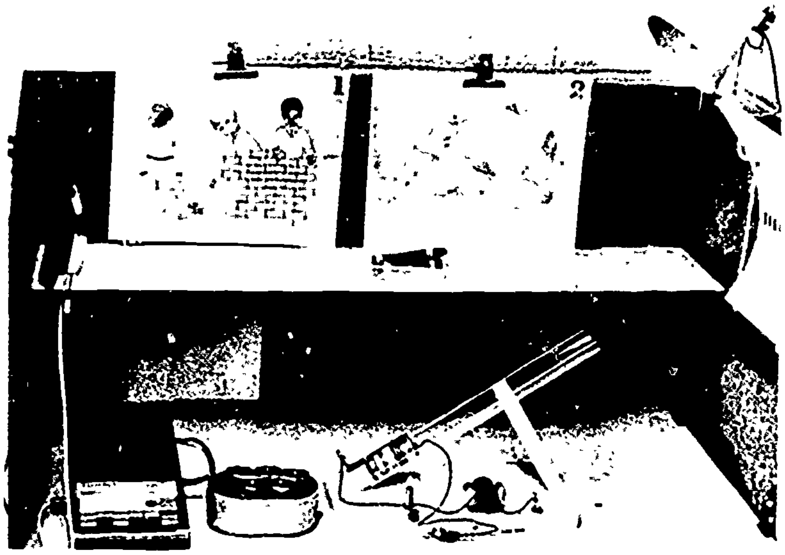

Figure 4. A first-grade lesson showing a device for demonstrating that more energy units (batteries) will result in more light or in faster motion from a motor.

Figure 5. An audio-tutorial unit shown as commonly used in classrooms.

tions proves unsuccessful, we may have to scrap the apparatus and begin all over again. More often, changes in the language used, slower pace of audio guidance, or minor modification of the apparatus will suffice to solve the problem. At least three or four revisions of every lesson are necessary before it will be relatively trouble free and successful with most children in the target population.

At this point we commence extensive field testing with lessons placed in classrooms, learning centers, and other locations. (See Figures 5 and 6.) Periodic observation of students is still needed, but now a trained technician may be employed to

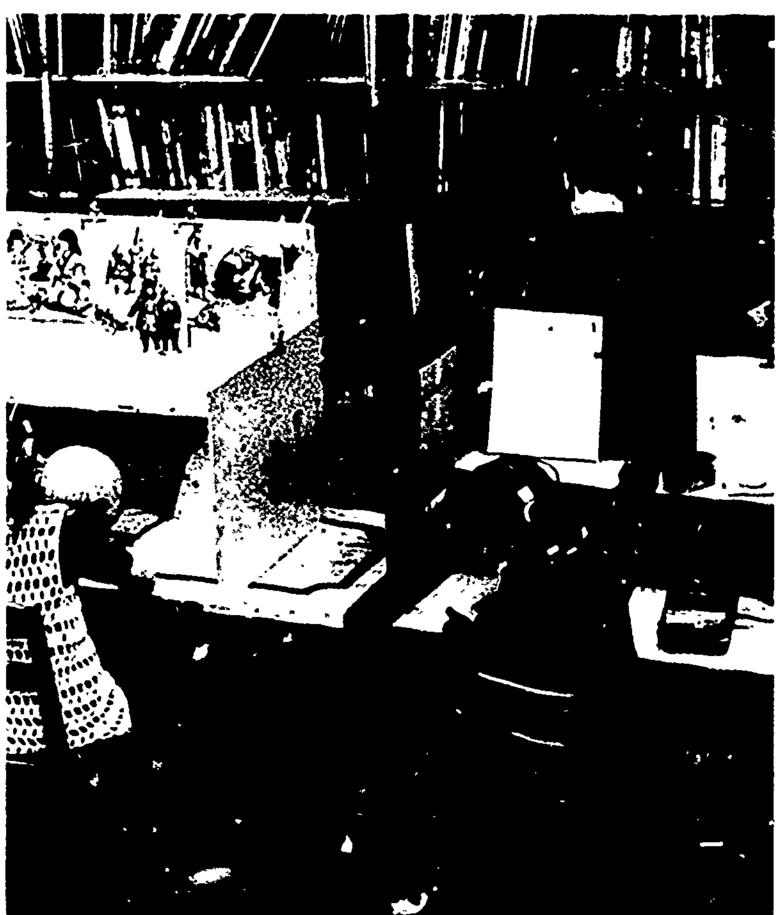

Figure 6. Two audio-tutorial lessons set up in a school learning center.

identify possible trouble spots. We use "behavioral checklists" to record observations as well as interviews with students to determine why they had trouble with segments of the program. Following is a sample of items from one checklist:

ACTION BY SUBJECT	YES	NO	COMMENTS
Picked up big and small battery	___	___	
Placed all batteries on table	___	___	
Pointed to battery tester	___	___	
Placed battery tester in front of him	___	___	
Picked up small light bulb	___	___	
Acknowledged picture of girl testing battery	___	___	
Picked up one battery	___	___	
Placed battery properly in tester	___	___	
Tested battery correctly	___	___	
Placed battery properly in pan	___	___	
Tested second battery	___	___	

When 90 percent or more of the students are successful on all of the critical items of our checklist, we consider the lesson to be "operational" and move on to other work. However, long-term evaluation and careful analysis of children's learning have shown areas of program deficiencies, resulting in scrapping of some lesson sequences and redesign of others. The process of program writing, field testing, long-term evaluation, and revision can go on endlessly, but practical necessity requires that program sequences be "ready" for mass tryout at some point.

Our experience has been that four to six revisions are needed for each lesson. Planning, writing, and pilot testing of a new program ordinarily requires 50 to 100 hours of staff time. Some of our programs have been revised much more than this, with input of up to 200 hours of staff and technician time. Consequently, each 15-minute A-T program we have developed cost about $2,000, even employing graduate students and other comparatively "cheap" labor. Clearly the development costs for quality A-T science programs at the elementary school level are completely out of range for individual schools or even large school systems. However, once developed and mass produced, the A-T approach to elementary science is economically feasible. Present market information suggests that a 30-lesson

(one lesson per week) A-T science program can be available to schools for about $5 per pupil per year. Moreover, special "science" teachers are not needed, and we have not had any teacher decline continued use of A-T lessons.

Although planning and developing an entire A-T science program requires resources available only at the national level, additional A-T lessons or planning of related class activities can be and has been done by individual teachers. The A-T approach to individualizing elementary science teaching will operate best where teachers add their creative talents and human presence.

Evaluation of the Program

Lesson evaluation begins at the time of lesson development. Even early exploratory work with children using a new piece of apparatus or a novel demonstration is part of the evaluation process. Every element in a lesson must make some sense to the children. With young children, motor dexterity is occasionally a limiting factor, and early, informal tryout of a new device may indicate the need for redesign of a piece of equipment or a game board. Similarly, the student's cognitive limitations, such as inadequate vocabulary, may mean that special care must be devoted to presenting new concept words or selecting adjectives to describe a procedure or phenomenon.

In the design of A-T programs for children, the same strategy applies as for all lessons designed for individualized study; the objective is to help all students acquire knowledge and skills *efficiently*, not to see who will succeed and who will fail. For each activity, each description, and each illustration we seek to determine whether changes can be made that will reduce or eliminate student failure. Though too often we think of evaluation as occurring with students only after a learning episode, Scriven has pointed out the need for careful evaluation during the curriculum design process. [12] By the time a lesson sequence is ready for wide-scale field testing, we already have good evidence that significant learning will occur simply because the instruction has been refined to the point where learning is assured, much in the same manner that manufacturers can guarantee performance of a product as a result of design and quality control procedures. To be sure, we must expect some failures or partial failures, and evaluation during program design must be followed up by other kinds of evaluation.

Paper-and-Pencil Tests

We have also used paper-and-pencil tests with children. Two basic forms of picture-test items abstract to some degree the concepts illustrated in the lessons. One type requires that the child recognize and mark on the appropriate picture or segment of a picture. This is basically a *recognition* item in which the child is required to see in the drawing a relationship, object, or phenomenon illustrated in the lesson. Some measure of the child's cognitive competence is indicated by simple recognition of elements essentially identical to those in the A-T lesson; success in correctly marking items where similar but novel relationships, objects, or phenomena are illustrated is suggestive of more adequate concept acquisition.

A second form of picture-test items we call *production* items. These are drawings that are in some way incomplete. The child is instructed to mark the picture in such a way as to illustrate a relationship or phenomenon. These items can also be of two types; some require marking in a way similar to illustrations given in lesson sequences, whereas others require transfer or illustration of relationships in new ways or phenomena not previously considered. Scoring production-type questions requires special procedures. We usually identify types or categories of response and record the "category" represented by a student's response, not whether the answer is right or wrong. Some response categories indicate better concept acquisition, whereas other categories suggest some type of cognitive deficiency.

Structured Interviews

Our most valuable information for program revision as well as for analysis of children's cognitive growth has come from *structured interviews*. The clinical interview or structured interview requires that the evaluator work with one student at a time, proceeding through a series of questions. Obviously, this is much more difficult and time consuming than picture-test evaluation. However, we have found that more useful information can be obtained through individual interviews, and these have also served as a good validation mechanism for our picture tests.

Interviews may deal with objects or phenomena identical to those in A-T lessons, or novel materials can be used. As with picture tests, the best indication of concept acquisition is that

the child can describe the behavior of novel objects or novel phenomena and associate these with similar observations made in A-T lessons. Figure 7 shows a child being interviewed.

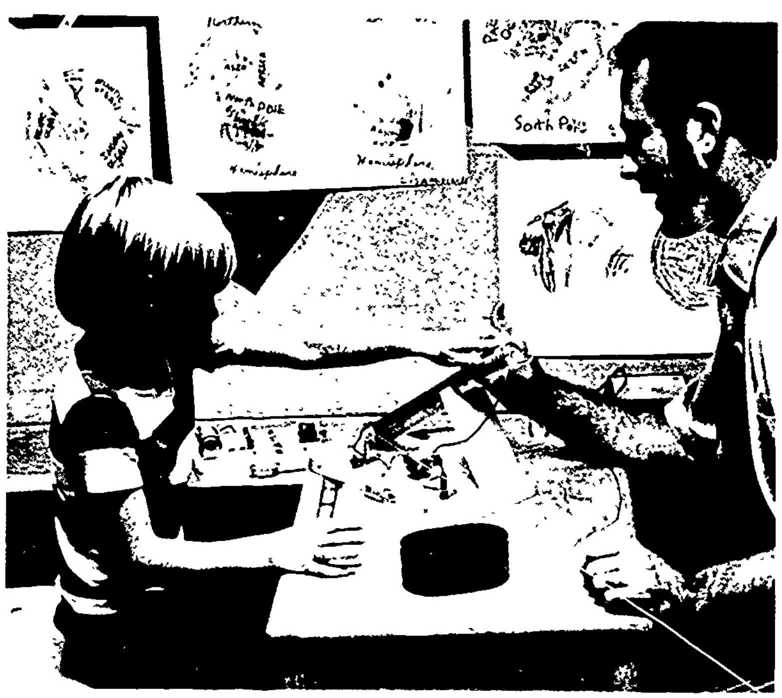

Figure 7. Interview evaluation of student's understanding of science concepts. The child is asked to manipulate the apparatus and explain what is occurring.

Of primary value in interview evaluation is that flexibility in questioning is possible. Sometimes from the mere expression on a student's face, it is possible to recognize that a word or phrase is not understood. The experienced interviewer can rephrase the question or change the illustration used. Our objective is to assess the upper limits of the student's knowledge of concepts taught, not his ability to understand our questions. We have found that picture tests and similar paper-and-pencil tests tend to underestimate a student's knowledge gains by 20 to 50 percent. On the other hand lucky guessing or responding to spurious cues can accidentally lead to correct answers, and

some children may score inordinately high on picture tests. This can be misleading in lesson evaluation or in research on comparative gains of experimental groups.

Efficient audio-tutorial instructional design requires that we estimate as well as possible the maximum knowledge the learner acquires, or we may introduce unnecessary repetition or redundancy in learning tasks. We sometimes observe that only a small percentage of students have acquired key concepts. Chance success on objective-type questions or spurious cuing to the correct answer may mislead us to think that some elements of a learning sequence are adequate in the form developed when in reality important revision is called for.

The Future of Audio-Tutorial Elementary Science

We have used audio-tutorial science lessons in more than two hundred classrooms in five different states. Acceptance by teachers and students has been enthusiastic. Throughout the past six years of development and evaluation, we have had occasion to experience almost every type of classroom setting in communities ranging from rural to urban and from affluent to disadvantaged. My enthusiasm and the enthusiasm of colleagues who have worked with me derive from the success we have observed all kinds of students exhibit with audio-tutorial science. Our principal frustration has been the continuing difficulty of obtaining adequate financial support to carry on with our work. Nevertheless, our work has moved forward, and we have developed more than sixty lessons appropriate for the primary grades. Several research studies have been completed with results indicating that audio-tutorial instruction is a powerful tool for teaching science concepts to children. (See references.)

The trend toward "open" elementary schools where children are given more freedom to select learning activities and to move on individual schedules probably will increase substantially the demand for more instructional materials that students can use independently. We expect that various forms of audio-guided instruction will increase, and carefully designed audio-tutorial science lessons should become increasingly popular. This is not to suggest that we believe all learning should be by students working alone. Indeed our enthusiasm for audio-tutorial science derives partly from the way students cluster around a carrel unit and discuss the activities in the lesson. Furthermore, we have prepared teacher guides and supplements that suggest ways in which associated activities and teacher-

led discussions can extend the work presented in the carrel units. The pupil-pupil and teacher-pupil interactions we have observed growing out of audio-tutorial lessons are a very important part of this type of instruction. Inventive teachers have found many ways to use the science lessons as a starting point for activities in language arts and other subject areas.

New technology, especially electronic information processing, will undoubtedly appear on the educational scene. The current rush toward "individualization" may be replaced by new methods for group learning experiences, especially experiences that contribute to children's emotional development. However, audio-tutorial instruction probably will continue to have value, just as books, chalkboards, and films continue to be useful in school instruction. An investment in equipment and materials for use of audio-tutorial methods not only shows promise for individualizing instruction at this time but can promote other psychologically and sociologically sensible school practices. We hope that in the near future good audio-tutorial science lessons will become available to schools through commercial channels. ■

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3

THE INTERMEDIATE SCIENCE CURRICULUM STUDY

Stewart P. Darrow

Although goals in the development of a new program are sometimes shaped as the program matures, the expressed purpose of the Intermediate Science Curriculum Study (ISCS) project from its beginning was the structuring of an individualized, self-paced, activity-centered, sequential set of materials for the intermediate grades. Because some of these terms mean different things to different people, it might be wise to describe them in the context of ISCS. In fact the four terms themselves are somewhat interrelated. To be self-pacing, a program must be, to a large degree, individualized. Activities must be designed for individuals or small groups and carried out at speeds controlled largely by the students themselves. The sequence must allow for individual differences in content, approach, and the rate at which the materials will be used. ISCS is a three-year sequential program.

Individualization in the program is accomplished in part by a multitrack approach. Each student is expected to engage in the activities of a core of material, represented by the broad horizontal arrow in Figure 1. Branching out from this core are optional activities, aimed at specific problems, discrete concepts, or particular skills. These branches are called excursions and can be considered in two general categories—remedial and enrichment. Their purpose, and therefore their use by students, varies widely.

Early in the development of ISCS it was realized that, although core material might be aimed at students of average ability, there would be many who would need help on particular parts of the program. It would be foolhardy to assume that all

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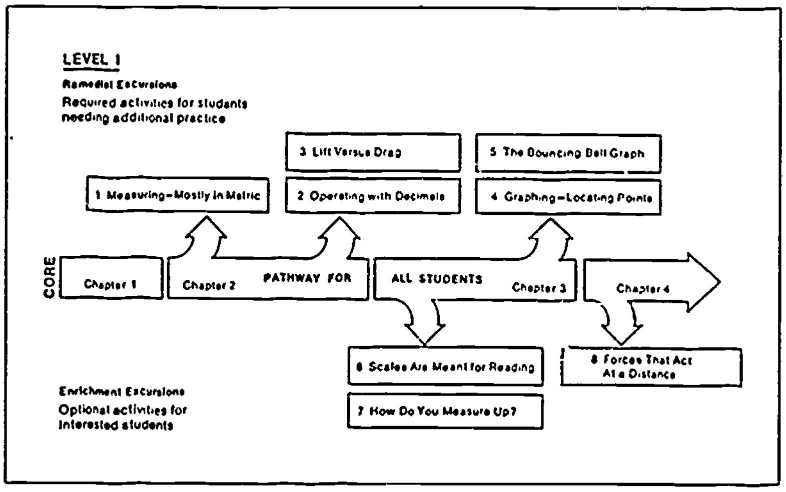
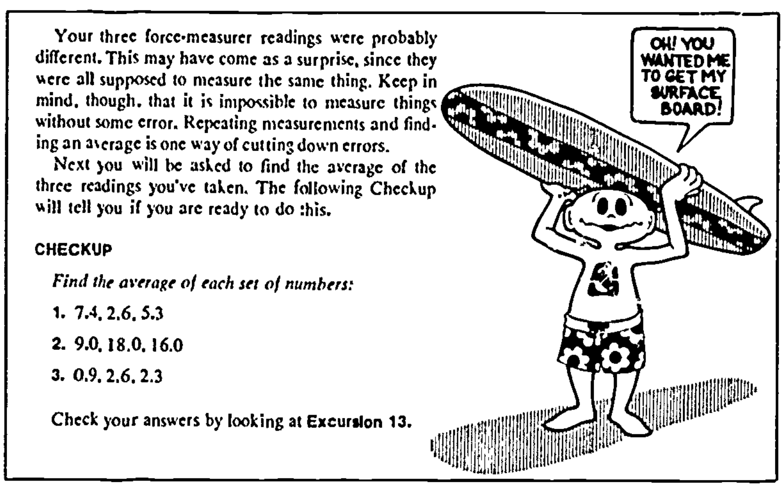


Figure 1. Core and optional activities of Level 1 of the Intermediate Science Curriculum Study.



Your three force-measurer readings were probably different. This may have come as a surprise, since they were all supposed to measure the same thing. Keep in mind, though, that it is impossible to measure things without some error. Repeating measurements and finding an average is one way of cutting down errors.

Next you will be asked to find the average of the three readings you've taken. The following Checkup will tell you if you are ready to do this.

CHECKUP

Find the average of each set of numbers:

1. 7.4, 2.6, 5.3
2. 9.0, 18.0, 16.0
3. 0.9, 2.6, 2.3

Check your answers by looking at **Excursion 13.**

Figure 2. An ISCS self-test or checkup exercise.

students could use the metric system, or work effectively with decimals, or draw and interpret graphs. Even more important, however, was the realization that not all students would need the same help with the materials. Perhaps an elementary program had given adequate preparation in the use of graphing methods, but an individual student was still weak in the mathematics of decimals.

How should a student be led into doing remedial work in a specific subject? It was decided that the help should come precisely when the need for a skill arose. Therefore, the mechanism of a short self-test, called a checkup exercise, was employed. Suppose, for example, the student has been engaged in the activity of finding the amount of friction resulting from sliding a wooden block over different textures on a surface board. He has been led to take three separate readings as he tests each surface. The following excerpt from the text illustrates the procedure:

> **Excursion 13:** Answers to CHECK-UP
> 1. 5.1 2. 14.3 3. 1.9
> (If you missed any of these, do this excursion now.)
>
> **Averaging**
>
> Smokey Bear seems to be smarter than the average bear. What does that mean? What is an "average bear"? Does it mean that Smokey is smarter than all bears? What is an average?
>
> If you've used averages, you probably know what funny things averages are. Then you don't have to do this excursion. But if you're not sure what averages are, this excursion should help you.
>
> Suppose someone asked you, "How long is your arm?" You could ask, "Which arm?" Did you know that most people have one arm that is longer than the other? Let's find your "average arm length." The only piece of equipment you will need is a meterstick.

Figure 3. An ISCS excursion to improve the concept of averaging.

When the student turns to Excursion 13, as he is directed in the exercise, he finds the answers and further instructions (on the right in Figure 3).

If students answer correctly, they continue working in the core materials. If they cannot perform the skill satisfactorily, the excursion provides the necessary remedial help to get them over their difficulties.

If the accepted definition of independent learning is that it proceeds without the teacher, then ISCS does not qualify. The materials of both the core and the excursions have been designed on the premise that teacher help is available whenever needed. The student is encouraged to be self-directed; the teacher is freed from many of the conventional classroom tasks and is able to interact with individual students on their problems. ISCS is individualized learning.

Other excursions, or departures from the core, are illustrated by the downward-turning arrows in Figure 1. They provide an extension of the basic concept in the material. Some are based on the historical development of ideas in science; still others utilize a quantitative approach for the more capable student. The excursions are again keyed at the appropriate points in the text and are designed to appeal to the interests of the pupil. Teachers sometimes encourage a student to do an appropriate excursion, or even repeat a part of one for more help, but no student is expected to do all excursions, or even any set sequence of them.

In traveling through the core and excursion pathway, there is no prescribed rate of progress. The individual sets the pace. In practice, the teacher may encourage the laggard and suggest a more painstaking approach to one who perceives the program as a race. When difficulties arise in comprehending the materials or interpreting an activity, the teacher is available to provide the kind of help that is most needed.

Experience has shown that a program can be made self-pacing only by design. Materials must be readily available without the necessity of being doled out by the teacher. There must be a clear, concise, and complete list of everything that is needed. There must be a readable statement of the purpose of the activity and adequate instructions for setting up the equipment, in word and in picture form. Figure 4 illustrates a sample activity.

Note that the student is called upon to respond to questions regarding the activity immediately following its completion. The purpose of the exercise is thereby re-emphasized, and results are recognized.

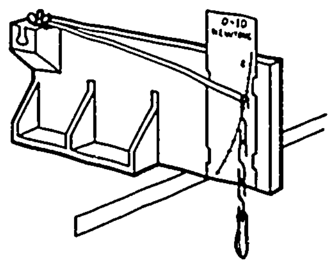
An important part of the individualized and self-paced nature of the materials is the self-evaluation that occurs at the end of each chapter. This is in the form of a self-administered, nongraded test. An answer key is readily available when the test is finished. This provides immediate feedback to students

Fortunately, there is a common unit of force. It's called a *newton*, and scientists all over the world use it to measure force.

But what's a newton anyway? You've probably never heard of this unit and have no idea how much force it represents. To give you an idea of how much a newton of force is, you will weigh a few things using this unit. To do this you will need this equipment:

1 force measurer equipped with a
0-10 newton scale and a thick blade
1 sinker
2 half-kilogram mass
several paper-clip hooks

ACTIVITY 4-1. Set up your apparatus as shown. Put the hooks in place, but do not attach the sinker yet. Adjust the plastic card until the zero mark lines up with the tip of the blade. Then attach a sinker.



☐ 4-1. The sinker exerts a force (pulls down) on the blade. How many newtons of force does the sinker exert?

You probably had trouble reading the scale on the force measurer because the sinker weighs less than one newton.

☐ 4-2. Is 1 newton too small, or too large, a unit to easily weigh a sinker?

Just what does a newton *feel* like anyway? Try making a guess.

Figure 4. Presentation of an activity on the concept of force.

☐ 7-11. Get the liquid labeled 7-11A from your teacher. Using a thermometer, measure the temperature of the liquid and record it below.

Have your teacher check your results.

Teacher's Initials

Figure 5. Performance test item.

on their individual progress. Incorporated in the answer key are suggestions for review and specific references to materials in the text that bear on the questions.

The self-evaluation tests were developed on the basis of performance objectives for the program. Consequently, the questions are aimed at demonstrable skills, concepts, and content. Being intimately tied to the materials in this way, the tests fulfill the need for summation and review, guidance, and encouragement for the student. The teacher may be called upon to set up a performance test item (Figure 5) and judge the adequacy of accomplishment. There is a constraint against using the self-assessment for grading purposes, however, for such a procedure could destroy the effectiveness of the device.

A basic philosophy of ISCS is to let the student discover, by activities and investigations, the concepts of science, rather than just to be told these concepts. Stated in a slightly different way, this activity-centered nature of the program proposes that if a thing can be discovered, don't tell it. Understandably this approach requires more time, equipment, and textual space. For instance, it would be easier to tell the student that sliding friction depends mainly on weight and surface texture than to have him do a series of activities to discover this. (Figure 6)

There are certain peripheral advantages to the activity-centered approach. Use of the illustrations of equipment tends to make a more open format of the materials, promoting readability. In fact, there are indications that poor readers are stimulated to better performance by the liberal use of activity art, and at least some of them attain more than a normal increase in reading ability while using the ISCS materials. And again the teacher is freed from the role of a presenter or demonstrator to carry on worthwhile individualized interactions.

Perhaps the facet of the ISCS program that has received the least emphasis in the minds of many is its sequential nature. Actually, this feature adds another dimension to an important aspect of the materials. If the parameters of individualized learning are as diagrammed in Chapter 1, Figure 1, it must be admitted that Level I of the ISCS program, though aimed at individualization, allows relatively little independence. Likewise, what and how the student learns (directions and sources), though varied, are limited. Excursions offer alternate directions and filmstrip-tape sets are available as alternate sources with the books and lab material. But when the student proceeds to Levels II and III, there is simultaneous movement upward in

individualization, independence, and in the four process variables. (Figure 7) It is as if the three-dimensional diagram in Chapter 1 has added to it a fourth dimension—time. In the three years of the program, there is a steady shift in the amount of independence, in student decision making, and in content and method.

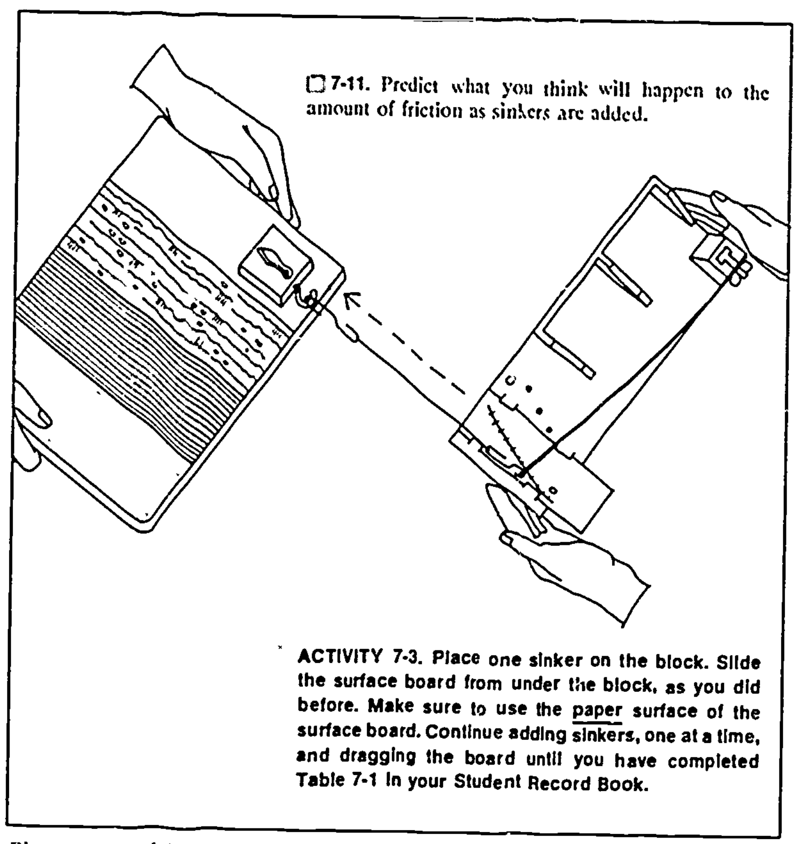


Figure 6. Activity to discover relationship of weight and surface texture to sliding friction.

This shift can be noted best in the change in content and in the decisions that the student makes about his participation in it. Level I is aimed generally at a physics type of subject matter, with equal emphasis on the scientific processes of measurement and the operational definition. (Figure 8)

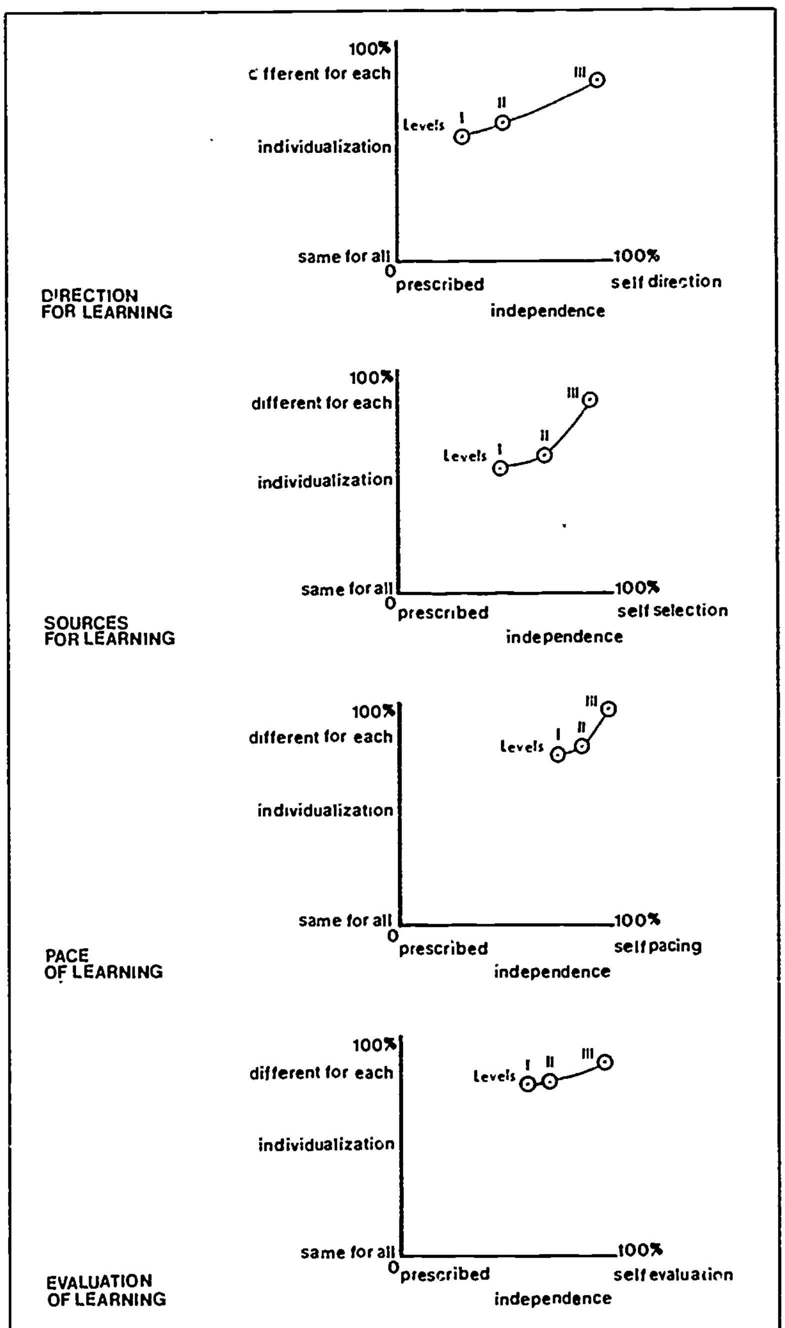


Figure 7. Parameters of individualized learning in ISCS.

As the student completes the first level, there is a gradual shift to a chemistry orientation. Level II continues with this and with the process theme of model building, leading in the final third of the year's work to biological ideas. Level III is centered on life, earth, and space science. with the process emphasis on individual investigations. The materials are rather tightly structured early in the three-year sequence. The student is led down a restricted pathway of core material but, of course, can use the excursions on an individual basis. Gradually the constraints are eased. As the student develops skills in the use of fundamental processes, the first chances to try independent investigations are provided. For example, in Level II, after the student has had some experience with solutions and with tests that could be made for particular particles in a solution, the problem in Figure 9 is posed.

At the upper end of the sequence, the subject matter diverges into a variety of areas, with opportunity for choice in both content and in method of attack. A large amount of the core material in Level III is in the form of "problem breaks" where the student is given the opportunity to design experiments or use methods of his own choosing. (Figure 10)

The choice of sequence for both the subject matter and the scientific processes was carefully considered in the light of individualization. Content sequence was planned to follow a rational path, at a unique pace, and with a minimum amount of outside guidance in science. It was felt that, for this purpose, the concepts of physics could contribute to chemistry and together they could lead into life and earth sciences. Likewise, the skills of measuring, operationally defining, and model building, together with other fundamental processes, could lead to more worthwhile independent investigations. Work with variables, controls, and simple experiments can be accomplished more easily with objects in physical science than with living things. Furthermore, it was felt that possibly the physical science in the ISCS sequence might be the only exposure that many students would have to the subject in their school careers.

It is interesting to note that the proof of the individualization of ISCS lies in part in the difficulties experienced by some teachers who seek to implement it. Many of these difficulties arise when students, working individually or in small groups, arrive at different points in the text at different times and need various kinds of help. To teach the program properly, the teacher must delegate to the individual student many duties

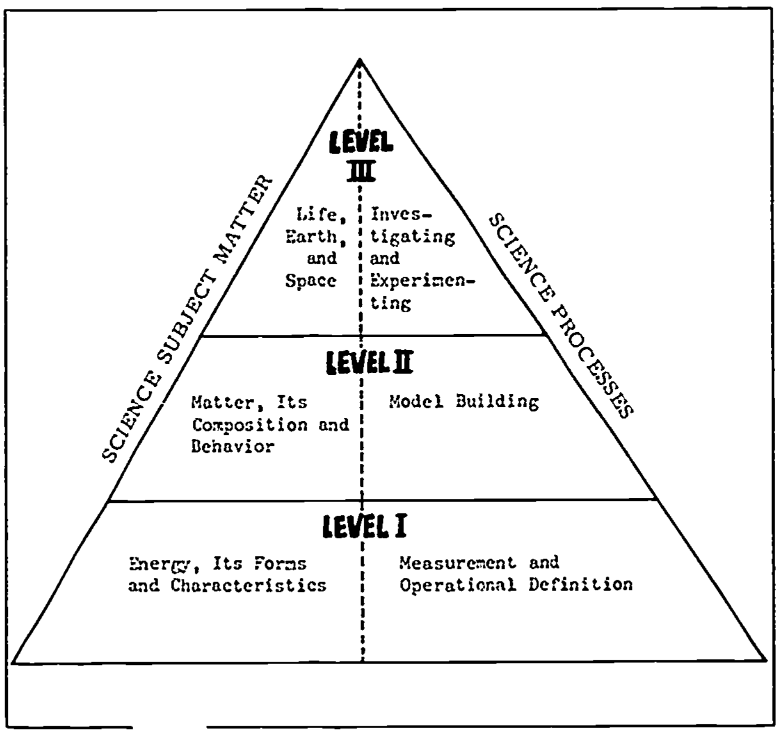


Figure 8. Subject matter and processes in the three levels of ISCS.

that were formerly left to the teacher. New skills are required to deal with individuals and small groups, but necessary adjustments can be made by the average teacher who really wants to see the program work. Indeed, wanting to see the program work may be among the most important teacher prerequisites.

For teachers who have the attitude that they really want to see the program work and who are willing to gain the skills, concepts, and strategies necessary to make it work, the ISCS project staff is presently developing a set of Individualized Teacher Preparation (ITP) modules with a format and style similar to the ISCS student materials. Teaching strategy modules include such topics as rationale for individualization, classroom organization, questioning, your student's role, individualizing objective testing, and evaluating and reporting progress. Science content modules familiarize teachers with the science concepts and processes relevant to the students' program with the scope

☐ **10-11.** Write an operational definition for dissolved sulfate.

Test your operational definition for dissolved sulfate on another sulfate compound—cobalt sulfate ($CoSO_4$). Outline your plan in your Record Book. Then get your teacher's permission.

My plan for testing the operational definition for identifying sulfate:

Test Results:

Figure 9. An independent investigation of a solution.

Problem Break

●3-10. Predict the effect an increase in micro-organisms would have upon the biochemical oxygen demand. ____________

____

●●●● PROBLEM BREAK 3-1

Having a hypothesis (a tentative explanation) is one thing; being able to back it up with data is another. Here's your chance to test the hypothesis you gave in question 3-10.

Design an experiment to find out if increasing the number of yeasts increases the amount of oxygen consumed. Let your teacher review your plan before you begin the investigation. Record your plan, results, and conclusions in your separate notebook.

●●●●●●

Figure 10. A problem break in which student designs an experiment.

and sequence as presented there. Thus, the ISCS teacher gains an opportunity for considerable professional growth while implementing the ISCS program.

In association with the ITP modules on individualizing objective testing and on evaluating and reporting progress, criterion-referenced performance objectives are being prepared. The objectives are being described for students who may have specific math, reading, or concept difficulties and are being related to specific performance check items that in practice will become criteria for deciding when a student has achieved an objective. Put in the hands of a sensitive and knowledgeable ISCS teacher, these tools can greatly facilitate the learning process and optimize individualization of learning. ■

4

OPEN LEARNING ENVIRONMENTS:

The Ultimate Individualization

John Thompson, Gail Griffith, Rich Joko, Robert Lepper, William Page, William Romey, Robert Samples, and Verna Todd

The problem is that I lived half my life before I realized it was a do-it-yourself job.

Charlie woke up at 7:30.

"My God," he groaned, "I'll be late for school again."

He had stayed up late reading the latest issue of *Mad* after he got home from play rehearsal. Then he remembered that there were two tests today—one in algebra and one in German—and he hadn't studied for either.

As he gulped down his breakfast, Charlie thought about what a drag algebra was and how he hated math, and he felt his stomach tighten as he bolted the last half of his jelly donut.

He ran out to the garage, grabbed his bike, and started down the driveway, pedaling like mad to try to beat the late bell. Halfway down the block he skidded in the powdery new snow and slid onto the ground. He could feel the gravel on the street rake some of the flesh off his knee. At least the pants weren't ripped. Well, there was only a small hole. There wasn't time to go back and change, or he would get chewed out by his homeroom teacher, that dragon who sent you to the principal's office every time you looked cross-eyed at her.

As he neared the ultramodern complex of buildings (the architect had won a prize for it) he heard the last bell ring. The knee burned as his pant leg rubbed it; his jelly donut threatened to rise right up out of his stomach, but he managed to choke it back down again.

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Charlie dumped his bike on the ground and ran to the side door near his homeroom. Locked already! You couldn't get in or out during regular school hours. What were they afraid of? "Somebody might come in and find out how they treat us," thought Charlie. He meandered around to the main entrance, the only one left open during school hours. No point in hurrying now. He had already had it.

Charlie tried to sneak past the office without being seen, but the vice principal was standing in the hall and ushered him into his office. Charlie heard the familiar lecture. As he sat there, not even listening to the speech (he was used to it after eight and a half years in school), his knee began to ache.

That ugly moment over, Charlie limped on to his homeroom, where the dragon accepted his tardy slip, and he made his way to his seat.

The bell for first class rang. Charlie had only four minutes to get to his locker, work the combination, try to pry it open, kick it three or four times when it jammed, grab four heavy books, and run on to the algebra test.

He slid in as the second bell rang. Mr. Small made everyone put his books away, and the test papers came around. Mr. Small warned against cheating and started to pace around the room while Charlie and the others wrote furiously, erased, corrected, and erased again. When the period was over, he had finished only 15 of the 20 problems. Mr. Small looked at Charlie's paper as he handed it in, then frowned at Charlie, who turned and left so Mr. Small wouldn't have a chance to say anything to him.

His next class was at the other end of the building, and he tried not to knock people over as he ran. Entering the room, he glanced at the board. "Oh, no, not sentences to diagram."

Another deadly hour later he ran to science class, only to find the blackboard covered with formulas that the teacher then proceeded to lay on him. Ten minutes into the period, he felt his head nodding and was suddenly aware that the teacher had just asked him a question. He mumbled that he hadn't heard the first part of what she said. She told the class that she could well understand why he hadn't heard. The rest of the kids snickered, only too glad she hadn't caught them.

By lunch time Charlie felt terrible and was ready for the respite. But when he finally got through the line, only five minutes were left to finish lunch, get a book from his locker, and make it to his German class.

Figure 1. The real world is a very rich learning environment if students are given a chance to be aware of it.

Frau Schwartz wasn't so bad, but she insisted that all of the genders, tenses, and endings be just right. Charlie had been to Germany with his parents, and he could understand and speak German fairly well. But grammar was his bugaboo and, even though the other kids couldn't really speak a word of German, Charlie usually ended up close to the bottom of the totem pole.

"God, I must be dumb," he muttered every time he got his papers back with C's and D's and an occasional B− on them.

Next hour was gym. The first thing that happened was that Charlie got two demerits for forgetting to bring clean socks. Then the teacher made him wrestle a big bully who seemed to delight in grinding Charlie's face into the mat. The scab that had formed on his knee opened up, and the scrape started to bleed again. The rest of the afternoon, Charlie dragged along through study hall and music almost unconscious of what was around him. In study hall, one of the other kids offered to sell him a joint. but Charlie wasn't to that point yet. Still, he was beginning to think, "Why the hell not?"

* * * * *

Sound pretty extreme? Perhaps so, but all of us had experiences similar to Charlie's when we were in school. You can find anecdotal records of such situations in traditional schools in a whole group of books. (See Appendix.) The experiences are real and commonplace, but there are alternatives. Freedom is just as legitimate as authority.

The alternatives to the traditional authoritarian classroom are as varied as the teachers who use them. We do not wish to abolish the authoritarian classroom, for there are teachers and students for whom it is best; but an open educational alternative must be equally available for the large numbers of pupils and teachers who do not function well within a rigid, extrinsically imposed structure. The one essential element, however, whatever the degree of openness or authority you prefer, is having genuine regard and love for the students and being a whole human being. Because we are science teachers, we have experience and expertise in science, but we choose not to limit ourselves to the scientific realm. Our whole being includes our love of, perhaps, a girl friend or a husband; our anger over a car that won't start; our joy in skiing; our pride in the picture that we took of a sunset; our honesty in admitting we were rude to the parent who challenged us and our calling him to apologize; our disappointment when the baby got sick and we couldn't spend the weekend in the mountains; our eagerness to get home and get started on painting the den; and our enthusiasm for Bach. It is this whole being that we wish to open to each child, in the hope that he will open himself to us. When we set out to develop a loving, trusting relationship with each child as a person, we can let each child's needs determine what learning activities he will do. *True* "individualized education" will be the result.

For the purposes of this chapter we will need first to define or redefine a number of terms. The kind of individualized science learning we are concerned with begins at the preschool level and extends through and beyond grade 20. Thus we redefine "intermediate school" to include schooling that is intermediate between birth and death. By "individualized" we mean that the individual student has primary control over what he studies, for how long, where, when, and with whom. It is science for the individual and not the individual for science. It means finding all the ways that science might help students develop in ways that they are concerned about. After all, it is *their* education—not ours. When we think of individualized

learning environments we mean truly personalized learning environments where students are intrinsically motivated in all of their decision making.

When we talk about freedom or openness versus authority, just what do we mean by "freedom" and "openness"? Ideally, an open classroom is one in which arbitrary boundaries do not exist—boundaries between "periods" (Why should an activity stop at 2:03?); between varieties of subject matter (Why should science be concerned with cloud formation and not Debussy's *Clouds*?); age groups (Why shouldn't a 12-year-old play, or learn, with a 7-year-old or with a 20-year-old?); roles (Why shouldn't Bill or Barb teach you instead of the other way around?); walls (Isn't the gym or the schoolground or downtown often a better place in which to learn than the classroom?); and assignments (Perhaps Joe would learn more today by investigating which fuel is best for his gas-powered model plane than by answering questions 1-8 after Chapter 16). An open environment allows each student to explore the world around him and the one within himself. It allows him to decide what boundaries he will place on himself regarding time, subject matter, work partners, roles, walls, and assignments. His "teacher" becomes a fellow-learner and a resource person whose knowledge and opinions are requested when he feels he needs them.

There are many intermediate steps between this kind of openness and the traditional structure. Contracts, audio-tutorial programs, content lectures, reading, field work, lab investigations, demonstrations, meditation, working with an expert in a field of interest—all can be a part of either openness or an authoritarian classroom. The extent to which the student can choose among alternatives at any given moment distinguishes structure from freedom. To clarify a key point, structure *does* exist in an open learning environment. In fact the open environment may very well have more structure than we may find in the authoritarian environment. It is inherent in the things around, the people available, the ground rules for learning, and in each student. The principal difference lies in the freedom to accept and reject any part of it. Which step is right for you and your students at a particular moment must be determined by experience. The more freedom you are able to allow, the more choices are open to the student to select the kind of structure he needs and wants. Therefore, the more open you can be, the easier it is to provide truly individualized education. We want to try to meet every child's needs, and we want to help each

Figure 2. Big kids can help little kids and both learn from it.

child to become a more fulfilled, self-actualizing person. In order to help him become a happier, freer person we must provide an environment full of care, trust, love, and alternatives.

Our expectations help us determine how free we will be. We must put our expectations out in front of our students where they can be discussed and dealt with. Students also have a whole range of hidden expectations, and we want to be aware of them. Mutual awareness of our true expectations enables us to deal with ourselves, our colleagues, and our students in a more open and trusting way. If we allow our expectations to be negotiable and if our students can also negotiate then we have a chance to develop a truly functional kind of freedom.

Figure 3. The teacher is in constant touch with each student each day.

Psychological Environment

Two things are essential to openness: a rich psychological environment and a rich physical one. You are the most important factor in the psychological environment. If you care, if you are willing to share your whole self with your students, then the psychological environment will be rich. One of us had a chemistry teacher in high school who had become a father moments before he walked into class five minutes late. But none of the people in our class knew the reason for his unaccustomed tardiness until later in the day when word got out. How we wished he had shared this much of himself with us! Students are unlikely to share deep feelings and to be open with us unless we share ourselves first. If we share our own feelings we are more likely to accept feelings that others bring to us, too. Sharing emotions and feelings involves great risks, which is perhaps why people hold themselves back. Whenever we expose our feelings, hopes, or problems, we face the risk that others will think we're silly, sentimental, or weak. Whenever we give students the freedom to work where, when, if, and on what they choose, we face more tangible risks. But trust is essential. We must be willing to take the risk.

Trust extends in another direction too—trust of your fellow teachers and administrators. It is the same kind of trust, but

often harder to achieve. Ideally you trust them to teach their way and they trust you to teach your way, even though the approaches may be very different. This is hard, because typically they are skeptical: "There's *the* right way and *the* wrong way to do something." Consequently, if you are not teaching their way (and of course their way is right) then your way must be wrong. It takes skill, tact, and time to get some people to accept that there may be more than one good way to do something.

Physical Environment

The other essential for providing greater openness is a rich physical environment. Unless there are tantalizing choices in the student's environment and unless he has full access to them, no choices will be made. Physical resources for a rich environment start with litmus paper and end with the universe. Since science deals with the real world, encourage your students to get into it. A list of locations for field work, with brief notes about what each place offers, would be helpful. Students, parents, and colleagues can help with such a roster. Include places within walking distance on or off schoolgrounds and those requiring transportation—city dumps, paper mills, city agency offices, weather stations, observatories, quarries, and lakes.

An extended field trip where students and teachers live together for a period of several days or more can become a school on wheels, using the outside world as a place to learn to the fullest extent possible. The rich environment includes places for students to keep work in progress and records of their work, as well as places to rap with each other and with their teachers. Even a tree outside on a warm day makes a pleasant conference site.

Written materials in a wide variety should be kept in the classroom and the library. Try to provide one of each of all current texts, lab manuals, and teacher's guides available for your course. Pamphlet series are excellent resources. So are magazines—order plenty. Don't get hung up on reading level. Desire to learn will usually overcome reading level difficulties, and ideas can always be gathered from "easy" resources. Tests, diagnostic and achievement, should be made available as informal yardsticks for those who want to measure themselves against external standards.

Lab equipment should include the standard items, such as glassware and balances, as well as specialized equipment, "seductive" equipment, and "just junk." Kits produced by curriculum projects should be available. The popular stream table, for example, may be drained of sand and used as a wave tank or a fish tank for studying the habits of fingerlings. If the school has expensive or potentially dangerous equipment, such as an X-ray machine, level with the students and tell them they must be able to demonstrate they can use it properly before it will be available to them. An A-T unit could help students develop the needed skills.

Audiovisual materials are also important physical resources. Provide the equipment and viewing space for slides, film loops, films, audio tapes, audio-tutorial units, posters, and maps, and then furnish catalogs of what's available in the school and through loan agencies. If it's a school resource, be sure it's readily accessible to students. Provide sufficient audio-tutorial units—or have cameras and tape recorders available so that the students can design and make their own. Don't overlook games and simulation exercises. Several pollution games are already on the market, and you can make up others on your own by adapting existing games, such as Monopoly or card games.

Once you've gathered all the resources, encourage your students to spend a few days just browsing. There's no sense in having a seductive piece of equipment if nobody knows it's there. Of course, whatever you've gathered is just a beginning. The rest will be generated as one resource leads to another. Some of the things you have won't catch on. Perhaps a well-timed question, a suggestion taped to the piece of equipment, or a new packaging idea will stimulate interest. If not, accept the lack of attention and try to help your students find other topics or materials of real interest. The acceptance of apathy as a valid behavior is a necessary precondition to real openness. Once we have accepted a student's right to be uninterested in anything we can set before him, he commonly will take off on a tangent of his own, if we have patience and continue to let him know that we do care for him and for his education.

A final "physical" resource is human resources. Count on teachers in other subject areas, not only because of their subject knowledge, but also because of their outside interests, hobbies, and experiences. Students, too, are rich human resources since they are "experts" in all kinds of things, from the gulch out behind one kid's house to sewing. The local, state,

and national "communities" have people paid to be resources, such as the staff of the health department, and volunteer resources, such as an oil company geologist or a TV meteorologist. Parents and older students have a great wealth of skills and information they'd be delighted to share. Often the student's key human resource is *himself!* This can be the only human resource he needs or even wants in a given moment.

Providing a rich learning environment is a monumental task. It is never complete, but it can be started and added to. You change from a teacher who conveys subject matter and organizes studies to a teacher who provides the rich environment of opportunities. You become an encourager to each student to pursue something the student wants to do. You try to think the way the student does so you can make suggestions that will appeal to him or that he will at least understand. If nothing around the student interests him, you try to get him excited and working on something, that is, learning. If he does not become excited you accept his disinterest and try to communicate with him on how he feels about his life, about himself, about you, and about others. This means that you must share with him some of your own uncertainties and anxieties.

The Environmental Studies Project

To ease the transition period between a lesser and a greater degree of openness, Environmental Studies has developed a set of materials that encourage the development of the two essentials for openness—relationships of trust and sharing among students and teacher and student decision-making in a rich learning environment. The materials ES has produced thus far consist of four packets of cards suggesting highly ambiguous assignments that lead each child to explore the particular aspect of his environment that he chooses. The risks that both students and teacher face with each assignment in terms of opening themselves as whole human beings to each other are pointed out, and one of the packets deals specifically with the area of interpersonal relations. The primary purpose of the entire set is to help students develop the attitudes and skills that will help them to realize their own capacities and aspirations—in other words promote affective growth. They are a unique device to help you during an often trying period, but they are not meant to be an end in themselves. The desired end is spontaneous sharing and caring and student choice.

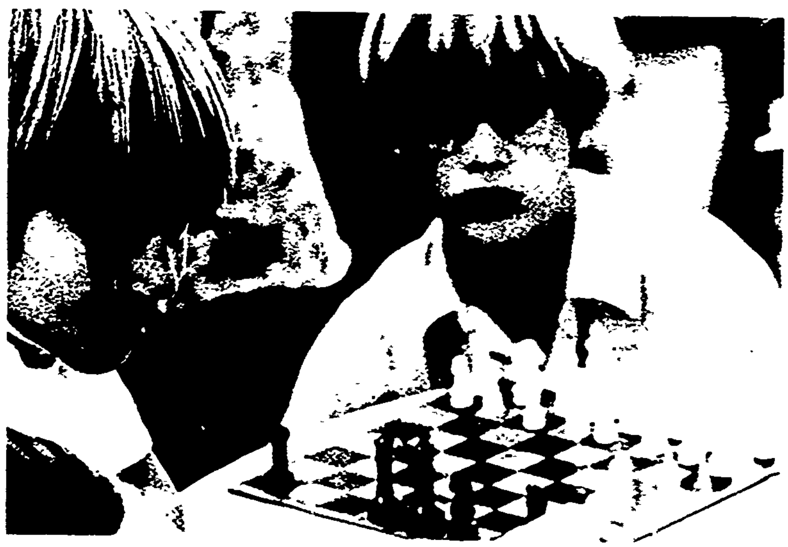

Figure 4. Doing nonscience things sometimes is O.K.

Many people who have not seen an example of a high degree of openness are often reluctant to try it, for a variety of reasons. Their most obvious questions, knowing the choices the students have regarding what to study, when, and how, are, "Does it really work? Do the kids learn anything?" Quite a good deal of research has been done concerning open learning, and an annotated bibliography of some of this research can be found in the Appendix. This should provide some answers for those not sure of the value of humane openness. However, perhaps the most convincing answers to the questions can be given by furnishing examples.

One of us (Thompson) taught a required eighth-grade earth science class in a highly open mode during the 1969-70 school year in Boulder, Colorado. Cognitive tests illustrated that the class compared favorably with classes using a more traditional approach. (Complete data may be obtained by writing to ES/ESTPP.) But to him, the proof of the success of the open mode lay in the way the students responded to the experiment:

Two girls became very involved in trying to determine whether Boulder Creek, the main stream running through town was polluted. After looking in vain for information in the textbooks on how to test for water pollution, the girls and I sat down to discuss where they could get such infor-

mation. They decided that the public health department would be the agency concerned about stream pollution and called its office to learn what they could. They were told the book that gave information on how to test for pollution was too complicated for them to understand. They did, however, get the name of the book, which, as they learned when they scoured the library for it, had been checked out by the health department. The librarian called in the book for the girls and, sure enough, it was too complicated. But a local college professor was persuaded to translate the tests into terms the girls could understand. When they ran the tests, the girls came up with a numerical answer. Of course, they had to find out what the number meant, and then they got involved with standards for pollution. The project gave the girls excellent experience in many areas, including human relations.

I was curious to know how a student who had been a discipline problem in more traditionally taught classes would get along in the open environment. I was able to observe how one such student reacted when such a boy transferred into my class at midyear. I cannot report that he became a shining example, but he did get involved in stream table experiments, in chemistry experiments, in building a dam on a small stream running through the schoolyard, and in working on minibike motors, among other things. And he was no discipline problem. None of the students were, for that matter.

These are examples of what students did in the class and how they became involved. These kinds of activities took place all year, giving me real confidence in the student's ability to choose what he wants to learn.

If you wish to try the humane, open approach, these are workable steps:

1. Know where you are *really* coming from on humane openness.
2. Let administration and colleagues know what you plan to do.
3. Prepare the rich learning environment.
4. Let students and parents know what your plans are and the other alternatives available to them.
5. Spend the five to ten initial contact days with students building trust, getting to know each other, working with what an education is and how science relates to it.
6. Give students a chance to explore the rich learning environment.
7. Turn students loose to do science.
8. Counsel slow starters but do not impose you on them.
9. Counsel, interact with, share with, aid each student as he proceeds on a continuing basis.
10. Be alert to the richness of the environment and continually improve on it.

11. Be aware of your students and their growth as they communicate verbally and nonverbally.
12. Be aware of your fantasy trips and try to stay with reality.
13. Be prepared to grow yourself as you experience frustration, joy, tiredness, excitement, love, questions, and an awareness of whole people growing.
14. Continually evaluate (not *grade*) the total learning environment including you, them, and it as a means of continually improving the experiences for all.

The relaxed and warm feeling that an open environment can generate is illustrated in this account of a class in earth science at North Arvada Junior High (Arvada, Colorado) taught by Ed Maruna during the 1970-71 school year:

The door was open and a steady line of fourteen year-olds trooped in and out with plastic bottles of water. The water was being dumped on a hillside near the back of the school building. Some who didn't carry water stood around and encouraged the workers. Some just talked among themselves about pep club, boy or girl friends, and what they intended to do after school. However, everyone's attention became immediately focused when a great event took place in "North Arvada Canyon." Cheers went up when a pebble that had long resisted the stream flow tumbled over and slid to the channel floor. With such heightened drama providing emotional release, the students returned to conversation. Sometimes they would pause to note how the errant bursts of water made side streams that became more and more molasses-like as they ran down the slope. Some became fascinated by the way the mud "froze" near the bottom.

Bored by the progress of the canyon, a small group broke away to continue a study they had started two days ago . . . they were trying to find and prove the existence of a million of some thing in the environment. Just before they got out of earshot they were arguing about which solution to attempt. Grass blades and bricks were being dismissed as being "too obvious."

Somebody yelled, "Flood!" . . . So I went outside to look. Five plastic bottles were being emptied into the canyon at once. It *was* a flood! The delta at the bottom grew remarkably. Upstream more pebbles were exposed and bigger chunks of rock had been washed down. Ed was teasing the group in search of a million and, though I couldn't hear what they were saying, I could see them laughing with each other as he rejected the trick proof they had laid on him.

I didn't know what they would do tomorrow, nor did I care. I found that this comfortable, relaxed class had filled me with more data than any convention talk or college lecture I had had to listen to. Many students were enjoying science (and school) for the first time because of this class. They became involved with their environment in ways they chose and that had meaning for them. Even the threat of grades had been removed

since each student evaluated himself. He wrote how he felt about what he had done, and then he and Ed sat down and talked about it. They decided on a grade together.

Inservice Experience

The University of Colorado conducted an in-service institute funded by NSF for science teachers interested in using an open learning environment. The participants were given the opportunity to determine what the institute program would be; who would be used as resource persons; where the field trips would go and how they would be conducted and by whom; what they would do with the experiences they gained in the institute; whether they would show up at the sessions; and what grades they would get for their credits. The learning environment was as rich as possible in both human and physical resources.

Some topics selected by the participants in the institute included:

Making topo maps
Soil formation
Limnology
Flights to study geomorphology of Front Range
History of mining camps
Encounter groups and techniques for classroom use
Open learning experiments
Making A-T units
Making labs for students
Use of telescope
Air and water pollution measurement
Float trip down Green River
Environmental Studies cards
ESCP, TSM, SRA earth science investigations
Fossils in the Denver metro area
Thin section making
Junk Day
Visit to a working mine
Administrator's Night
Denver-Boulder eco systems
Trip to Wilson School, Minnesota
Ski touring
Evaluation in the affective
Anthropology and archaeology
Weather prediction locally
Oceanography
Chromatography
Glaciation in Colorado

Figure 5. Finding a dead bird may lead to environmental awareness.

The results are best judged by the responses of the participants.

The exchange of new ideas was terrific and my educational philosophy was greatly influenced by the other teachers. We went on so many field-trips (especially the raft trip) that provided a great deal of new information to increase my knowledge of the environment. Friendship development was terrific with everyone. I now feel we will develop lots of new ideas on curriculum this year. . . .

. . . the behind the scenes interactions between the participants has been very rewarding. I have found that contrary to popular opinion, teachers are human beings and have their hangups. I believe this insight has given me the key to my relationships with students. Let them know you so you can better know them. We must remove the brick wall which we as teachers put up to serve "knowledge" over to our young clientele.

This institute was an almost complete surprise in that it really put theory into action.

I have been very impressed by the staff's position of permitting almost total self-direction. This is a tremendous step in education—allowing people the responsibility and recognizing maturity to make our own decisions as to what our needs are.

The most valuable educational experience, without a doubt, relating to teaching philosophy and techniques and to school organization and curriculum, was the trip to the Wilson School in Mankato, It really turned me on and tuned me in to open school techniques and possibilities.

The evaluation done of the institute showed that the participants gained a great deal of subject matter competence not held previously, grew a great deal as human beings, and actually changed their classroom behavior substantially in an open learning environment direction, making it much more humane. Trust was at a high level in the institute. A year later, most teachers are more open than before.

Preservice Experience

The Geology Semester, run through the University of Colorado, provides another example of many things we have been talking about. Twenty-five students, a cook, and two instructors toured the western United States in a bus and stayed in the field for three months. The students discovered that sudying rocks in the field is much more exciting than reading about them in a textbook. When a student wanted to read about what he was doing, he went to the well-stocked library on the bus. At each stop of four or more days students picked something that interested them and explored it on their own. They were free to pick their topic, though geology was suggested.

Operational Efforts

The Wilson School at Mankato, Minnesota, is the best example we know of to illustrate how an entire school works based on openness. Preschool through twelfth grade, this school (soon to include a college curriculum also) has been described by its principal, Don Glines, in *Creating Humane Schools*. [Appendix II, 13]

Our office has more than a hundred additional accounts, with more coming in every month, written by the teachers themselves, of the degrees of openness they have practiced and the success (and failure) they have experienced. These have been compiled in a book, *The Cutting Edge . . . or How to Innovate and Survive*. [Appendix II, 6]

Conclusion

It is not sufficient to individualize instruction if this is only putting students through predetermined paces as individuals rather than as groups. Going at his own rate allows a student to escape some of the anxieties of a prescribed sequence of subjects. But many students we know have told us that they get that overwhelmed feeling of never being able to learn "all that 'they' say I have to learn." We see students coming to feel more and more insecure in their own lives as teachers try to make all of their decisions for them. We know of students who spend double or triple the amount of time on individualized learning packages that they spent previously on regular, authoritarian classwork. They still get hung up on grades and on doing someone else's "thing." They get little or no chance to ask the questions, "What's in it for me? What do I want to do with my life? What things will help me to discover what my life is about? And how can I realize the potential that is within me? How can I grow as the unique individual that I am rather than just be molded into what 'they' say I should be?"

It is possible that adult concern for preparing children for later life (ultimately, adulthood) is having a stultifying effect on our youth. Perhaps we should allow our children and youth freely to come to grips with what is very real, meaningful, and exciting in their lives today. In doing so, we may be offering them the best possible preparation for adult life. Open learning environments provide one important way in which we can help students find their own goals, develop their own potential, and become the caring, flexible, responsible people who will be necessary to insure our survival. ■

Humane openness—Try it! You'll like it!

5

PACE

Personalized Adventures in Chemical Education

Harold Wengert

One could reasonably ask, "Why develop a new high school chemistry program when large sums of federal monies have already been spent developing programs such as CHEMS and CBA?"[1] The following is the author's rationale for the development of a new chemistry program, PACE (Personalized Adventures in Chemical Education). The previously mentioned federally funded programs updated the ideas to be taught, placed heavy emphasis on laboratory experiences, and involved the student in the processes of science. However, they were still teacher oriented. The PACE chemistry program puts the child at the center of the learning environment, thus allowing for maximum development of each individual regardless of his cultural background or his intellectual abilities.

Currently, high national priorities are being placed on the development of structured but flexible programs. The author believes that the chemistry program should be primarily designed for general education. Yet it should be flexible enough to provide for in-depth experiences by the science prone and to develop basic ideas that can be conceptualized by the less able students. Emphasis at all educational levels on such concerns as education for minority groups and the disadvantaged, flexible scheduling, individualization, and personalized learning also focuses on the need for a fresh approach to high school chemistry.

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[1] Chemical Education Materials Study and Chemical Bond Approach Project

The description of the PACE program follows the parameters established in Chapter 1. The variables are classified by the processes of direction (what the learner learns), sources (how he goes about learning), pace (how fast he learns), and evaluation (how well he learns).

Direction

The PACE program centers on the conceptual schemes of energy, the mole, and periodicity. Multiple exposure to these conceptual schemes in many varied situations and on several levels of sophistication improves both understanding and retention. (See Figure 1.)

The core materials are structured, both as to order and content. Outside of the basic core, however, independence of choice exists in the form of special projects, options, and alternate routes. The specific direction a student takes depends upon his personal goals, expectations, interests, and mathematical background. Branching activities include remedial, general interest, and extensions. The student encounters them through free choice or in consultation with the teacher. It has been found, specifically in schools using modular scheduling, that this independence generates miniprojects designed solely by the student but based on his core activities.

Experience in the development of PACE, particularly as the enrollments were extended to include lower ability students, indicated that a structure was essential to positive learning and to the generation of a success-oriented environment. Total free choice produced a rather chaotic and unsuccessful learning environment. Student success with the structured core materials facilitates the success of the independently selected investigations.

Sources

Audio-tutorial (A-T) systems are used to individualize the chemistry course in areas that do not readily lend themselves to other suitable methods. Basically, these systems fall into six general classes:

1. *Minicourses.* Remedial minicourses include concepts and skills, such as graphing, ratio and proportion, slide-rule manipulation. scientific notation, and dimensional analysis. In-depth minicourses on topics like bonding, hybridization,

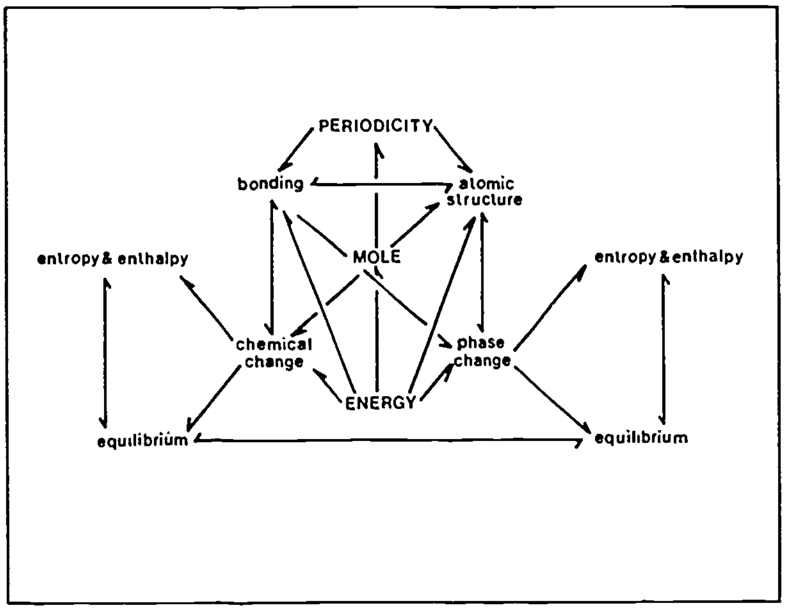

Figure 1. Central conceptual schemes and related topics in the PACE program.

Figure 2. A student works through an audio-tutorial minicourse.

the mole concept, and spectroscopy include the use of film loops, filmstrips, lab investigations, and audio tapes.

2. *Conceptual developments.* The learning of some concepts can take advantage of technological materials such as Super 8mm film with stop action, slow motion, and time-lapse photography. Examples are diffusion, equilibrium, and motion experiments where a film can record data that otherwise could not be collected because of the motion involved.
3. *Summaries.* Filmstrips, transparencies, and slides correlated with an audio tape serve as a convenient way to present an 8- to 10-minute sequence or learning experience.
4. *Substitution for or supplement to laboratory investigations.* Occasionally, investigations are very useful in the development of a concept but require several days to carry out. A-T systems are used effectively to condense the student's time without sacrificing the conceptual development. Often the concept is more effectively learned because the whole concept can be fully developed at one time rather than over several days.
5. *Techniques.* Conventionally, techniques are discussed as part of a demonstration-discussion session. In the PACE program few students are ready for a given technique at the same time. A-T systems on techniques minimize time-consuming repetition. Such technique systems are: how to use a Spec 20, a pH meter, Dial-O-Gram balance, and a burette.
6. *Interest motivators.* These are tangential or science related but not necessarily an integral part of the PACE program. They include such topics as investigation of plastics, pollution, and drugs and are available for independent use by the student when he is interested or has the time. They are changed at intervals of two to three weeks.

Since student use of reading materials is strongly encouraged, the multireference approach is effective. In some cases a student is guided to specific resource materials commensurate with his particular background and ability. A reference file of about one hundred and eighty current articles indexed by content is also available for student use.

A variety of supplementary materials is invaluable in further individualizing the program. The more variety and levels of materials available to the student, the more effective the program will be. Commercial filmstrips with audio tapes, pro-

Name ____________________ Class ____________ Course ____________

Part No.	Date Started	Target Date	Date Finished	Total
1				
2				
3				
4				
5				
6				
7				
8				
9				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				

First 9 Weeks

How many parts do you hope to complete this 9 weeks? ________
Are you more interested in quality, quantity, or both? ________
Are you planning to go on to school after high school? ________
Are you interested in a career related to science or engineering? ________

Second 9 Weeks

How many parts do you hope to complete this 9 weeks? ________
Are you more interested in quality, quantity, or both? ________
Are you planning to go on to school after high school? ________
Are you interested in a career related to science or engineering? ________
Are you satisfied with your progress? ________
Are you interested in doing a better job this nine weeks? ________
Do you expect to do a better job this nine weeks? ________

Third 9 Weeks

How many parts do you hope to complete this 9 weeks? ________
Are you more interested in quality, quantity, or both? ________
Are you planning to go on to school after high school? ________
Are you interested in a career related to science or engineering? ________
Are you satisfied with your progress? ________
Are you interested in doing a better job this nine weeks? ________
Do you expect to do a better job this nine weeks? ________

Fourth 9 Weeks

How many parts do you hope to complete this 9 weeks? ________
Are you more interested in quality, quantity, or both? ________
Are you planning to go on to school after high school? ________
Are you interested in a career related to science or engineering? ________
Are you satisfied with your progress? ________
Are you interested in doing a better job this nine weeks? ________
Do you expect to do a better job this nine weeks? ________

Figure 3. A student sheet for a record of goals set and completed.

grammed materials, A-T systems of the teacher's own design, and supplementary worksheets to fit specific student problems are excellent aids in giving depth and breadth to the realm of student choice. Generally the student chooses which source and how many sources he is to use. However, teacher guidance and counseling are needed when a student's responsibility or background blocks effective learning.

Also built into PACE is the alternate route method of how the student learns. This provides a choice for the student as to whether he uses a laboratory approach or an A-T approach—for example, in developing a specific concept. In some cases the alternate route gives the student a choice as to the level of the mathematical approach used in the development of a concept. The route chosen by the student depends on his own interests, background, and goals.

The PACE program provides the teacher and student with the flexibility to move within the parameters of independence and individualization, using student individual needs and ability as the determining criteria.

AREA	YOUR INDIVIDUAL PERFORMANCE LEVEL DESCRIPTION	LEVEL OF PERFORMANCE	PARTS
[illegible]	(1) insightful, (2) creative, (3) abstracts, (4) interrelates	5	
	(1) compares, (2) needs direction, (3) relates	3	
	(1) imitates, (2) duplicates, (3) copies, (4) dependent	1	
[illegible]	(1) complete, (2) novel, (3) accurate, (4) labelled, (5) neat	5	
	(1) acceptable, (2) lacks depth, (3) some errors	3	
	(1) sketchy, (2) incomplete, (3) copied, (4) inaccurate, (5) messy	1	
[illegible]	(1) self-directed, (2) neat, (3) precise, (4) careful, (5) interested	5	
	(1) follows directions but inconsistent, (2) passive	3	
	(1) sketchy data, (2) no planning, (3) neglectful, (4) careless	1	
Self-Responsibility: Use of Time	(1) organized, (2) independent, (3) efficient	5	
	(1) [illegible], (2) usually positive, (3) get by	3	
	(1) excuses, (2) distracts, (3) copies, (4) slow progress	1	
Performance Test Evaluation	(1) well prepared	5	
	(1) acceptable, (2) suggested minimum to continue	3	
	(1) unacceptable, (2) needs more work and review	1	

Figure 4. PACE form for evaluation of self-responsibility.

Pace

The PACE program employs a continuous progress, team-learning approach to pacing. This means that the program takes advantage of the positive learning effect of group dynamics by having the students work in groups of two or three members, with the group membership being determined by the students. Discussing, questioning, peer-peer teaching, and utilizing the different backgrounds and abilities of the students in the group set the stage for effective learning to take place.

In general, the pace of learning is independently established by a group. What the student or the group learns depends upon goals, aspirations, self-image, and background. A good clue to whether or not the group or individual feels successful with the program is the pace that is set in relationship to the expected pace as based upon ability and background. When an unacceptable pace is set, in the view of the student and/or teacher, guidance and counseling are sometimes needed. Freedom without responsibility will lead to an ineffective and chaotic learning situation.

Goal setting on the part of the student is a necessary component of individualized instruction. If conventional teacher-imposed goals are removed, then a vacuum forms in the student's behavior pattern, and it must be filled by something. The most effective substitute is a set of self-imposed goals. These goals should be both long term (nine weeks) and medium range. The way the PACE program presents these goals can be seen in Figure 3. If the student still has trouble functioning, daily goals can be set by the student for quantity and quality of work to be completed each day. Some students need deadlines to help them structure their self-discipline.

The variable of pacing is called self-responsibility on the evaluation form. (See Figure 4.) If the pacing is as fast as possible and still achieves understanding, then the student is operating at a Level 5 regardless of the actual quantity of material covered. Therefore, a student of very low ability could easily be achieving at a Level 5 while a very able student could be achieving at a lower performance level.

Evaluation

Effective evaluation and student feedback are critical to the success of any individualized program. PACE is no exception. Since many extrinsic goals are removed, the student must have a great deal of input from which to set intrinsic goals. This is particularly true in the first semester while the student is learning to set his own pace and accept personal responsibility for his own learning.

Several points regarding evaluation deserve special comment.

Personalization. Individualized instruction emphasizes that the teacher must know *all* of his students on a one-to-one basis very quickly in order to help guide the student to the best route for learning. Instead of 5 classes of 25 students, the teacher now has 125 classes of one. This requires energy, time, and *patience* on the part of both the student and teacher. The work of the teacher will not be easier, but it will be more effective and rewarding.

Teacher's initial boxes. This feature of the PACE materials has come from student feedback. At critical points in the conceptual development of a packet, the student comes to get the teacher's initials. This allows teacher-student interaction frequently enough and at important points so that the student gets feedback on his progress every day or two. A two- or three-

Figure 5. Students may work in small groups as well as individually.

minute check of the answers during class and a question or two directed to the student will indicate whether he is ready to proceed. When an acceptable level is reached, the box is initialed. This is a very important step and is used conscientiously, but with as little time spent as necessary to determine whether the student is ready to go on.

A "master" unit available for reference by the student allows him to check his ideas and answers before he comes for initials. Answers that are identical to the ones on the "master" units are not accepted. This places emphasis on understanding rather than "right" answers.

Self-tests. This is an important aspect of an individualized program. It allows the student to assess his progress without in any way putting his "grade" on the line. It helps the student pinpoint weaknesses and areas for further study before the performance test is taken. The student checks the test from an answer key located in the file. When the student achieves at below a 70 percent level, he is encouraged to review, get help where needed, and take the B test form over the same packet. This is the student's choice, however, since he is the only one to see the self-test results.

Performance tests. Performance tests are used as much for a diagnostic tool as for a grading tool. Several forms of the same test are used to give the student several chances at a satisfactory level of performance. A quiet resource center or

media center where the test can be taken is a conducive environment for this learning experience. The author uses an open book and open reference approach based on the honor system. It has been found that cheating occurs most frequently when overemphasis is placed on a test, its value, or weight in determining a grade.

The final evaluation of the student on a specific learning packet is a composite of self-evaluation and teacher evaluation. Five areas are evaluated with each area weighted equally. (See Figure 4.) After the packet, including the mastery tests and extra work, has been critiqued by the teacher, the whole set is given back for correction, modification, and improvement as seen necessary by the student. He then self-evaluates by marking his performance level in each of the five areas and returns it to the teacher for final evaluation. The teacher marks the performance level as he deems appropriate. Any differences in the levels as recorded by the student and teacher, any remedial teaching, and any guidance and/or tutoring are discussed in a conference when the packet is returned to the student the last time. Mechanically this is somewhat time-consuming, but educationally it is a very critical point in the successful implementation of individualized materials. At this final conference personalization and individualization become a reality. The composite of quantity and quality based on each individual's performance is used to determine a grade.

Now in its fifth year of development, PACE is being used in 32 schools with 2,300 students. Extensive feedback and evaluation have gone into its revisions and modifications. The feedback has come from inner-city schools, rural schools, suburban schools, and private academies. Test results in both the cognitive and affective domains and significant increases in chemistry enrollments in the schools using PACE indicate that it might serve as an effective model for the development of other individualized secondary science programs. ■

6

AUDIO-TUTORIAL LEARNING

in the Secondary School

D. H. McGaw, C. A. McGaw, K. H. Bush, R. N. Hurst, and C. L. Smiley

A new era in programmed instruction arrived in this past decade. The singular teaching machine with the sequence approach has given ground to a multimedia approach known as audio-tutorial (A-T). The audio-tutorial system has become a commonly used term for a teaching approach involving a complex of specially designed material presented with the aid of tape recorders, motion pictures, slide projectors, demonstrations and experiments, book reference work, and oral and written quizzes.

While outcroppings of this approach have appeared in every area of the country, the credit for its initial development and use, which occurred in the natural sciences, must go to Samuel L. Postlethwait of the Department of Biological Sciences at Purdue University. Mimicking a program which Postlethwait developed for a botany course, instructors in several other disciplines organized courses using similar individualized formats. The enthusiasm for this instructional strategy spread beyond the Purdue campus and into the West Lafayette High School biology department, where the 1969-70 school year marked the advent of an A-T programmed instruction biology course for 220 students.

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The course was established in the belief that programmed instruction would facilitate the use of behavioral objectives, individualized instruction and participation, and course evaluation and that it would improve teacher-student relations. It was and is still taught by Kenneth Bush, Curtis Smiley, and David McGaw.

The best setting for learning in an A-T program is a booth or carrel which contains the texts and tangible materials. The carrel and headphones provide the isolation which is essential in an area of diversified activity. Since the student is alone with his tape player and materials, he may repeat portions of the program until the achievement of the objectives can be documented by an evaluation.

The West Lafayette department constructed 36 student carrels in an ordinary biology laboratory-lecture room complex. Each carrel was equipped with a cassette tape player with A-C adapter and headphone. Also purchased were 14 cassette tape recorders, one cassette master recorder, and a mixer panel for duplicating. The room containing the carrels is now called the A-T learning center. Students attend the usual five 55-minute periods each week.

Each lesson is a module consisting of a taped discussion (not a lecture) which programs the student through a series of learning activities. In the production of an audio-tutorial module the teacher performs many of the same preparation steps as for producing a good lesson plan. First, the goals and objectives of the module which define the desirable ideas, skills, concepts, and attitudes are listed. The teacher then takes inventory of all his resources (i.e., slides, filmstrips and filmloops, laboratory equipment and experiments, texts, and resource people) and designs a multiple-path program of instruction in which the student can include or omit experiences according to his needs and background. Having before him the materials and equipment to be used by the students for the module, the instructor produces the audio-tape program.

Direction

The Activities Flow Chart (Figure 1) relates the possible pathways of the program to the grading system. The student first examines the performance objectives. These objectives tell the student what he needs to accomplish, how well he will have to do it, and how he will be tested. The student then proceeds

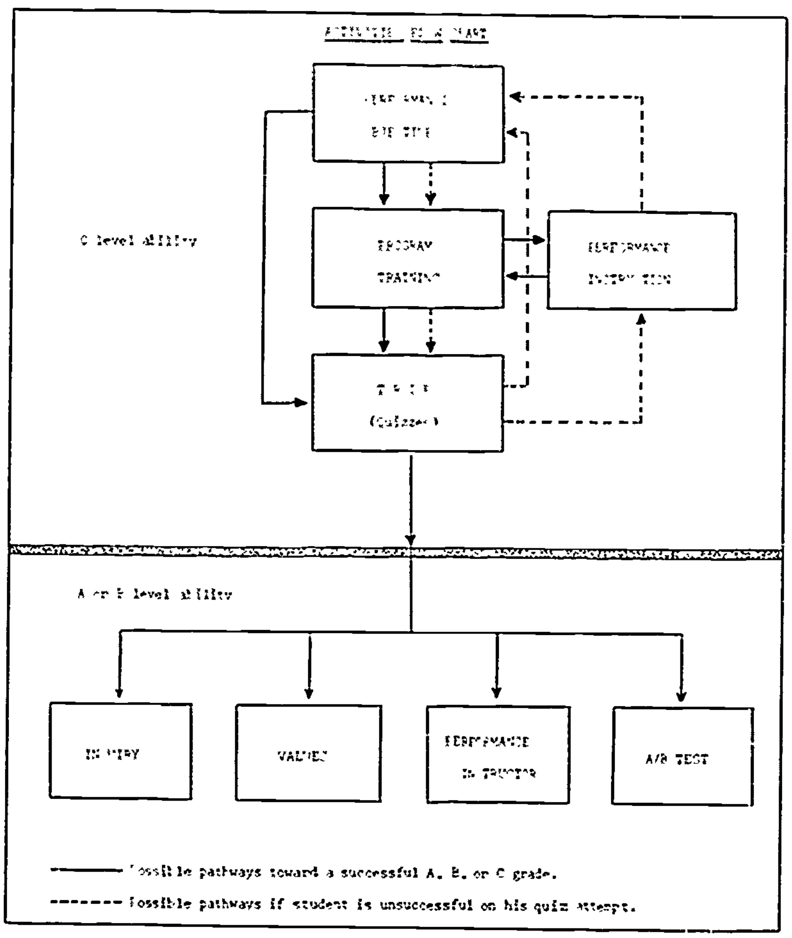


Figure 1. Audio-tutorial activities flow chart.

to the programmed training. Training options may include listening to taped information, conferring with the teacher, drilling with other students (performance instruction), performing laboratory experiments, observing demonstrations, viewing films, and/or reading the texts. When the student feels that he has mastered the objectives, he will demonstrate his mastery by scoring at least 80 percent on a written quiz and 100 percent on an oral quiz. Once the student has mastered the objectives, he attains the grade of C which signifies he has completed the module. He may then proceed to another module or to some of

the experiences for which he will receive A/B points. The student may qualify for the grade of A or B by collecting enough A/B points to achieve a predetermined total.

An inquiry, worth ten points, is an open-ended miniresearch project which is partially designed by the student. The inquiry write-up must be signed by an instructor who observed the student perform the inquiry. Students may design an inquiry based on the objectives. For example, there might be an objective on the C level which states that the student should be able to type blood. The student might design an inquiry in which he would collect the blood types of 30 students and compute their ratios.

In each of nine basic units, the student is given the choice of working with one or more social issues which are called values. These problems are designed to help a student form a value system for himself, and each is worth 10 A/B points. For example, a value might read:

> For years the federal and several state governments have subsidized the killing of coyotes in the western United States. The coyotes kill sheep, and the ranchers want the coyotes controlled. Many people think that this treatment is unwarranted. State your position of what the role of the government and the role of the rancher should be in the control of the coyote. [1, p. 78]

To establish a value position, the student must go to the library and locate information concerning the issue. He must then attend a value discussion with a small group of peers and an instructor. In this group he may be asked to describe his own library research and listen to the research of others. Each student then states his opinion on the issue. Following the discussion the student writes a position paper in which he supports his stand with the information gained from the module related to the problem, his library research, and student opinions presented during the discussion. The process of forming and supporting decisions of social and scientific significance in each unit is one of the unifying threads of the course.

When a student has completed a week's work and has passed the quizzes, he may teach another student that week's work and receive 10 A/B points. The student who has received the instruction submits the performance instructor's name when he takes his quizzes. If the student completes the quizzes, th performance instructor is awarded the points. Students and teachers have deemed this mode of teaching both popular and

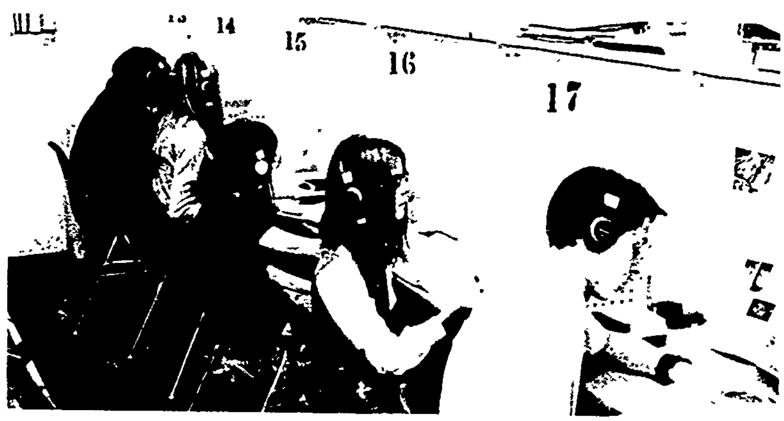


Figure 2. A training option includes listening to taped information.

successful. This is to be expected since peer group teaching has often been more successful than instructor-pupil.

Each student may take an A/B test at the end of each unit and score up to 40 A/B points. The test questions are all multiple choice and require the student to analyze, to compare, and to synthesize information in order to select the best answer.

Students may engage in a continuing research project called "Research Directions" which may be continued from unit to unit in place of or in addition to other A/B activities. Each of the two project areas currently being developed—*Tribolium* beetle and *Chlorella* algae research—has four research directions of study: (1) genetic, (2) nutritional, (3) social, and (4) environmental. Before starting the research, the student must complete several A-T modules which cover the basic information and skills necessary in the research direction. He then chooses one of the four directions, inspects a model project, and starts to design his own research, while maintaining constant contact with the instructor and other students who are working on the same direction. Each student must make many design and research control decisions to develop his project.

Sources

A *Systems Approach to Biology* [1] written by the West Lafayette High School biological team members and edited by Robert N. Hurst, Department of Biological Sciences, Purdue University, is used as a study guide for the course, along with the

state-adopted texts. The guide lists the performance objectives, inquiries, and values used in the course. Each of the 12 units (9 basic and 3 optional) is prefaced with an abstract which is an overview of the unit. A checklist of the activities in the unit follows the abstract. The unit is divided into a number of modules or lessons, each with its own rationale, performance objectives, and practice exercises.

The A-T learning center contains a demonstration table which is used for displaying specimens and setups which are difficult to mass produce. This table also permits efficient use of limited equipment.

Additional help is given by students who have previously completed the course and have come back to help as teaching assistants (TAs). They lead many of the discussions, assist in monitoring quizzes, and give advice to students in the laboratory areas.

Pace

Although the running time of a tape averages 30 minutes or less per module, each student determines how much time he needs to spend on the module. A value takes about one class period, and an inquiry requires several periods to complete. Most units require three weeks to complete, and the research directions continue for much of the year.

The instructors determine and impose deadlines on the students. If the student does not finish the unit at the time of the deadline, an instructor reviews the student's attendance record and consults with him. If the instructor feels that the student has applied himself, or that further time and effort on the part of the student would be beneficial, the teacher continues to work with the student after school or during the student's study halls. Sometimes a student is requested to return the following year when the same unit is being taught and finish the objectives at that time. The course grade is withheld until this work is completed.

If a student is consistently having trouble, the instructor will consult with that student and prescribe a course of action. Sometimes the student will be required to check with the teacher several times during the period and give him a progress report. Sometimes the instructor will suggest that the student disregard several of the more complex objectives, or he may match the student with a performance instructor. A number of

visiting teachers have remarked that, because of the interaction of students and the independent type of instruction, it is difficult for them to identify students of low ability in the classrooms. This invisible condition is responsible in part for the good attitude of the slower students.

Evaluation

Criterion-referenced oral and written quizzes for each module are taken when the student feels he is ready. The written quiz is composed of 20 multiple-choice questions. It is graded on the spot, and a list of the incomplete objectives is given to the student. The student must attain an arbitrarily set mastery level of 80 percent correct to complete the module.

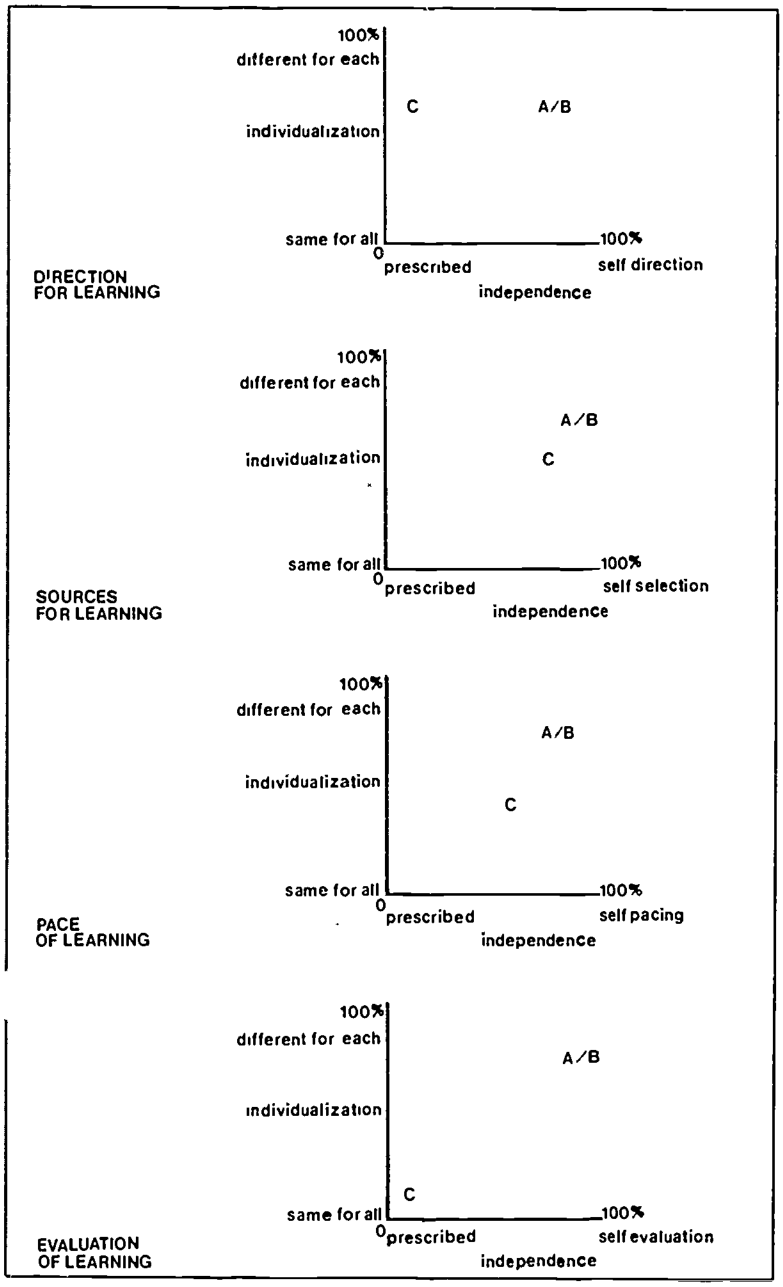
The student's performance on one objective selected by the instructor at random from the module comprises the oral quiz. If the student can perform the objective, but requires a bit of prompting, he will receive only a C for completing the module. If he performs at a higher level, he may receive a bonus of one A/B point. Usually a small group of students take their oral quizzes at the same time. After a student has completed his objective, any student in the group may add or correct information for additional bonus points. Therefore, it is possible for a student to get one bonus point for performing on a higher level and one for adding information to another's oral quiz.

An A/B test worth 40 points is given only once at the end of each unit. It covers the objectives and other related materials. The multiple choice questions require the student to compare, predict, analyze, and synthesize information.

The Nelson Biology Test [2] is given as a pre- and post-test for the course. The test is used to compare group performances, to check progress against national norms, and to identify students who may need special attention.

A student may elect to take the written quiz as a pretest before he has trained for the performance objectives. This quiz acts as a diagnostic tool, since he can use the list of objectives on which he faltered to help direct his studies. Oral quizzes are also diagnostic because the instructor can immediately guide the student having difficulty toward what to study.

Teachers and courses must be evaluated, too. Students are requested to jot down criticisms and suggestions for the course and put these in a suggestion box (which has been labeled the Student Power Box by the students). During the A/B examina-



Figures 3 through 6. The A/B and C symbols in the graphs indicate that the amount of independence and individualization given the student depends on the type of activity and the grade desired by the student.

tion, each student completes both an objective and subjective opinion poll for the unit. Twice during the year, when the Nelson Test is given, the students also answer a summative opinion poll. The information gathered from the opinionnaires and the information obtained from the Nelson Test help the instructors to experiment and make sound changes in the course.

Grades are issued every nine weeks. Any student who completes all of the modules in that period of time earns at least a C. A student who attains 50 percent or 66⅔ percent of the possible A/B points achieves a B or A grade, respectively, for the grading period. Any student with an incomplete will be issued a grade according to his point score upon completion of the required modules. Any student who receives an incomplete is assured that the instructor will follow through with a telephone call to the student's parents. Three years of experience have shown that grades are distributed as follows: 20 percent C, 40 percent B, and 40 percent A.

The results from the Nelson Biology Test indicate that the West Lafayette students compare favorably with the national norms established by that test. The mean response rose from the 20 percentile on the pretest to 69 percentile on the post-test, a gain of 49 percentile units. However, the teachers believe that the test does not measure the decision-making skills which the course emphasizes. The summative opinion poll which was constructed and validated in an unpublished study [3] indicates the following increase in favorable opinion of students during the three years of operation: 79 per cent in favor the first year, 86 percent in favor the second year, and 95 percent in favor the third year. The improvement in attitude is attributed to the fact that the students' suggestions were followed in yearly modifications of the course.

The same study correlated SCAT scores with the students' opinion of the course during its first year of operation. A slight inverse relationship ($r= -.39$) indicated that the less intelligent students favored the course slightly more than did the highly intelligent students. A "t" test of 5.47 indicates that the correlation is significant at the .01 level of probability (2.576). [4] The factors of self-pacing and repetition might be reasons for this positive attitude expressed by the slower students. This information prompted the instructors to construct the research directions. The higher ability students have enthusiastically endorsed this addition.

Summary

Programmed instruction using the A-T method has allowed more efficient use of time by both students and teachers at West Lafayette High School and at seven other high schools where it is currently in operation. But perhaps more important, student decision making appears to have fostered more positive attitudes toward the science of learning. We recommend that some form of A-T instruction be considered by teachers not completely satisfied with their present methodology.

The West Lafayette teachers are pleased with the evolution of their audio-tutorial program and welcome inquiries from interested colleagues. ■

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7

INDIVIDUALIZING YOUR OWN CLASSROOM

Henry J. Triezenberg and Richard J. McLeod

In a very real sense, your reading of this volume so far is an example of group study. True, it is probably independent study—you're doing it of your own free will without the external direction of a teacher. However, most of you are doing the same thing by reading the chapters sequentially, and there isn't much that is individualized about that. Some people would claim that your learning is individualized because you are experiencing highly individualized impressions and reactions as a result of your reading. But that is due primarily to your individual natures and backgrounds; certainly no one could claim that any attempt is made in this book to individualize its study. It is individualized only in the sense that you could proceed at your own pace, and, of course, you could skip chapters if they did not meet your needs. Actually, this book is about as rigidly organized as any course of lectures.

But that is about to come to a screeching halt. If you study individualized curriculum design from this chapter on, it will likely remain independent and become individualized. For now you must decide what to do in your own classroom, and it is a safe prediction that what you do will depend largely on your individual contacts as well as characters. There are few operations in American education that are more independent or more highly individualized than what a teacher does when he closes the classroom door. Then, your real values become evident.

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And if one of those values is an appreciation for human dignity —for the unique individuality of each person in your classroom—your behavior will give evidence of an attempt to individualize your instruction. Your study of individualized curriculum design itself will become more different than that of your colleagues. You will realize more fully your own unique potential as a counselor and guide to individual students.

How different you become from each other depends partly on whether you choose to implement curriculum materials that have already been designed, like those described in this booklet, or whether you choose to design your own. This is a decision you should not take lightly; from thousands to millions of dollars and hours have been invested in the development of the curricula described here. Obviously, it would be much easier and less expensive for you to adopt one of them and to put your local resources to work in making an effective implementation. But that is not the way these projects got started, and you also may want to cast off on your own. Or perhaps you want to adopt one of these programs and design some supplementary lessons. In any case, this chapter is meant to assist you in progressing from here.

Whether you implement an individualized curriculum, design one of your own, or perform a combination, you will be individualizing the "course" you are taking by reading this book. If you do nothing further, it will remain group study. But if you apply these ideas to your own situation and implement them daily in your classroom, this course can become more than 95 percent individualized. The bulk of such a course is yet to come. It can be such a highly individualized course because it is so much an independent study. The option is yours. This chapter is designed only to help you get started.

Planning Your Own Project

Individualizing your own classroom does not happen overnight. It can happen over a year if you choose a curriculum already developed and over five years, if you develop your own. But in any case, it takes time; and it is far better if you plan the time. Partly, the amount of time depends on the extent of individualization and independence you choose. An immediate immersion into independent individualized learning for *all* of your pupils *all* of the time may be more than you, your pupils, their parents, your fellow teachers, or your administration can

take. If you choose an independent style, it is well to begin with an experimental class. If you choose a well-organized curriculum, you may wish to begin with an entire level of instruction. If you are designing your own activities, it depends on the amount of time you can use for the development. Perhaps some of your students can help you develop the learning activities, especially if you are working in the audio-tutorial mode. In any case, the transition from group learning with high dependence on the teacher to individualized learning with a varying measure of independence takes a flexibly planned amount of time.

Some critical factors in your plan of moving toward individualization are the people in your school system. Whether they become positive or negative factors in your plan depends very much on your consideration of their opinions, influence, and professional commitments. In most school systems, these people are:

1. Yourself—How committed are you to the concept? If commitment is low, when things go wrong, you may be tempted to quit rather than to see it through.
2. Pupils—Although glowing reports are made about the successes of individualization with problem children, it is still true that "good" pupils do most things best. Work out the kinks with a group that is most likely to succeed.
3. Fellow teachers—The attitude of fellow teachers is most important. If negative, expect criticism when things are going well. When things go badly, the pressure to return to more "normal" teaching approaches may be more than you can endure. On the other hand, positive support, especially from those respected as leaders in the building, is an invaluable asset. If you can persuade one or more of your fellow teachers to try the innovation *with* you, the chances of success are greatly enhanced. Not only do you have positive support, but you will have the opportunity to work out problem areas together. Your most valuable asset in any move toward individualization is a set of regular weekly or monthly meetings with colleagues who are moving in the same direction.
4. Principal—Make sure the principal is cognizant of your approach and supports it. You will need his support against the complaints of negative teachers. He must also be in a position to explain your mission to fellow administrators and to the public.

5. Community resources—You'll need the support of your community residents and their representatives on your school board. Any new teaching approach usually demands an additional investment in terms of time and money. Perhaps you will need some additional training in the materials you will use. Maybe you can get this on your own through reading and consulting with appropriate people. Do you have this time? Are people available who can help you? Use the local news media. Locate the resources early. Obtain a commitment from them to help you if you can. Will you need additional books, equipment, audiovisual materials, living organisms, facilities? If so, has the route for obtaining these been carefully outlined and assurances obtained?

These five factors are certainly not an exhaustive list of variables that may affect your success. You should identify others. It is important to keep in mind, however, that most factors can be either negative or positive. If they are positive, consider ways to increase their contribution. For example, if your principal is already enthusiastic about individualized instruction, how can you increase and maintain this enthusiasm? Consider writing a short description of your approach for him to include in a newsletter that he sends to parents. Offer your help at a PTA meeting to explain. In other words, keep him well informed and help him to inform others. Never put him in the uneasy position of not being fully aware of your program when a parent calls and asks for more information. On the other hand, if one of the factors is negative, consider how you can reduce this effect. A particularly negative teacher should not be ignored. Admit your differences, but point out that you are merely experimenting to determine whether this might be a better approach for some children. Solicit his or her help in evaluating the results so that he or she feels more a part of the experiment. If possible, solicit ideas on making the approach work better. In fact, these may come without solicitation as the teacher becomes more involved in the project. The name of the game is "accentuate the positive and eliminate the negative."

Once you have the psychology of your situation figured out, you will want to give some consideration to the rationale for your curriculum itself. Some of the projects described here, like ISCS and ES, have their rationale well articulated in a form easily presentable to your colleagues. In fact, ISCS is develop-

ing an entire set of modules expressly for individualized teacher preparation which will greatly assist you in an implementation. Dr. Novak's chapter in this book can help you in working out your own rationale and procedure for curriculum development. You will have occasion often to explain why you do what you are doing, and it helps to have an answer well formulated ahead of time. Perhaps you will find yourself drawing your ideas from several of the projects described in this book. It is quite conceivable that in practice the descriptions in this book complement more often than contradict each other. Then when viewed from your practical classroom perspective, you end up with a rationale uniquely your own. It depends largely on your own approach to life in its totality. Above all, you ought to be honest with yourself and select principles you can practice. What you say you do should complement what you actually do. Your rationale ought to match your classroom actions. It doesn't make much difference which comes first, but they ought to grow together as you consider new standards for your professional life and evaluate your own practices.

Your own rationale makes a difference in your selection of an individualized curriculum, but it makes even more of a difference in how you use what you select in your own classroom. If you are really interested in any of the curricula described here, your best bet is to see them in action in a variety of classrooms. You will probably see as many different operations of the curriculum as you see teachers, and you will see what a difference the teacher makes in the success of the curriculum. In the process, you will gain some very good insight in what to do and what not to do for your own classroom. For instance, some of the curricula described here appear to be very open and others are more structured, but you can impose openness and independence in a very structured, intolerant, and authoritarian fashion or vice versa. How you use curriculum materials in your classroom becomes a very personal and idiosyncratic action that reflects your true rationale—influenced but not at all predetermined by your curriculum selection.

Developing Your Own Software

The design and development of your own materials should also be a very personal thing. Consider the materials an extension of your teaching personality, allowing you to approach your students on a one-to-one basis. You might record some

cassette tapes for students with reading difficulty. Or you might add some slides or filmstrips for supplementary units. Whatever your purpose, it helps personalize your approach if your voice is clear enough so that you can record the tapes yourself. But don't make them a series of lectures. If lectures bore your students, taped lectures will do so much more quickly. Liven your tapes with background music and stops for activities. Construct the tapes so that you would like to learn from them yourself. If students are to be motivated to learn without external pressures, the motivation must be built-in. They must enjoy doing your units. You might like to begin with some remedial or enrichment units, give students a free choice in what they desire to use, and notice which units they choose. Sometimes helpful are commercial supplementary resources like the Elementary Science Study units or a variety of science texts or library books. But even if you utilize such resources, do it under your personalized guidance. And don't guide all your students in the same way.

Managing Your Own Classroom

A very important aspect of individualized learning is the manner in which the options are displayed to your students. If options are not presented, or if they are not presented in a way that attracts students, it is the same as not having options at all. Some schools display the options in the form of behavioral objectives, but until students learn what they mean to them, it is not a very attractive method of display. An open display of laboratory equipment often attracts students toward the performance of activities. Books, films, posters, and files are other items that can be designed to motivate students to progress individually.

Some schools use display space in the library or media center to show students small kits of laboratory material, booklets, cassette tapes, and films, that they can take home to investigate a local pond, the sky at night, and other natural sites or phenomena. The possibilities for such independent investigations are limited only by your own imagination and that of your students. The materials are displayed in an attractive fashion, as in a supermarket or a country store, in order to motivate students to choose them as they move freely through the library.

Other schools display the options in the form of objectives stated to an intermediate level of generality on a cumulative

record—not only can the student recognize what his options are for the future but he can also recognize those that he has already accomplished. The display of options for individualized learning contributes much to the communication of individuallized learning—like it is. Physically and psychologically rich learning conditions are essential to the success of individualized learning.

Once a student chooses a particular activity, it doesn't necessarily follow that he will stay with it long enough to realize its benefit. A mechanism that will help to ensure the completion of the study is a written contract between the teacher and the student stating that certain work will be done for a specified grade. More work (depending on ability) results in a higher grade. While the contract has the advantage of stimulating the student to complete a selected study, it will also mitigate against students changing their topic as they see other children doing interesting things. Particularly at lower elementary grades, students' interests tend to change quickly as they see others working. It may be desirable to permit such diversity of exposure at this age. If a contract is used at that level, it should be short in duration and easily attainable by the students for whom it is designed.

The contract need not always involve only one student. Individualization is not synonomous with learning by oneself. Too frequently, individualization is construed as each child encountering materials by himself at his own rate. Keep in mind that many of us learn better in pairs, in small groups, or, indeed, in large group settings. In addition, our needs change from time to time and topic to topic. At one time, we may learn best by ourselves and at another, we need the interaction of a larger group. Individualization, then, implies establishing learning situations which are uniquely "right" for each individual. Don't be disturbed when this turns out to be four or five students working together on a project. In fact, provide for this opportunity as carefully as you provide for the student to work by himself.

One final thing to plan for in the design of your own individualized approach to learning is the evaluation and revision of the curriculum materials. Evaluation of student progress can become more rigorous after the materials themselves are refined. Basically, you need to know how well you are communicating to your students and what you must do to improve that communication. Objective tests will certainly aid

your evaluation. But perhaps more important at this stage of the development, subjective evaluations through structured interviews will help you and your students identify communication failures and articulate what must be done to correct them. You need to learn what will motivate students to learn. Listen—and revise your materials accordingly. A distinguishing feature of most of the successful projects described here is that they were evaluated honestly and thoroughly and thus were literally written by many students and teachers acting in concert.

What are the expectations if individualization really works? First, students should become more interested in learning as they become more important in the decisions affecting their learning. Second, as individualization becomes a reality, discipline problems decrease. Most discipline problems arise out of frustrations when the class is moving too fast or too slowly for the individual, or when the material is just not of interest to the student. Third, greater learning takes place as students encounter materials of interest to them, at a rate consistent with their ability, and in a manner consistent with their needs. Fourth, your work becomes more challenging and rewarding as you become one of the resources in the educational package instead of *the* resource—as you become a counselor and guide for learning activities rather than *the* learning activity. ■

APPENDIX

Bibliography of Research Studies Related to Open Humane Education

Prepared by the authors of Chapter 4

1. Alberti, Jean W. *Correlates of Self-Perception in Schools.* ERIC No. ED 048336. 1970. Can be retrieved from any ERIC Center.
   Self-perception and academic achievement, school behavior, and popularity correlated positively with teachers' ratings of children's behaviors and academic achievement.
2. Almen, R. E. *Adjective Checklist Follow-Up Questionnaire.* ED 027575. Minneapolis Public Schools, Minnesota. Work Opportunity Center. 1968.
   A significant number of both boys and girls in a work-study program made positive gains in self-perception as their studies related to the real world.
3. Coleman, James. *Equality of Educational Opportunity.* U.S. Department of Health, Education, and Welfare, Office of Education (OE-38000). Washington, D.C. 1966.
   The most significant finding was that the degree of success as measured by the "pupil attitude factor" (which appears to have a stronger relationship to achievement than do all the "school" factors together) is directly related to the exent to which an individual has some control over his own destiny.
4. Coopersmith, Stanley. *Implications of Studies on Self-Esteem for Educational Research and Practice.* University of California, Davis. 1969.
   All of the studies concluded that high self-esteem is positively related to academic success.
5. deCharms, R., and W. J. Bridgeman. *Leadership Compliance and Group Behavior.* Technical Report, ONR Project Nonr 816 (11) Washington University, St. Louis, Missouri. November 9, 1961.
   ". . . when group members feel they have some freedom to control the situation—if they feel they can be the origin of suggestions . . . their feelings toward the teacher and willingness to work for him will be much more positive than if they feel that they have no say in the procedure and that they are treated like pawns."
6. Dubin, Robert, and Thomas C. Taveggia. *The Teaching-Learning Paradox.* Published by the Center for the Advanced Study of Educational Administration, University of Oregon, Eugene. 1968.
   No shred of evidence was found to indicate any basis for preferring one teaching method over another as measured by performance of students on course examinations.

7. Felker, Donald W., and Donald J. Trettinger. *Self Concept, Divergent Thinking Abilities, and Attitudes About Creativity and Problem Solving*. ERIC No. ED 047347. 1971. Can be retrieved from any ERIC Center.
This study gives empirical support for the frequently postulated positive relationship between self-concept and creative ability.

8. Frerichs, Allen H. *Relationship of Self Esteem of the Disadvantaged to School Success*. ED 040223. American Educational Research Association, Minneapolis, Minnesota. 1970.
Concluded that high self-esteem is positively related to academic success.

9. Lundquist, Gerald W. *Evaluation of Open Living School, Jefferson County*. University of Colorado, Boulder. 1971.
One hundred percent of the parents would send their children to the open school the next year, if they had a choice. Responses of staff and students to similar questions were equally positive. The Open Living School had a lower rate of absenteeism than any of the control schools. In every reading and arithmetic category, except for grade 6 arithmetic, the open school children were above grade level and equal to or above children in the other schools. Jefferson County now has two open schools.

10. Mangano, James F., and Richard C. Town. *Improving Migrant Students' Academic Achievement Through Self-Concept Enhancement*. ERIC No. ED 049868. 1970. Can be retrieved from any ERIC Center.
The academic achievement of the migrant student experimental group increased significantly over the control group. The experimental group was given direct work on self-concepts of abilities.

11. Mohindra, Gill P. *Relationship Between Pattern of Achievement and Self-Ideal Congruence*. ERIC No. 047329. 1971. Can be retrieved from any ERIC Center.
A low level of perceived self and low ideal self congruence is highly related to underachievement.

12. Purkey, William W. *The Development of a "Pupil Behavior Inventory" to Infer Learner Self Concept*. ED 050153. College of Education, Florida University, Gainesville. 1971.
Students enrolled in the humanistic–open school evidenced greater self-esteem than did students enrolled in the comparison school, and as grade level increased, so did measured differences in self-esteem between the two groups of students.

13. Renbarger, Ray Nisch. *An Experimental Investigation of the Relationship Between Self-Esteem and Academic Achievement in a Population of Disadvantaged Adults*. ED 038623. Michigan State University, East Lansing. 1969.

Concluded that high self-esteem is positively related to academic success.

14. Scanlon, Robert G. *Factors Associated With A Program For Encouraging Self-Initiated Activities By Fifth and Sixth Grade Students In a Selected Elementary School Emphasizing Individualized Instruction.* ED 015785. Pittsburgh University School of Education, Pittsburgh, Pennsylvania. 1966.
The mathematics classes receiving the experimental treatment of individualization developed more self-initiated activities than did the teacher-dominated science and social science classes.

15. An eight-year study published in 1942 focused on nearly 1500 high school seniors who were allowed entrance into college, not on the basis of particular unit patterns, content or grades, but rather on the recommendations of their principals and other noncurricular requirements of the college of their choice. Results: While the experimental group did not, as some progressives had hoped, set the college world on fire, they did do as well as or better than the matched control sample undertaking the more traditional program and being directed by grades and particular unit programs. One could not differentiate between the two groups in college grades, honors, or extra-curricular participation. The experimentals did slightly better in terms of being perceived as more intellectually curious, more objective in their thinking, appreciative of the arts, and they were judged as more resourceful in meeting new situations. It was clearly substantiated that the experimentals without the rigid grading and subject orientation were as well or better prepared for college. The graduates of the experimental schools earned grades which were slightly higher (consistently so) than those in the comparison group.

Bibliography of Humanistically Oriented Education

Prepared by the authors of Chapter 4

1. Allen, Dwight W. "The Seven Deadly Myths of Education and How They Mangle the Young." *Psychology Today* 4:70-72; March 1971.

2. Brown, George Isaac. *Human Teaching for Human Learning: An Introduction to Confluent Education.* The Viking Press, New York. 1971. The report on the Ford-Esalen Project in Affective Education includes the Gestalt experiences the teachers had and their application to ordinary public school classrooms. The book offers teachers a look at a few of the techniques of humanistic

psychology as applied in the effort to blend the cognitive and affective aspects of learning with public school children of all ages.

3. Cole, Jim. *The Facade, A View of Our Behavior.* Jim Cole, 625 19th Avenue, Greeley, Colorado 80631. 1970. An excellent cartoon book on the facades we hide behind and what doing so does to us.

4. ———. *The Controllers—A View of Our Responsibility.* Jim Cole, 625 19th Avenue, Greeley, Colorado 80631. 1972. A book for students and teachers on who is responsible to whom for what. In some ways even better than *The Facade.*

5. Earth Science Curriculum Project Newsletters #21-22 and Environmental Studies/Earth Science Teacher Preparation Project Newsletters 1 to 8 (with more to come). ESEP, P.O. Box 1559, Boulder, Colorado 80302.
These contain many ideas for developing student-centered learning experiences.

6. Earth Science Teacher Preparation Project: *The Cutting Edge . . . or How to Innovate and Survive.* 1972. Write to ESTPP, P.O. Box 1559, Boulder, Colorado 80302.

7. Environmental Studies Project. Environmental Studies Packets 1, 2, 3, and 4. 1971-72. Write to ES, P.O. Box 1559, Boulder, Colorado 80302.

8. Fantini, Mario D. "Public Schools of Choice and the Plurality of Publics." *Educational Leadership* 28:585-591; March 1971.

9. Farber, Jerry. *The Student as Nigger.* Pocket Books, New York. 1970. 142 pp. Farber's essays in the section entitled "School" carry a strong message about some of the idiocies practiced in today's schools. He has many positive things to say also.

10. Gardner, John. *Self-Renewal.* Harper & Row, New York. 1963. Paperback 1965. 141 pp. Gardner inspires hope and faith in our capacity to develop a self-renewing society. The role of education in developing self-renewing people is clear.

11. Herndon, James. *The Way It Spozed To Be.* Bantam Books, New York. 1968. An anecdotal record of the author's experience in a junior high in a large city. Humorous and insightful.

12. Glasser, William. *Schools Without Failure.* Harper & Row, New York. 1969. 235 pp. Glasser suggests the use of group methods of confronting classroom problems. He puts much emphasis on abolition of failing grades as a primary way of helping children learn. This is a conservative approach compared with most items on this list, but the ideas as expressed will be easier to accept for people just beginning to change in directions of more humanistic education.

13. Glines, Don E. *Creating Humane Schools*. Campus Publishers, Box 1005, Mankato, Minnesota. 1971. 281 pp. Glines describes a K-12 "open" school that has been operational since 1968. He gives a good description of how to start an open school and discusses problems encountered in implementation. Excellent 23-page bibliography.

14. Goodman, Paul. *Compulsory Miseducation* and *The Community of Scholars*. Vintage Books, Random House, Inc., New York. 1962. 339 pp. Goodman would do away with compulsory schooling altogether. *Community of Scholars* provides an ideal view of Goodman's idea of a learning community.

15. Gordon, W. J. J. *Synectics*. Harper & Row, New York. 1961. Paperback, Collier Books, 1968. 180 pp. A discussion of techniques used in helping people develop their creative abilities.

16. Hart, Harold H., Compiler. *Summerhill: For and Against*. Hart Publishing Company, New York. 1970. 271 pp. Hart has invited a number of educators to comment on *Summerhill*. Comments range from those of John Holt and Goodwin Watson to those of Max Rafferty. John Holt's excellent essay analyzes the accusation of "permissiveness" leveled at open models of education. He gives very good arguments to counter those who accuse.

17. Holt, John. *How Children Fail*. Delta Books, New York. Paperback 1964. 181 pp. Holt's examples are largely from the area of math education for elementary school children, but his approaches have obvious implications for science.

18. Jones, Richard. *Fantasy and Feeling in Education*. Harper & Row, New York. 1968. Paperback 1970. 276 pp. Jones points out the need to allow the emotions to be expressed and used in education at all levels. Part of the book contains high level psychological theory, but there are also many useful and informative suggestions and anecdotes.

19. Kohl, Herbert. *36 Children*. New American Library, New York. 1967. An anecdotal record of the author's experiences with 10-to-14-year-old children in a ghetto classroom and what happens when you are humane.

20. ———. *The Open Classroom: A Practical Guide to a New Way of Teaching*. Vintage Press, Random House, Inc. New York. 1970. 116 pp. Recipes can't be written for openness. Kohl tries it anyway, with many good ideas of a practical nature. Many people trying to "open up" will find it readable and useful.

21. Leonard, George. *Education and Ecstasy*. Dell Publishing Company, New York. 1969. 239 pp. (Delta Books). Leonard suggests that extrinsic punishment, extrinsic rewards, and coercion in classrooms have led us to view education as an unpleasant

experience to be tolerated. He suggests solutions that can make it easier for us to help learners feel the intrinsic joy necessary for continuing, self-directed learning.

22. Macrorie, Ken. *Uptaught*. Hayden Book Company, New York. 1970. 187 pp. Macrorie shows examples of the excellent writing done by students, freshman through graduate, who are given freedom of a type rarely made available in composition and writing courses.

23. Neill, A. S. *Summerhill*. Hart Publishing Company, New York. 1960. 392 pp. This classic book should be read by everyone interested in open forms of education. Neill creates a highly idealistic model.

24. Polanyi, Michael. *The Tacit Dimension*. Anchor Books, Garden City, New York. 1967. 188 pp. In somewhat obscure language Polanyi points out that not all knowledge can be verbalized. We know much more than we can say.

25. Postman, Neil, and Charles Weingartner. *Teaching as a Subversive Activity*. Delacorte Press, New York. 1969. 219 pp. Although the authors take many examples from English and the humanities, many of the issues they discuss are pertinent to science teachers. They propose a virtually complete reorientation toward teaching and learning.

26. Raths, L. E., M Harmin, and S. B. Simon. *Values and Teaching*. Charles E. Merrill Publishing Company, Columbus, Ohio. 1964. The authors point out the need to help students break free from fact-centered learning and to make value judgments about what they do. They suggest concrete ways of shifting the emphasis to value.

27. Rogers, Carl R. *Freedom to Learn*. Charles E. Merrill Publishing Company, Columbus, Ohio. 1969. 358 pp. Rogers presents ideas on how to get away from "teaching" and how to become instead a "facilitator of learning." Rogers believes that learning should involve the whole person and not proceed from the neck up only.

28. ———. *On Becoming a Person*. Houghton Mifflin, Boston. 1961. (Paperback). 420 pp. Several chapters in this book deal with student-centered teaching. Others deal with psychotherapy and other topics related to humanness.

29. ———. *Carl Rogers on Encounter Groups*. Harper & Row, New York. 1971. 172 pp. If you're interested in group processes, this is good. For those who have experienced encounter groups as well as those who have not.

30. Romey, William D. *Risk, Trust, Love: Learning in a Humane Environment*. Charles E. Merrill Publishing Company, Columbus, Ohio. 1972. An anecdotal record of personal experiences from

K-graduate school reflections on some aspects of the facilitator's role in creating a humane learning environment.

31. Roszak, Theodore. *The Making of a Counter Culture*. Anchor Books, Doubleday and Company, Garden City, New York. 1969. 303 pp. An angry book, very dull in places. But it has gripping chapters such as "The Myth of Objective Consciousness." The book is a scary view of what we've let our young people come to feel.
32. Samples, Robert E. "Toward the Intrinsic." *The American Biology Teacher*. Spring, 1970. Samples presents some interesting assumptions in the teaching of science, leading to a highly independent, decision-making role for the learner.
33. Silberman, Charles E. *Crisis in the Classroom*. Random House, New York. 1970. 533 pp. This much-quoted book, based on several years of work done under a Carnegie Corporation grant, contains detailed descriptions of many schools—a grim picture. Silberman also suggests remedies, mainly along open school lines.
34. Weber, Lillian. *The English Infant School and Informal Education*. Prentice-Hall, Inc., New York, 1971. This book offers the reader a view of the British Infant School, what happens there, the philosophy behind it, and some insight as to why. It also deals with some of the adaptations of this form of education and what happens.
35. Weinstein, Gerald, and Mario D. Fantini. *Toward Humanistic Education—A Curriculum of Affect*. Praeger Publishers, New York, 1970. This work presents a model for considering a curriculum based in great part on the development of the affective domain in the learner. The affective curriculum is a model based on pupil's concerns and feelings rather than on purely cognitive goals.