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ABSTRACT

This paper presents the theoretical basis for the model of individualization used in an elementary-school science program and describes the Individualized Science (IS) individualized-learning management system, which is an operational realization of the model. The science content and science learning goals of the curriculum reflect the authors' views that an elementary-school science program should be multi-faceted. It indicates that a child can be taught to be responsible for his or her own learning. Tables presented include: (1) student characteristics related to learning as a function of the learning environment; (2) goals of IS; and (3) learning resources of IS as contributing to the specific goals (scientific literacy, student self-direction, student co-evaluation, affective goals, and inquiry). (Author/EB)

INDIVIDUALIZED LEARNING IN INDIVIDUALIZED SCIENCE

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Introduction

Individualized Science (IS), an elementary-school science program being developed by the Learning Research and Development Center at the University of Pittsburgh, is the only individualized elementary-school science program presently under development in the United States. IS is a complete program designed to serve children in present school grades K through 8.

There are ten levels in the IS program, each of which consists of approximately one year's work in science. The science content of IS is drawn from both the biological and the physical sciences. One unique aspect of the program is its emphasis on the cultural aspects of science and the interactions of science and society. IS is a comprehensively individualized elementary-school science program. Not only does IS provide mechanisms for a child to help plan his or her science activities, to manage his or her own instructional materials, and to take part in the assessment of his or her learning, but it also provides opportunities for the child to make selections from among alternative learning resources and from among alternative units of study.

IS represents a second generation effort on the part of the Learning Research and Development Center to develop individualized learning systems for use in elementary schools. The Center's earlier efforts followed a pretest-prescription-posttest model of individualization and resulted in the development of Individually Prescribed Instruction (IPI) systems in elementary school

mathematics and reading. Our efforts have modified and elaborated on the IPI model, but have remained remarkably consistent with the philosophy of individualization espoused by the originators of IPI.[1]

For the purpose of analysis, we view the IS program's learning system as a science curriculum closely integrated with an individualized-learning management system. The science content and science learning goals of the curriculum reflect our view that an elementary-school science program should be multifaceted. The individualized-learning management system reflects our belief that a child can be taught to be responsible for his or her own learning. In this paper we shall examine the theoretical basis for our model of individualization and describe the IS individualized-learning management system, which is an operational realization of the model.

IS Model of Individualization

Individualization occurs when the learning environment is adaptive,[2] and, conversely, an adaptive learning environment is one which has the capability of matching instruction to various characteristics of individual learners. Several important characteristics in which individual learners differ are noted in the top portion of the accompanying Table 1. The relationship between

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Insert Table 1 about here.

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each of these characteristics and the learning environment may be briefly reviewed.

Student Characteristics Related to Learning

Intelligence is a measure of individual difference which was operationally defined to predict success in school. However, as Glaser[3] suggested, the aim of intelligence tests was to predict scholastic success in an essentially fixed educational mode. Carroll[4] has noted that intelligence measures do little more than predict the rate at which a child will learn. Thus, for a learning environment to be adaptive with respect to intelligence, it would seem to require at least two essential elements: first, it would provide the child with a variety of materials which utilize different instructional strategies; second, it would provide a management mechanism which allows the child to devote as much time as is necessary to master learning objectives.

Children come to any learning environment with different amounts and kinds of acquired knowledge. An environment where a child must "work through" instructional materials which are designed to teach the child skills or information he or she already knows is wasteful of the child's time and may have negative effects on the child. It is a relatively simple matter to pretest children for the skills and knowledge they have already acquired and then to design their learning plans on the basis of going on from there to subsequent learnings or other interests. An instructional system that has specified a set of desired learning outcomes can become adaptive to an individual's needs with respect to acquired knowledge by identifying those learning outcomes in which the child is proficient and providing him or her only with the instruction required to attain those outcomes in which proficiency has not been demonstrated.

The work of Jean Piaget demonstrates that the cognitive development of children proceeds sequentially through definable stages. Moreover, the kinds of logical reasoning available to the child are directly related to this development.[5] The consequence of the child's level of cognitive development for the learning environment can be viewed in two ways: either instruction should be strictly adapted to a child's level of cognitive development, or instruction should be provided which will systematically influence the process of cognitive development. Like intelligence and cognitive style, cognitive development is an aspect of the individual's aptitude for learning. Research suggests that the learning environment can be made adaptive to individual differences in each of these aptitudes, either by adapting instruction to differences in aptitude or by consciously modifying aptitude. While the implications of research are clear, the mechanisms by which the learning environment can be made adaptive to the individual's cognitive development have only begun to be explored. The case is clearer, as we have seen, for acquired knowledge, a characteristic in which individuals differ that is more easily understood and for which the mechanisms for making the learning environment adaptive are well known.

The research of Cohen,[6] Kagan and Kagan,[7] and others provides evidence that certain personality and cultural differences in individual children profoundly affect their success in school. These diverse personality and cultural factors have been lumped together under the general rubric of cognitive style. The research which relates cognitive style to school success suggests that, when personality factors (e.g., reflection, impulsivity) or cultural factors (e.g., immediate vs. delayed rewards) are not congruent with the learning environment of the school, child fail. In consequence, two possible routes are suggested to ensure every child's success: either the learning environment must allow for the success of children with differing cognitive

styles, or the opportunity must exist within the instructional system to modify the child's cognitive style. However, as in the case of cognitive development, the mechanisms for adapting the learning environment through either possible route to individual differences in cognitive style are just beginning to be explored.

That individuals differ in interests is widely recognized, and the extent to which learning environments can be made adaptive to individual differences in interests has only practical limitations. The most important learnings are not factual and, therefore, can be imparted in almost any context. The adaptive learning environment is one which capitalizes on interests the child currently holds while systematically exposing him or her to possible new areas of interest.

A child's attitude toward school is both influenced by and influences his or her success in school.[8] Thus, any mechanisms which increase the probability that a child will be successful in his or her school work will in turn increase the probability of future success. A child's attitude toward school can also be improved if the child understands the instructional system and feels a sense of participation and control in the process of learning.[9] As a first approximation toward the development of positive attitudes toward learning, it would seem wise to teach the child how the instructional system functions and to give him or her a sense of participation in the decision-making within the system, rather than to immerse the child in a vaguely defined system in which his or her academic success is dependent solely upon meeting the standards of performance and knowledge meted out through subject-matter instruction.

Dimensions of Learning Environment

Intelligence, acquired knowledge, cognitive development, cognitive style, interests, and attitudes are some of the learner characteristics to which the learning environment must be made adaptive. A learning environment has many identifiable dimensions, and there are many possible variations within each of the dimensions. Anyone desiring to create an adaptive or individualized learning environment has a dual task: first, to identify the crucial dimensions of the learning environment; second, to provide the learner with as many variations within each of the dimensions as possible.

The lower portion of Table 1 identifies nine dimensions of the learning environment and several possible variations within each dimension that are available to the designer of the learning environment--be the designer a teacher or a curriculum developer. The hallmark of a learning environment adapted to individual learners is that its designer has utilized as many of the variations within each dimension as can possibly be accommodated. In general, a learning environment that focuses exclusively on only one variation in a dimension, or an environment that utilizes just one variation for any great length of time, is not adapting to individual differences in learners. Good teachers have long known this and have shifted their focus accordingly. We may also note that for the first four dimensions in Table 1 (Learning Goals, Instructional Materials, Instructional Unit, Setting), the variation at the left of the chart indicates a learning environment that is not likely to be adaptive.

In developing the IS program, we have attempted in a multitude of ways to provide variations within the dimensions of the learning environment that will be good matches to the differing characteristics of individual learners. To accomplish this, we had need of a sufficiently powerful mechanism that would be

both practical and usable in real schools. The mechanism that provides the desired variations in the dimensions of the learning environment, that makes the IS learning environment adaptive to individual learners, are the program's learning resources.

Learning Resources

A learning resource in IS is any material or procedure designed to aid the student in his or her attainment of any of the goals of the program. Five goals have been specified for the IS program. These goals are listed in Table 2,

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Insert Table 2 about here.

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and a brief explication of each goal is given in Appendix A. Three of the program's goals are related to science content learning and two are related to the student's management and evaluation of his or her own science learning. Each of the five goals is subdivided into level competencies and the science subject matter learnings are specified in unit behavioral objectives. The analysis of goals into competencies and behavioral objectives has guided the development of the learning resources of IS that define the program's learning environment.

The many learning resources of IS differ in function, components, instructional strategy, primary sense modality, and the social setting in which they are used. (See Appendix B for descriptions of the learning resources.) For example, the function of the learning resource called an "Individual Lesson" is to impart information to the student. The information may be about science content or it may describe to the student how to plan his or her learning in a unit. Information is imparted to the learner by means of an illustrated lesson

booklet with an optional read-along tape. The student may read the lesson booklet, read the lesson booklet text along with the audiotape, or just listen to the tape and look at the pictures. Lessons devoted to science content usually include a kit of manipulative materials. The instructional strategies of the Individual Lessons are didactic and guided discovery. The social setting in which Individual Lessons are used is not adequately described by the name of this learning resource: while the Individual Lessons are designed to be used by an individual, students often engage in them together with other students.

Individual Lessons are only one of the many learning resources of IS. A large variety of learning resources is necessary to create a learning environment that provides instruction toward the attainment of the several IS goals and is, at the same time, adaptive to the individual differences of learners. Table 3 lists the names of the various learning resources of the IS program

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Insert Table 3 about here.

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and relates each learning resource to the goal or goals it is designed to aid the learner in attaining. Every learning resource does not contribute to the student's attainment of all the goals. In Table 3, an X under a goal on the line across from the name of a learning resource indicates that this resource provides a significant part of the instruction or is an important mechanism in the learner's attainment of the goal.

We have noted that the IS learning resources create a learning environment adaptive to individual differences in learners. Thus, the learning resources not only contribute to the student's attainment of the goals of IS, as just described, but they also are the mechanism through which the IS learning environment is made adaptive to various charasteristics of individual learners.

Adaptiveness to Intelligence and Interests

The existence of many learning resources that are almost all designed for rather short-term use makes it possible for every student in IS to be engaged in a different activity at any given time. In effect, each student can design and follow a unique learning plan. This flexibility allows each student to progress at his or her own rate, and thereby provides an adaptive learning environment for students who differ in intelligence. But, for the gain of this form of adaptiveness, there is a price. If we are serious in our assertion that each student may progress according to his or her own rate, we must be ready to allow for variation in different individuals' attainments of the goals of IS. It is our view that only minimum competencies for all students are defined by the goals; beyond that minimum, the rate of learning and interests of the student will define his or her individual goals.

Applying this view to the Scientific Literacy goal of IS, we expect that every student will demonstrate a minimum competency, which is defined by the behavioral objectives for the mainstream units that are required for all students at each level of the program. Recognizing, however, that students differ with respect to interests and rate of learning, the IS program offers the student opportunities to select various alternative pathway units which may interest him or her and allows different students to complete varying numbers of these optional units within a level. We do expect each student to become acquainted with what the science content of all the alternative pathway units is by completing a unit overview, but beyond that exploration to enlarge interests, the student decides whether or not to work in any alternative pathway unit and the objectives that he or she attains there are the student's choice.

Adaptiveness to Aspects of Cognitive Style

One aspect of cognitive style is probably related to a student's preferences for the social setting in which his or her learning takes place. This aspect of individual differences is directly related to the environmental dimension we have labeled "instructional unit" (see Table 1). Some students learn best interacting alone with instructional materials, others are happier interacting on a one to one basis with a peer or the teacher, still others function best in a small group setting. The type of instructional unit has implications not only for adapting to differences in cognitive style but also for the kinds of learning that take place.

For some kinds of learning to take place, either one to one or group interactions are necessary. Some learning resources of the IS program are designed to be done by individuals. Individual Lessons, Readings in Science, and certain Student Activities are examples of such resources.[10] Other Student Activities are designed to be done by two or more students together as are Miniature Explorations and Student Seminars. Student Conferences are planned one-to-one interactions between the student and the teacher, and Directed Group Activities are structured interactions between one or more students and the teacher. These examples illustrate how the availability of learning resources which utilize various types of instructional units is a means of providing the interactions necessary for various kinds of learning to occur, as well as providing a learning environment adaptive to an individual difference among learners.

Another aspect of cognitive style relates to the strategy used in defining problems and suggesting possible solutions to the student. Some students seem to prefer to have problems defined for them and to be told how to solve them,

while others prefer to be led to the solution of a program-defined problem through the strategy of guided discovery. Other students, whose cognitive style is less convergent, would prefer to use an inquiry approach and to define and explore problems of their own. The three types of strategies which different learners prefer correspond with the three levels of inquiry instruction that are available to a teacher or curriculum developer.[11] Several learning resources of IS, such as Miniature Explorations, Student Activities, and Self-Initiated Independent Activities, provide students with opportunities to experience all three levels of inquiry instruction at various times and with different science subject matter.

In the foregoing discussion, we have illustrated some ways in which the learning resources of the IS program provide the learner with an adaptive learning environment where he or she can attain the program's goals. We are aware, of course, that the illustrations we've given do not exhaust the topic, but they must of necessity suffice here as we conclude our presentation of the IS model of individualization and turn to its operational realization in a classroom of thirty or more students. To operationalize the IS model of individualization, we have developed an individualized-learning management system.

IS Individualized-Learning Management System

A learning management system is a practical necessity for an individualized science curriculum which utilizes many different kinds of materials. The materials management problem becomes real when one considers the number and variety of materials used in the IS program. Printed materials include: booklets for each Individual Lesson, Invitation to Explore, Reading in Science and MiniEx; Student Activity cards; answer sheets for each Individual Lesson, various worksheets; Planning Booklets for each unit, "How to . . ." booklets,

and Keys Books for each level. There are many kinds of manipulative materials, some of which are contained in kit boxes, others in a central supply area. All activities with a large amount of printed materials to be read by the student have read-along audiotapes.[12]

Materials management is only a part of the overall management system. Individual learning plans must be designed. Students in IS progress at different rates, engage in different learning activities, and follow different learning sequences. Students have different interests and have opportunities to make choices from among available learning resources and alternative pathway units of study. Learning plans for each student have to be made and recorded, and the student's progress through his or her plan needs to be documented. Materials have to be managed, learning plans formulated, and progress evaluated for individual learners. Clearly, the total management task is too great for the teacher alone.

Each learner must be and we believe should be,[13] actively engaged in all facets of his or her individualized-learning management. For this to happen two conditions must prevail: first, the learner must be taught how to manage his or her own learning; and, second, provisions must be made to increase systematically the responsibility taken by the learner for his or her own learning. Mechanisms which assure that both these conditions prevail are built into the IS individualized-learning management system. A discussion of these mechanisms will be more meaningful if the reader is familiar with the specific procedures of the management system. We shall set this discussion in the context of describing a student's (Karen) progress through a Level E mainstream unit, through a Level E alternative pathway unit, and into Level F from Level E.[14]

Level E of IS is composed of six units. Three are mainstream units and are required for all students. Three are alternative pathway units from which a student may elect to take none, one, two or all three. The names and science topics of the Level E units are:

Level E Units

JOULE (energy)
BEAUMONT (digestion)
VOIT (nutrition)

VOLTA (electricity)
ARCHIMEDES (machines)
LINNAEUS (plant growth)

During a Student-Teacher Conference, Karen's teacher briefly described the science content of the Level E units to her and told Karen that she could choose to start her Level E work in any one of the units.

Individualized Learning in a Mainstream Unit

Karen decided to begin her study in Level E with the mainstream Joule Unit. Her teacher gave Karen a Joule Planning Booklet and checked with Karen to see if she was clear about what to do next. Karen knew that she should fill in the heading on her Planning Booklet and then do Joule Lesson 1, which describes the science content of the Joule Unit and contains the Joule Unit Placement Test. When Karen got to the part of the lesson containing the placement test, she was informed that she should first read through the entire placement test and then decide whether or not to take the placement test.

After reading over the placement test, Karen decided that she already knew the answers to some of the questions, so she took the placement test. She

wrote answers for those questions she thought she knew something about and wrote "I don't know" for those she knew she didn't know about. When she was finished, Karen got the E Keys Book and compared her answers on the placement test with the answers in the E Keys Book. Then Karen analyzed her placement test results by following the directions given in Joule Lesson 2. Her analysis of the placement test told her which parts of the science content of the Joule Unit she should study. The analysis is made possible by having questions on the placement test keyed to the content of the Joule lessons. Thus, for example, Karen knew she should study the science content of Joule Lesson 4, because she could not answer questions 3 and 4 on the Joule Unit Placement Test.

Having determined which science content she already knew and which she should study, Karen's next task was to formulate her learning plan.[15] She was aided in this task by directions from the lesson booklet for Joule Lesson 2 and by information from her Planning Booklet. Various kinds of learning resources are available to help the student learn a single concept. These are grouped together on the Planning Booklet under a descriptive title. For example, learning resources available in the Joule Unit about the concept of different forms of energy include an Individual Lesson, a Directed Group Activity, several Miniature Explorations, Student Activities, and Readings in Science. This information is provided to Karen on her Planning Booklet in the way shown in Figure 1.

Insert Figure 1 about here.

Karen decided which activities she would do and the order in which she would do them,[16] and she indicated this plan on her Planning Booklet. She then discussed her plan with her teacher in a Student-Teacher Conference. In

the course of this conference, the original learning plan may be modified, but once the plan is satisfactory both to Karen and her teacher, Karen begins work. Karen's Planning Booklet has a record of her conferences with her teacher, her score on the placement test, and her learning plan.

The science content lessons of the unit give the unit its basic structure, and every student generally does those content lessons he chooses to do in a specified order. The uniqueness of the learning plans of individual students is a result of the operation of two factors. First, every student does not necessarily take all the content lessons in the unit, but only those he or she is required or has chosen to do. The student's performance on the placement test permits the student to identify those lessons that he or she may choose to omit if mastery of the corresponding content has been demonstrated. The second and more important factor is that the various other learning resources can be integrated in many diverse ways with the content lesson sequence. Consequently, any two students in IS will rarely have exactly the same learning plans. That is what we would expect, of course, in a genuine process of individualized learning.

Since all students studying a given science concept will take the content lesson associated with that concept, the systematic assessment of concept attainment has been made a part of the lessons. Thus, when Karen completes Joule Lesson 4, for example, she also will have completed a Check Up, a short diagnostic test, on the science content of the lesson. Karen corrects this Check Up herself using the E Keys Book, and she uses the score on the Check Up to decide if she should go on to study another science concept or if she should do some further activities involving the concept that she is currently working with. Karen gets help in making this decision from the assessment box printed

at the end of the answer sheet for the lesson. In the upper part of the assessment box, Karen circles the number corresponding to the score she made on the Check Up, and below the circled number she reads the suggestions to the student for future action. Once Karen has decided on a plan for her next activity, based on the assessment box's suggestion matched to her Check Up score, she discusses the plan with her teacher. When Karen had completed all the activities in her full personal learning plan for the Joule Unit to her and her teacher's satisfaction, Karen took the Joule Unit Posttest. Karen and her teacher discussed her performance on the posttest, and decided that Karen's performance was satisfactory and that she was ready to choose her next unit of study.[17]

Individualized Learning in an Alternative Pathway Unit

Karen wanted to do an alternative pathway unit next, so her teacher briefly reviewed for her the science content of the three Level E alternative pathway units. Karen thought that both the Volta and Archimedes units were interesting, so she did the Unit Overviews for both of them. The Unit Overviews provided her with sufficient information about the content of the units to make an informed decision about the one in which she would work. Having made the decision to work in the Archimedes Unit, Karen began to look through the unit's Invitation to Explore (ITE's). Each alternative pathway unit has two or more ITE's, which contain instruction in aspects of the unit's science topic and suggest activities that the student can do to learn more about the topic.

To devise her learning plan for the Archimedes Unit, Karen selected those ITE's she would read carefully, the suggested activities she wanted to try in the ITE's, and other learning resources in the unit that looked interesting. After making these decisions, Karen wrote out a learning plan outline indicating the ITE's she had selected and, for one ITE, listing the activities and associated

learning resources she would complete. At a student-teacher conference Karen and her teacher discussed her learning plan, and Karen made some modifications in the plan persuant to her teacher's suggestions. Then Karen began work on her Archimedes Unit learning plan. Karen had several conferences with her teacher during her work in this alternative pathway unit. During these conferences Karen and her teacher discussed the science content of the ITE's, co-evaluated Karen's accomplishments in each selected ITE, and updated Karen's learning plan. Karen's work in the Archimedes Unit was considered complete when Karen's learning plan had been carried out to the satisfaction of Karen and her teacher.

Following her completion of the Archimedes Unit, Karen decided to return to the mainstream units of Level E. She next worked in the Beaumont Unit and finally in the Voit Unit. When Karen had completed four Level E units, she and her teacher compared Karen's competencies with those delineated for Level E, as listed in the IS Teacher's Manual. The teacher and Karen agreed that Karen had sufficiently demonstrated the competencies expected of a student who is completing Level E, and that she could begin to work in Level F of IS.

Learning to Manage Learning

Our account of Karen's route in individualized learning has illustrated how the student in Level E of IS participates actively in the planning and assessment of his or her own learning. The student working in this level also has complete responsibility for obtaining all the materials that are needed in using every learning resource and for returning the materials to their proper places when finished with them. The mechanisms and procedures used in IS for managing materials, devising and documenting learning plans, and assessing each individual's progress are basically the same throughout Levels A through E.

The teacher and the student share the responsibility for carrying out the necessary procedures. In the lower levels of the program, the learner takes major responsibility for materials management, and the teacher takes major responsibility for planning, recording and assessment of progress. Gradually and under the teacher's guidance, the student takes more and more responsibility for the planning and assessment of his or her own learning.

The learning of the skills involved in managing materials, planning learning, and assessing progress is not left to chance. Students entering Level A or B of IS are taught the basic skills of materials management in the Start Unit.[18] In this unit, the student learns how to use his or her Planning Sheet to determine which activity is to be done and what materials are needed to do the activity. The student learns to match the activity's name and number that are printed on the Planning Sheet with the corresponding name and number appearing on labels on printed instructional materials, kits, and tapes. As a result, by the time the student completes the Start Unit, he or she is able to collect all the correct materials and proceed with the activity. Students are also skillful in the use of the tape player after participation in the Start Unit. The skills involved in making choices from among available learning resources and in comparing answers to Check Ups with answers in the Keys Books are taught in Levels A and B of the program.[19] In Level C, the student checks his own answers on the placement test and learns how the placement test results are used in helping to determine which science content lessons he or she should study in the unit. The student also takes on more responsibility for keeping a record of his or her progress. In Level D, the first alternative pathway unit is introduced and the student has an opportunity to make a major long-term choice for his or her individual learning plan. In ways such as these, students

are taught systematically, unit by unit, and level by level, to take more and more responsibility for the management of their individualized learning.

We have found that students in the IS program need to be reminded periodically of their responsibilities in managing their own learning. To fill this need, several "How to . . ." booklets and sheets were developed to which students can be referred whenever necessary. These periodic reminders have combined with the systematic identification of and deliberate instruction in self-direction and co-evaluation skills to produce a pervading mechanism for developing in students the competencies necessary to operate successfully in an adaptive learning environment. The individualized-learning management system, which pervades the entire IS program and is integrated with the IS science curriculum, is our means of making operational the IS model of individualization in the real world of today's schools.

Our approach to individualized learning has been largely a pragmatic one, as we have sought to create a learning environment adaptive to certain individual differences of learners. Our formative evaluation[20] has demonstrated that students are capable of managing their individualized learning in the manner we have defined for the IS program. The individualized-learning management system is economically feasible and can be used successfully by elementary-school teachers with different personalities and teaching styles. The summative evaluation of the IS program will determine the extent to which the attention we have given to individual differences in learners and the means we have used in attending to these individual differences influence a student's learning of science and his or her long-term attitudes toward the learning process.

Footnotes

1 The philosophy of individualization underlying IPI has been described in numerous places at various times. For example, see: John O. Bolvin and Robert Glaser, "Developmental Aspects of Individually Prescribed Instruction," Audiovisual Instruction, 1968, 13, 828-831; Robert Glaser, "Adapting the Elementary School Curriculum to Individual Performance," In Proceedings of the 1967 Invitational Conference on Testing Problems (Princeton: Educational Testing Service, 1968), pp. 3-36; John O. Bolvin and Robert Glaser, "Individualized Instruction," In D. W. Allen and E. Seifman (eds.), The Teacher's Handbook (Glenview, Ill.: Scott, Foresman, 1971), pp. 271-279.

2 The term "adaptive education" has been introduced rather recently into discussions of the philosophy of individualization. For us, the meaning of "adaptive" accords with its usage in Robert Glaser, "Individuals and Learning: The New Aptitudes," Educational Researcher, June 1972, pp. 5-13.

3 Robert Glaser, op. cit., p. 7.

4 John B. Carroll, "A Model of School Learning," Teachers College Record, 1963, 64, 723-733.

5 Piaget's ideas are explicated in various ways throughout his voluminous writings. A thorough account of the child's cognitive development is given in Jean Piaget and Bernice Inhelder, The Growth of Logical Thinking from Childhood through Adolescence (New York: Basic Books, 1958). In the sizable secondary literature that seeks to explain Piaget's ideas, one work that we like is John H. Flavell, The Developmental Psychology of Jean Piaget (Princeton: Van Nostrand, 1963).

6 Rosalie Cohen, "The Relationship between Socio-Conceptual Styles and Orientation to School Requirements, Sociology of Education, 1968, 41, 201-220.

7 Jerome Kagan and N. Kagan, "Individual Variation in Cognitive Processes," In P. H. Mussen (ed.), Carmichael's Manual of Child Psychology, Volume I, 3rd ed. (New York: Wiley, 1970), pp. 1273-1365.

8 Though the interplay between students' attitudes and their school success is generally recognized and accepted by most teachers, the empirical research findings on the relationship between attitude and achievement are not so clear-cut. Representative research findings may be found in: W. H. Holtzman and W. F. Brown, "Evaluating the Study Habits and Attitudes of High School Students," Journal of Educational Psychology, 1968, 59, 404-409; S. B. Khan, "Affective Correlates of Academic Achievement," Journal of Educational Psychology, 1969, 60, 216-222.

9 Richard de Charms, "Personal Causation Training in the Schools," Journal of Applied Social Psychology, 1972, 2, 95-113.

10 The function, components, instructional strategy, primary sense modality and social setting for each learning resource are described in appendix B.

11 The notion of level of inquiry is discussed and illustrated in Marshall D. Huron, "The Nature of Scientific Enquiry," School Review, 1969, 79, 171-212.

12 In levels A and B Individual Lessons are all tape-directed. The lesson booklets at these levels do not contain text for the student to read.

13 Our stance in this regard is both philosophical and based on research. There is strong evidence that when an individual feels in control of a situation he or she functions more effectively. See, for example, de Charms, loc. cit.; and Richard de Charms, Personal Causation (New York: Academic Press, 1968).

14 Level E was chosen for this illustration because it is the highest level of the IS program for which the management system has been field tested and varified. Moreover, an illustration based on Level E exemplifies the maximum degree of student responsibility for management we have thus far defined and demonstrated to be functional.

15 Had Karen elected not to take the placement test, she would simply do all the Joule Unit science content lessons and selected related learning resources.

16 Karen can do any activity in the unit that she wants to, even if her performance on the placement test indicates that she already knows the concept covered by a particular activity.

17 If a student's performance on the posttest indicates that he or she has not satisfactorily learned the concepts tested, the posttest answers are analyzed and the student does further work in learning resources that will aid the student in attaining those concepts not adequately learned.

18 The Start Unit also assesses the student's competence in several academic skills considered prerequisites for the student's successful work in the IS program. For students entering upper levels of IS, the Launch Unit, corresponding in purpose with the Start Unit, is available. The Launch Unit teaches the basic skills of materials management taught in the Start Unit and Levels A and B, so that students beginning the program at Level C or above will be as familiar with these skills as students who have followed the IS route from the Start Unit on and through Levels A and B. The Launch Unit also provides instruction in certain basic science concepts taught in Levels A and B.

19 The brief descriptions here of the skills related to managing learning that the student learns in various IS levels are only illustrative, rather than exhaustive. Appendix C contains a complete list of the student competencies related to self-direction and co-evaluation for Levels A through E of IS.

20 Our particular perspective on formative evaluation and our views on the distinction between formative and summative evaluation are discussed in Audrey B. Champagne and Leopold E. Klopfer, "Formative Evaluation in Science Curriculum Development," Journal of Research in Science Teaching, 1974, 11, (in press).

21 A proper summative evaluation can be carried out only after a substantial portion of the IS program is in fairly widespread use in a variety of schools. This is now beginning to happen, with a published commercial version of IS Levels A through C available as we write. For the school year 1974-75, the commercial version of Levels D and E will be published. The publisher of the IS program is Imperial International Learning Corp., Kankakee, Ill.

Table 1

IS Model of Individualization

SOME DIMENSIONS OF THE LEARNING ENVIRONMENT	STUDENT CHARACTERISTICS RELATED TO LEARNING					
	INTELLIGENCE	ACQUIRED KNOWLEDGE	COGNITIVE DEVELOPMENT	COGNITIVE STYLE	INTERESTS	ATTITUDES
	POSSIBLE VARIATIONS WITHIN A DIMENSION					
LEARNING GOALS	Same for all students		Different for some students *(Decisions Needed)*		Different for every student *(Decisions Needed)*	
INSTRUCTIONAL MATERIALS	Same for all students		Different for some students *(Decisions Needed)*		Different for every student *(Decisions Needed)*	
INSTRUCTIONAL UNIT	Whole Class		Small Groups		Individuals	
SETTING	Traditional Classroom		Resource Center		Open Enviornment	
TEACHING FOCUS	Subject Matter		Processes		Values	
INSTRUCTIONAL MODE	Lecture	Programmed Instructional Materials	Discussion	Laboratory	Self-Instructional Materials	
INSTRUCTIONAL STRATEGY	Didactic		Guided Discovery		Inquiry	
RESPONSIBILITY FOR EVALUATION	Teacher alone		Student and Teacher		Student	
DECISION-MAKING	Teacher alone		Student and Teacher		Student Choice	

Table 2

GOALS OF INDIVIDUALIZED SCIENCE

I. SCIENTIFIC LITERACY GOAL

The student acquires a foundation for scientific literacy.

II. STUDENT SELF-DIRECTION GOAL

The student views the learning process as primarily self-directed and self-initiated.

III. STUDENT COEVALUATION GOAL

The student plays a major role in evaluating the quality, extent and rapidity of his learning.

IV. AFFECTIVE GOAL

The student displays informed attitudes toward his study of science, scientific inquiry, and the scientific enterprise.

V. INQUIRY GOAL

The student becomes skillful in using the processes of scientific inquiry and is able to carry out inquiries.

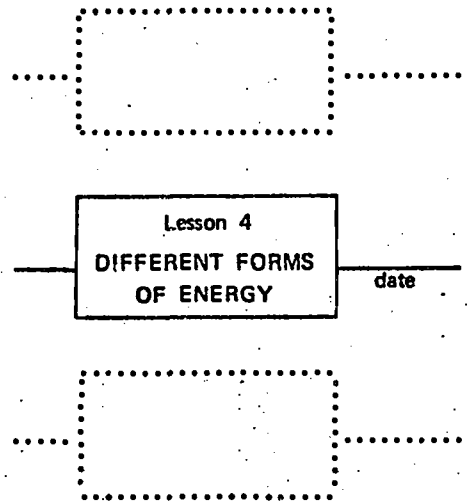
Table 3

Learning Resources of IS

Learning Resources	*Contribute to the attainment of . . .*				
	Scientific Literacy Goal	*Student Self-Direction Goal*	*Student Co-Evaluation Goal*	*Affective Goal*	*Inquiry Goal*
Individual Lesson (IL) focused on science content	X				X
Individual Lesson (IL) focused on learning management		X	X		
Planning Booklet		X			
Student-Teacher Conference		X	X	X	
Men & Ideas Filmstrip (M&I)	X			X	
Student Activity (SA)	X	X	X	X	X
Miniature Exploration (MinEx)	X	X	X	X	X
Invitation to Explore (ITE)	X	X	X	X	X
Science Learning Game (SLG)	X			X	X
Self-Initiated Independent Activity (SIIA)	X	X	X	X	X
Directed Group Activity (DGA)	X			X	X
Student Seminar (SEM)	X		X	X	X
Reading in Science (RIS)	X		X	X	
Science Notebook		X			X
Keys Book		X	X		
"How to . . ." Booklet		X			
Overview of Alternative Unit	X	X		X	
Eye Es Journal (JOUR) (student publication)	X				X
Miniature Investigation	X	X	X	X	X

Figure 1

Excerpt from Joule Unit Planning Booklet



Other Activities About		Date
DIFFERENT FORMS OF ENERGY	☐ MinEx 1 Can Light Energy Change Things?	
	☐ MinEx 2 Is Sound a Kind of Kinetic Energy?	
	☐ MinEx 3 How Can You Make a System to Convert Heat Energy into Kinetic Energy?	
	☐ MinEx 4 How Can You Make a System to Convert Stored Gravitational Energy to Kinetic Energy?	
	☐ MinEx 5 How Can You Make a System to Convert Electrical Energy to Magnetic Energy?	
	☐ MinEx 6 How Can You Make a System to Convert Stored Chemical Energy to Electrical Energy?	
	☐ SA 1 Can You Show That Energy Has Mass or Occupies Space?	
	☐ SA 2 Batteries	
	☐ SA 3 Elastic Energy	
	☐ SA 4 Community Electricity	
	☐ SA 7 Elastic Energy Machine	
	☐ SA 8 Energy Conversions	
	☐ SA 9 Observing Sound	
	☐ SA 10 Paper Cup Telephone	
	☐ SA 11 Radiometer	
	☐ RIS 1 Fireflies	
	☐ RIS 2 Gravity	

Appendix A

Explication of the Goals of Individualized Science

I. Scientific Literacy

The student acquires a foundation for scientific literacy.

The concern of this goal is to build that solid base of knowledge and understanding of and about science which the student will need to function in an increasingly complex world. Four components are encompassed in the concept of scientific literacy. First, the student should be able to describe his observations and experiences with terms drawn from a basic vocabulary of science words. A second and more fundamental component of scientific literacy is the student's understanding of certain important and relevant concepts, principles, and conceptual schemes of science. A third component of scientific literacy concerns the student's realization that scientific ideas change over time and his understanding of other key ideas about the nature of scientific inquiry. The fourth component is the student's understanding of significant ideas related to the social aspects of science. The attention given to this component in *Individualized Science* also contributes to the program's relevance to the child as a member of society.

II. Student Self-Direction

The student views the learning process as primarily self-directed and self-initiated.

This goal emphasizes the student's development into a competent and confident independent learner. As an independent learner, he is able to select and utilize a suitable learning environment and instructional materials that will lead him toward desired knowledge, insight, or satisfaction. He is also able to specify and follow a fairly long-term plan for his own learning.

III. Student Coevaluation

The student plays a major role in evaluating the quality, extent, and rapidity of his learning.

As the student develops into an independent learner, evaluation of his learning by a teacher or someone else should gradually decrease. The student should assume continually increasing responsibility for judging how well he performs in learning new information, ideas, and procedures. When a student has become responsible for evaluating his own learning, he will be able to set criteria for the completion or mastery of a learning task and recognize that he has completed his task upon meeting these criteria. He will also be able to assess his progress on a learning task as he proceeds, by analyzing the difficulties he encounters, revising his approach if necessary, and seeking out assistance if needed.

IV. Affective Goal

The student displays informed attitudes toward his study of science, scientific inquiry, and the scientific enterprise.

The student's attitudes and interests are the focus of attention under the affective goal. Holding well-informed, positive attitudes toward science is recognized as an essential ingredient of an individual's ability to live successfully in the contemporary world. In the process of developing attitudes, the student learns to value science for its contributions to man's intellectual growth and to society. He also learns to accept the processes of scientific inquiry as a valid way to conduct one's thinking. When carrying on inquiries or confronting problems, the student adopts the so-called "scientific attitudes," which include honesty, openmindedness, suspended judgment, self-criticism, and commitment to accuracy.

Appendix A (continued)

V. Inquiry

The student becomes skillful in using the processes of scientific inquiry and is able to carry out inquiries.

Student involvement in inquiry and the development of skills in using processes of scientific inquiry are manifested under this goal. Behaviors pertinent to inquiry are exhibited by the student both when he is investigating natural phenomena or solving problems in science, and when he is investigating problems outside of science. In carrying out an inquiry into any given problem, the student formulates a plan for his inquiry, designs procedures which implement his plan, carries out the indicated procedures, processes the data obtained, interprets the data and observations, and, finally, evaluates the results of the inquiry in relation to its purpose.

Appendix B

General Descriptions* of Learning Resources of Individualized Science

	Individual Lesson (science content) (IL)	Men & Ideas Filmstrip (M&I)	Student Activity (SA)	Miniature Exploration (MinEx)	Invitation to Explore (ITE)
FUNCTIONS	to impart information about science content to provide exemplars of logical reasoning in science	to impart information about the lives of scientists, the influence of science on society and of society on science	to provide the student with suggestions for practice activities, readings, investigations, and projects related to the content of the unit	to help the student develop the skills necessary to plan, carry out, and evaluate the results of simple scientific investigations	to impart information about science content to suggest investigations, both long- and short-term
COMPONENTS	Levels A & B: illustrated response sheet or booklet; tape which provides auditory instruction; manipulative materials Levels C and above: illustrated booklet with printed text; optional read-along tape; manipulative materials; response sheet or booklet	filmstrip audiotape	printed card which describes the activity; practice sheets; manipulative materials (for A & B Level SA's only)	booklet illustrated with photographs manipulative materials	illustrated booklet with printed text optional read-along tape manipulative materials response sheet booklet
SOCIAL SETTING	student alone (optionally, with 1 or 2 other students)	student alone or students in small groups	student alone; students in pairs or in small groups	student alone or pairs of students	student alone (optionally, with 1 or 2 other students)
INSTRUCTIONAL STRATEGY	didactic and guided discovery	didactic	(various)	guided discovery by means of modeling, or inquiry (see note)	didactic, guided discovery, inquiry
SENSE MODALITY	visual, auditory, kinesthetic	visual, auditory		visual, kinesthetic	visual, kinesthetic
INTRODUCED IN	Level A	Level A	Level A	Level C	Level D (alt. pathway) Level G (mainstream)
NOTES	An IL typically can be completed in less than 40 minutes			On the cover of the MinEx booklet, a problem or question is posed for which the student is asked to suggest a method for finding an answer. The student may seek an answer to the problem using a method he or she devised. (Inquiry mode) Alternatively, through the use of photographs and simple text inside the MinEx booklet, a method is suggested which the student may model to find an answer. (Guided discovery mode)	ITE's are similar to IL's (science content) except that they are more sophisticated and may take a week or more to complete.

*Since these descriptions are quite general, the characteristics of any specific example of a particular learning resource may vary somewhat from those described here.

Appendix B (continued)

	Science Learning Game (SLG)	Self-Initiated Independent Activity (SIIA)	Directed Group Activity (DGA)	Student Seminar (SEM)	Readings In Science (RIS)
FUNCTIONS	to provide the student opportunities to practice using vocabulary, facts, skills, and concepts learned in other activities	to provide opportunities for a student to engage in a scientific investigation of a topic of his or her own choice	provides opportunities for: (1) teacher-student discussion (2) students to use new science vocabulary (3) the teacher to assess the extent of student's attainment of science concepts	to provide students with opportunities to discuss their experiences in science to help students develop skills in oral expression and in using the language of science	to impart information about science content to illustrate the societal relevance of a unit's science content
COMPONENTS	gameboard, cards, dice, markers	a printed sheet which provides an outline for defining the problem, the method of investigation, observations to be recorded, and interpretations	printed suggestions in the teacher's manual for conducting the activity which include background information, questions, and directions for demonstrations; manipulative materials	printed booklet which provides directions on conducting the seminar activity (directions vary depending on IS level)	illustrated booklet containing several readings; optional read-along tapes; comprehension and extension questions following most readings
SOCIAL SETTING	two or more students	student-teacher planning conference; execution by a single student, a pair of students, or a small group of students	teacher and a small group of students	group of students	student alone
INSTRUCTIONAL STRATEGY	practice and guided discovery by means of gaming	inquiry	practice and guided discovery by means of group discussion or gaming	practice by means of modeling and group discussion	didactic
SENSE MODALITY	visual, kinesthetic	visual, kinesthetic	auditory, visual, kinesthetic	auditory, visual	visual
INTRODUCED IN	Level A	Level A	Level A	Level D	Level C
NOTE				As students become proficient in conducting SEM's, they should increasingly supplant the teacher-led DGA's	

	Individual Lessons (learning management) (IL)	Planning Booklet	Student-Teacher Conference	Keys Book	Science Notebook
FUNCTIONS	to impart information about mechanism of materials and learning management to aid the student in planning and assessing his or her progress	to provide: (1) an organized list of Learning Resources for a unit (2) a mechanism for recording an individual learning plan (3) a mechanism for recording student progress	to provide the student and teacher opportunities to discuss the student's individual learning plan and to co-assess the student's progress	to provide the student with answers to questions on Check Ups in IL's, unit placement tests, and posttests	to provide the student with a place to keep records (both written and diagramatic) of his or her science activities to provide the student with practice in writing about science and using science vocabulary in written form
COMPONENTS	illustrated booklet with printed text optional read-along tape response sheet or booklet	printed booklet with a topically organized listing of a unit's learning resources, and with spaces for recording a learning plan and student progress	suggestions for conducting certain student-teacher conferences are printed in the Teacher's Manual	booklet for each IS level containing reproductions of student response sheets or booklet pages with expected correct answers written in	a notebook
SOCIAL SETTING	student alone	student alone teacher alone student and teacher	student and teacher	student alone	student alone
INSTRUCTIONAL STRATEGY	didactic	practice	practice, didactic, or guided discovery by means of one-to-one discussion	didactic	practice
SENSE MODALITY	visual, auditory	visual	auditory	visual	visual, kinesthetic
INTRODUCED IN	Level A	Level A	Level A	Level A	Level C
NOTES	Placement tests and unit posttests, important parts of this learning management system, are included in this grouping of IL's.		Student-Teacher Conferences may also be used by the teacher as tutoring sessions or to introduce the student to study in a new unit.		Records kept by the student include descriptions of science investigations, both those defined by the program (e.g., in MInLx's and ITL's) and self-initiated ones in SIIA's, and their outcomes. Also included are answers to RIS and SA questions.

	"How to . . ." Booklet	Unit Overview	IS Journal (student publication)	Miniature Investigation
FUNCTIONS	to remind experienced IS students about self-direction, co-evaluation and laboratory safety procedures to instruct students new to IS in proper procedures for the use of learning resources and about laboratory safety	to introduce the student to the science content of a unit to guide the student in making decisions about his or her learning plan for the unit	to provide students with opportunities to share written reports about their experiences in science and about science news of current interest to their classmates and parents to increase the student's skills in writing about science and in using scientific vocabulary	to provide the student with experiences in planning, conducting, and interpreting data obtained in investigations concerned with social aspects of science to expand the student's comprehension of inquiry and scientific inquiry to extend the student's skills in carrying out inquiries
COMPONENTS	booklet of cartoons	an illustrated booklet with printed text an optional read-along tape	student-produced sheet or booklet	illustrated booklet posing a problem or question for investigation and suggesting models of some possible procedures
SOCIAL SETTING	student alone	student alone	students in small groups	student alone or students in pairs or in small groups
INSTRUCTIONAL STRATEGY	didactic by means of modeling	didactic	practice	guided discovery by means of modeling
SENSE MODALITY	visual	visual	visual	visual
INTRODUCED IN	Level C	Level D	Level F	Level G
NOTES		Unit Overviews are similar to IL's (learning management), except that they are longer and more sophisticated. The Unit Overview for an alternative pathway unit also includes watching and listening to the unit's Men and Ideas Filmstrip.		Miniature Investigations are somewhat similar to MinEx's, but the problems investigated are more sophisticated, generally take more time, and deal with aspects of the interplay between social concerns and science.

Appendix C

Competencies in Student Self-Direction and Co-Evaluation

Level in Which Competency is Introduced	Student Self-Direction	Student Co-Evaluation
Level A	When given the opportunity to work in science, the student obtains his own folder and proceeds to work according to the information in his folder. Using his Planning Booklet or Planning Sheet, the student identifies the activity he is to do and obtains the designated materials needed. Upon completing the activity, he returns the materials to their correct storage places. Given a cassette and a cassette player with headphones, the student inserts the cassette into the player, puts on the headphones, turns on the player, starts and stops the tape, adjusts the volume, turns off the player, and extracts the cassette from the player.	After completing a self-check page (identified by a key around page numbers) in a lesson booklet, the student compares his answers with those on a model page which is completed correctly.
Level B	Given the opportunity to select a Student Activity, the student chooses one which interests him from among those available, and records on the Planning Booklet or Planning Sheet the code for the activity and the date on which he does it. Given a situation in which he has no prescribed activity or in which a prescribed activity cannot be done, the student selects an appropriate alternative activity and goes to work in that activity.	The student corrects his work on selected booklet pages using a key.
Level C	Upon his completion of each day's activities in science, the student writes the date in the appropriate spaces on his Planning Booklet or Planning Sheet for each activity as a record of what he did that day.	After completing a check up and obtaining a key for it, the student compares his completed check up with the key, assigns point values to correct answers, and calculates his total points for the check up.

Appendix C (continued)

Level in Which Competency is Introduced	Student Self-Direction	Student Co-Evaluation
Level C (continued)	Given an outline of required activities in a unit and after obtaining the results of his Placement Test for that unit, the student identifies the science concepts he has already mastered and the concepts not mastered, and indicates on his Planning Booklet or Planning Sheet those required activities he may choose to do (since he has mastery of the related concept) and those he must do (due to non-mastery of the related concept). Given the list of Miniature Explorations (MinEx's) available in a unit and having examined the MinEx booklets and kits, the student chooses the MinEx's which he would like to do and records his choices in the Planning Booklet. Given the list of Readings in Science (RIS's) associated with particular MinEx's, individual lessons, or other learning resources in a unit, the student selects the RIS which he wants to do next and reads it at the appropriate time.	While taking a Placement Test (taken before beginning study in a unit), the student elects to answer any question for which he knows the answer or omits any question for which he does not know the answer.. After completing a Placement Test and obtaining a key for it, the student compares his answers with the key, assigns point values to correct answers, and calculates his total points for the Placement Test. In a unit with one or more integrating check ups (i.e., a check up which ties together the content of several lessons, readings, and/or other activities), the student participates with the teacher in making a decision about when he is ready to work on a check up. In a unit where a unit mastery test or activity is available, the student participates with the teacher in making a decision about when he is ready to attempt the test or activity. After correcting any check up he has taken or after obtaining the results of a unit mastery test or activity, the student identifies those topics he has not learned satisfactorily and participates with the teacher in making a decision about whether or not remedial instruction is necessary and, if so, what form of remedial instructio he will take.
Level D	Given an outline of a unit's activities grouped by topic, and after obtaining the results of his or her Placement Test for the unit, the student identifies those topics his or her Placement Test results indicate he or she must study and those topics for which the Placement Test results indicate a choice. On the	As a part of participation in an Alternative Pathway unit, the student in a Student-Teacher Conference assesses his or her accomplishments in the unit and suggests ways in which his or her work in the unit might have been improved.

Appendix C (continued)

Level in Which Competency is Introduced	Student Self-Direction	Student Co-Evaluation
Level D (continued)	basis of this analysis and his or her own interests, the student develops an individualized learning plan for the unit. The student makes any necessary modifications in the plan after discussing the plan with the teacher. Upon completion of the Unit Overview for an Alternative Pathway unit, the student decides whether or not he or she will work in that unit and discuss the reasons for the decision in a Student-Teacher Conference. The student decides which Invitations to Explore (ITE's) in an Alternative Pathway unit he or she will read and records his or her choices in the Planning Booklet. For each ITE selected for study in an Alternative Pathway unit, the student selects the activities he or she will complete and records his or her choices in the Planning Booklet. Upon completion of an individualized learning plan for an Alternative Pathway unit, the student discusses the plan with the teacher and makes any necessary modifications in the plan that resulted from the conference. The student takes the responsibility for making the necessary arrangements for holding a seminar simulation and prepares for his or her part in it. The student participates effectively in the seminar simulation and carries out his or her own responsibilities as a seminar member as well as facilitating the participation of others.	
Level E	Given the opportunity to read through a Placement Test, the student decides whether or not he will attempt the test. If the decision is not to take the test, he or she informs the teacher of this decision and includes	After completing and correcting a unit mastery test and given a list that relates questions on the test to topics considered in the unit, the student identifies those topics he or she has not learned satisfactorily.

Appendix C (continued)

Level in Which Competency is Introduced	Student Self-Direction	Student Co-Evaluation
Level E (continued)	learning activities from all the unit's topics in his or her individualized learning plan.	Upon completion of the analysis of a unit mastery test, the student uses activities related to the topics not learned satisfactorily to design a remedial learning plan and discusses this plan with the teacher.