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ABSTRACT

For the benefit of administrators and instructors, individualized instruction and the role of computers in managing it are outlined. Structural components of individualized instructional programs are identified, and the process of individualized instruction is described. A review of major computer-managed instructional (CMI) systems is provided, with the findings of the systems summarized. The Wisconsin System for Instructional Management (WIS-SIM) Model is then described in detail, including the instructional cycle, the use of individual student records, testing and test scoring, performance profiling, specifying performance expectations, diagnosing and identifying instructional needs, guiding the instructional process, and selecting appropriate educational experiences and settings. (SK)

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WISCONSIN RESEARCH
AND DEVELOPMENT
CENTER FOR
COGNITIVE LEARNING

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COMPUTER MANAGEMENT OF INDIVIDUALIZED INSTRUCTION

by

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Report from the Project on
Computer Applications for IGE

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WISCONSIN RESEARCH AND DEVELOPMENT CENTER FOR COGNITIVE LEARNING

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- developing improved instructional strategies, processes and materials for school administrators, teachers, and children, and
- offering assistance to educators and citizens which will help transfer the outcomes of research and development into practice

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The activities of the Wisconsin R&D Center are organized around one unifying theme, Individually Guided Education.

FUNDING

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ABSTRACT

The generalized Wisconsin System for Instructional Management (WIS-SIM) is being developed to serve the management needs of IGE. This paper identifies key dimensions which help define individualized education and relates these to essential components of a system of computer managed instruction. The processes of computer managed instruction (CMI) are integrated into a generalized model which accounts for the major structural and process delineations of programs of individualized education of which IGE is an example.

CMI as a management information system provides instructional managers with information required for decision making in individualized educational programs. In particular, decisions involved in identifying the instructional needs of students and in selecting the most appropriate instructional activities to cater to these needs are emphasized. The major processes specified in the model are testing (placement and posttest), test scoring, achievement profiling, diagnosing, and prescribing. Of these processes the last three are considered to be the most important.

CMI systems seem to have greatest potential in the management of instructional resources in the prescriptive process and the diagnosis of student instructional needs. These areas have only barely been touched in system development to this date. The review of other CMI systems provided indicates that many were conceptualized almost concurrently, and that they share much in common while differing in the emphasis on and reporting formats for each of the five processes.

In the WIS-SIM model it is possible to view these processes as a means of providing to educational decision makers, information on the instructional program being implemented. Achievement profiles may be produced which reflect the current status of performance relative to unit, building or district goals which have been formulated for an instructional activity or a set of instructional activities. If these goals are not achieved, the instructional activities and the program itself then become the focus of the examination.

WIS-SIM, unlike other CMI systems, incorporates a "total system" approach which is designed to have direct utility at the classroom, building, and district levels. Its utilization can directly assist in the effective implementation of an individualized program of learning for each student through assisting in the identification of the instructional needs and selection of appropriate instructional experiences and settings for each student. WIS-SIM also has a positive impact through the continual monitoring and refining of the school's instructional program. Thus, in a real sense, WIS-SIM is a model for making decisions about the instructional program as well as a model of individualized instruction. With the use of a CMI system, some of the typical problems of individualized programs can be overcome, making it possible for these programs to become fully operational.

I

INTRODUCTION

Education has been hard-pressed to keep pace with the cultural, social, and technological changes which have occurred during this century. In response to frequent criticisms that existing educational systems were ill-conceived and ill-equipped to meet the realities of a changing world, educators have attempted to implement and evaluate a multitude of educational plans all aimed, presumably, at improving the instructional or learning processes. A pervading theme among these many attempts at innovation has been that of individualized instruction. Proponents of individualized instruction consider that a teaching-learning situation which focuses upon the needs and abilities of the individual, rather than on the group, is a better way to conduct the educational process. Earlier attempts at individualized education met with only limited success because the resources of educational systems were frequently inadequate to meet the program objectives or because the attempts were too specialized or too localized to be of any significant value except to a few.

However, educators are continuing with attempts to implement strategies of individualized education hoping to provide a more effective alternative to traditional instructional practices. Recent programs designed to individualize education, such as Individually Guided Education (Klausmeier, 1971), Project PLAN (Flanagan, 1971), and Individually Prescribed Instruction (Cooley & Glaser, 1968), have met with promising success. Essential to the functioning of such programs of individualized education is the teacher's ability to cope effectively with the volume of information required to manage these programs. Due to the fact that differing instructional approaches may be used at different times with a large number of students, monitoring the progress of students and deciding upon optimal instructional objectives and tasks becomes difficult. This condition is compounded as more areas of the educational program are individualized. The complexity of instructional management in individualized programs has led to an increased awareness that computer-based management information systems may be of considerable value in assisting in the implementation and operation of individualized instructional programs.

This paper is designed to identify key parameters which help define various approaches to individualizing education and to relate these parameters to essential components in computer managed instruction. Building upon the identified relations, a generalized model of computer managed instruction is formulated and described. Accordingly, the topics of individualized education and computer managed instruction are reviewed in the next three sections.

II

STRUCTURAL COMPONENTS OF PROGRAMS OF INDIVIDUALIZED EDUCATION

DeVault and Kriewall (1967) consider that true individualization involves recognition of the "potential for variability at every major input point of the instructional system [p. 413]." The development of a model for this concept of individualization was originally carried out by Romberg and DeVault (1967) and represents a systems approach. The model has four input components--learner, teacher, content, and instructional methods--each of which includes three or four variable characteristics or parameters. Learner parameters include the intellectual, emotional, social, and physical traits of the individual child; teacher parameters are the roles, knowledge and skills, and personality factors; content of the instructional material varies for each learner in terms of rate, scope, and sequence; and finally, instructional methods vary according to communication styles, degree of automation, and instructional materials. Although the model is presented as one for differentiating instruction in a mathematics curriculum, Romberg and DeVault's discussion is directed toward the more global aspects of individualized instruction which they believe to be the most viable instructional approach for most curricular areas.

The primary focus of any system of individualized education is the growth of the individual learner. To achieve this aim, individualized systems, unlike those which utilize more traditional classroom and group modes of instruction, stress the importance of self-initiative and self-direction. The individual learner, rather than being the passive object of instruction, becomes an active part of the teaching-learning situation. Teachers, while remaining in charge of instruction, provide opportunities for individuals to set their own objectives, asses's students' abilities, and prescribe courses of action which will lead to goal attainment. Further, in planning instructional activities, teachers take the individual differences of pupils into account and gear their efforts toward having each child progress through the objectives at his or her own pace. An intended outcome of such adaptive, individualized systems is to provide meaningful learning experiences for each pupil while serving individual needs and interests. Systems of individualized education are thus geared to individual abilities, interests, and needs. They are not group instructional programs which are inflexibly applied to all pupils in a class.

Because they recognize that individuals learn content at different rates and have different levels of motivation, systems of individualized education provide for self-development and maximized educational benefit for each student. Personal decision-making and problem-solving skills of the pupil are enhanced and favorable attitudes toward learning are developed (Wright, 1970). By remaining cognizant of different learning styles, instructional levels, rates of progress, and beginning levels of performance,

individualized systems account for real, as well as ideal, levels of attainment (Klausmeier, 1974).

The instructional process focuses upon the individual, and subsequent assessment determines the degree to which prespecified objectives have been attained. This process, which includes both teacher and pupil involvement at each stage, points to the key components of an individualized education system. These components are now discussed in more detail.

The existence of a well-defined set of instructional objectives is prerequisite to any individualized education program. Figure 1 presents a hierarchical development of instructional objectives. This hierarchy is a six level organization from general instructional missions of the district or school to specific instructional objectives.

The Instructional Missions cell refers to those district or school instructional policies which give general direction to instructional activities. These mission statements include activities such as the development of communication skills or skills in mathematical processes. They are statements of policy, usually very long range, reflecting societal desires, aspirations, and the organization's reason for being.

Arising out of these global concerns are Instructional Programs. These programs are broad and represent functions pointing toward the attainment of the instructional missions. Goal statements within instructional programs are long range, but they focus on terminal points or activities to be accomplished. Two R & D Center products which fall into the instructional programs cell are Developing Mathematical Processes (DMP) and the Wisconsin Design for Reading Skill Development (WDRSD). Each of these is an instructional program with broad goals focused on terminal points which, when combined with other programs, should lead to the accomplishment of an instructional mission.

Instructional programs are made up of subdivisions, here called Instructional Areas. Within this category are included significant and measurable outcomes to be achieved as major components of the instructional program. These broad objectives give specific direction to the attainment of program goals. They may also suggest challenges to and problems in the instructional program. The areas of Word Attack, Study Skills, and Comprehension are examples of instructional areas within the WDRSD instructional program. Instructional areas are not defined in DMP, so in that program the classification is non-functional.

Each instructional area is made up of Instructional Units, which can be of two types labeled content/process organization and level/grade organization. Instructional units are smaller programs of shorter duration and narrower scope than the instructional programs. Content/process organization refers to the sequencing of content and defines paths through the instructional material. Within DMP, an example of such a content/process organization is the sequencing for concepts in geometry. While not well defined, sequences or strands also exist in WDRSD; the sequence of materials on "consonants" is an example.

The level/grade organization component is composed of instructional units which are based upon administrative considerations such as pupil grouping. Such units often cover grade level or curricular work of approximately a school year's duration. Within DMP, this administrative organization would include "Grade Level Kits" which cover the work expected

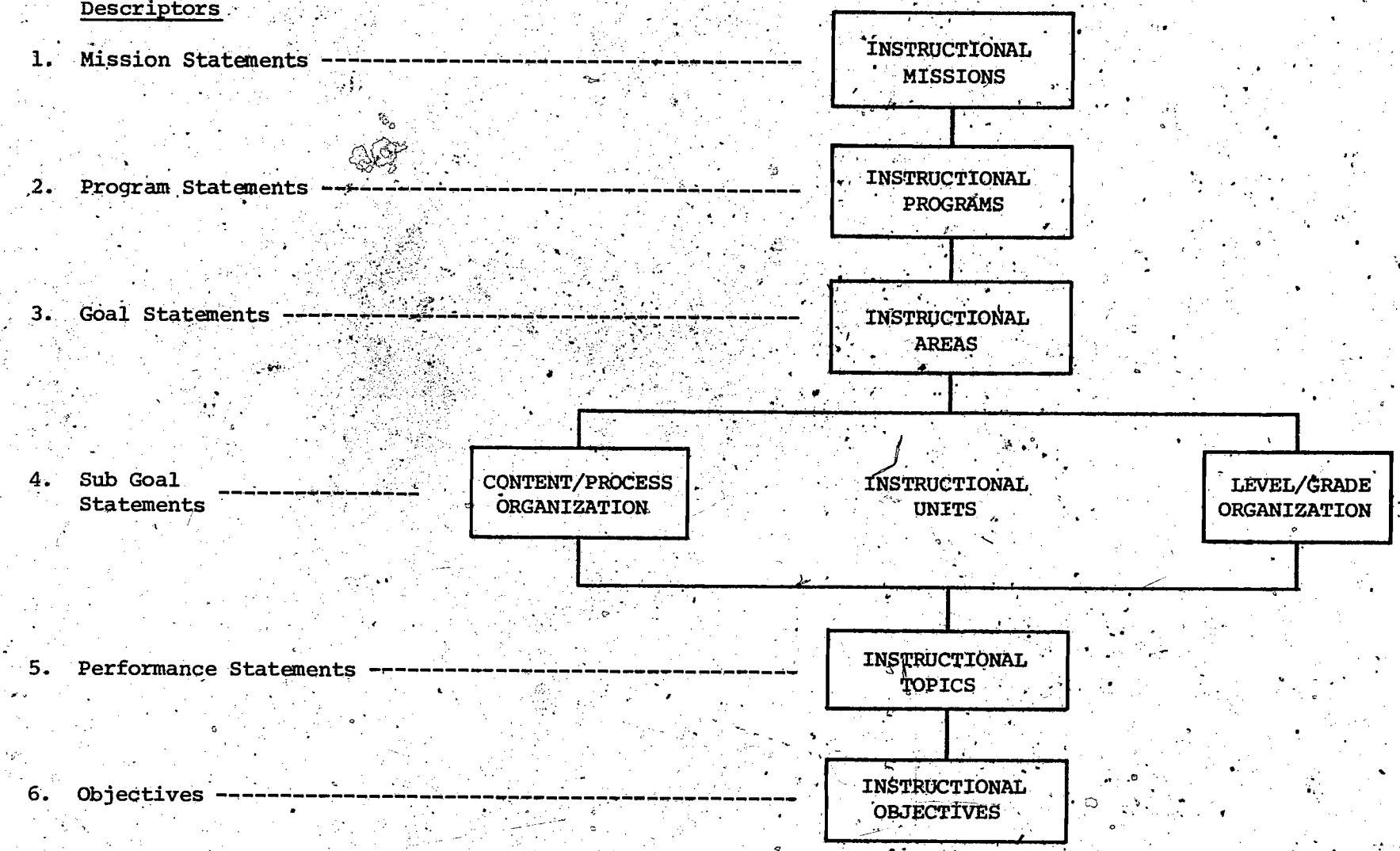

Figure 1. Hierarchical development of instructional objectives.

at a given grade level. WDRSD has administrative organizations called "levels" which also aggregate work units into approximately one school year's work. Though these grade/level units are not followed closely in classroom instructional planning, they are important to the information management of an instructional program.

As is apparent in both WDRSD and DMP, both content/process and grade/level types of instructional units exist. When both are present they form a two-dimensional array as displayed in Figure 2. Individual cells are defined by the intersection of content/process categories and grade/level categories and within each cell are instructional topics and objectives. It is not necessary that each of these cells be used in the instructional area; that is, some cells may be empty.

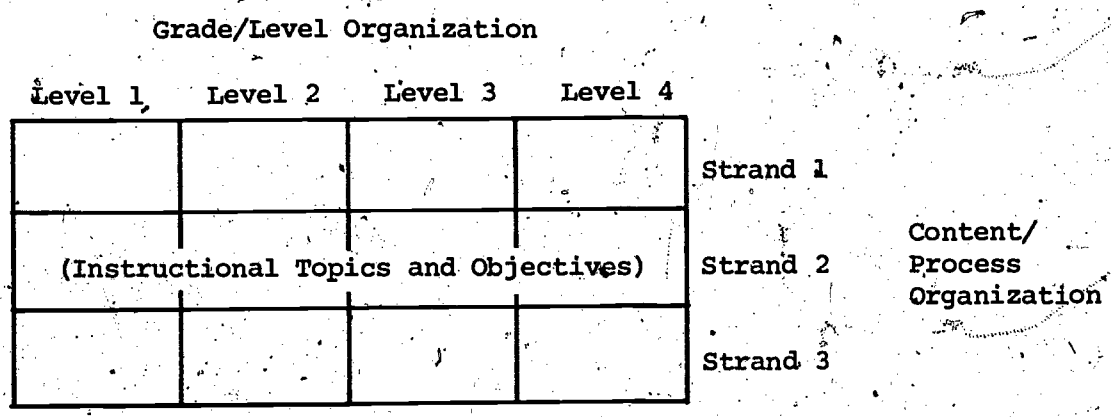

Figure 2. Instructional unit in terms of instructional topics.

Within each instructional unit are Instructional Topics. These are relatively short-term aggregations of instructional objectives with a well-defined set of specific products, processes, or achievements. These topics may be organized around content, process, activity, or media. The DMP curriculum uses the term "topics" to describe such a collection of objectives. The DMP topics reflect a content/process organization within which instructional objectives with a common goal are collected. However, there are also some topics which contain instructional objectives which are preparatory to later topics. These reflect the grade/level organization which can co-exist with content/process organization at the instructional topic level. WDRSD organizes some instructional objectives into

instructional topics called skill clusters. These skill clusters have only a grade/level organization; they do not necessarily reflect content or process contained within the instructional objectives.

Instructional Objectives are the most specific outcome oriented statements for goal attainment. They are criterion-referenced, measurable, and focused on a single product, process, or achievement. Instructional objectives for each pupil state what is to be accomplished, at what level of expertise, and sometimes by when it will be done. These are the most specific, targeted objectives in the hierarchy of instructional missions and programs. In the DMP program these instructional objectives are called objectives, while in WDRSD they are called skills. In both cases, however, they are specific behavioral objectives appropriate to the instructional topics and programs.

Klausmeier (1974) has identified a three-dimensional model useful in classifying programs of individualized education. The three dimensions included in this model, as illustrated in Figure 3, are (1) sequencing or non-sequencing of objectives, (2) common or variable objectives, and (3) full mastery or variable attainment. These three concepts in combination define eight possible types of individualized educational programs.

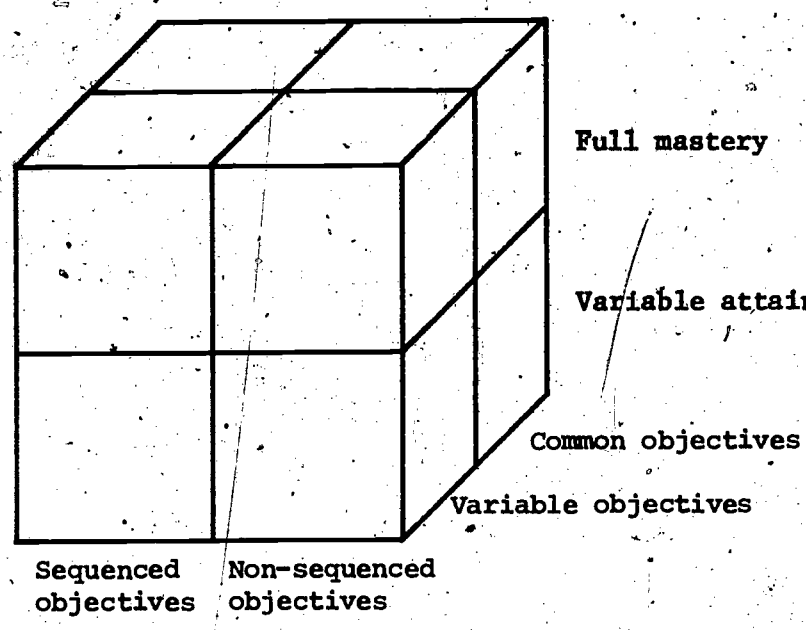

Figure 3. Dimensions defining programs of individualized education.

Instructional objectives or topics within an instructional program may be interrelated in predetermined ways, establishing for the program a network of prerequisites. If such prerequisites exist within a program, the objectives are sequential. For example, the achievement of objectives in a mathematics curriculum is often sequential in nature, with completion of lower-order objectives being prerequisite for progress toward higher-order objectives. Not all objectives need be related sequentially, however. Many may be relatively independent, and can be attained at any one of several points in the program of individualized learning. Some instructional programs are characterized by the absence of prerequisites and are therefore non-sequential in nature.

In an individualized instructional program, all objectives may not be required of all students; that is, those objectives which comprise an instructional program may vary among students. Some objectives may be common in that all students are required to attain them while others may not be so required. This defines a program with variable objectives.

Programs of individualized education may also vary the mastery level required of individual students. The required level of attainment may vary from student to student or a program may require full mastery wherein all students in the program are expected to achieve the same level of attainment on a given objective.

Two other important concepts useful in analyzing individualized instructional programs are compatibility of instructional activities and compatability of instructional objectives. Compatibility is concerned with the efficiency of the instructing and learning processes. Analysis of the instructional program may identify two or more objectives which can be effectively taught at the same time; these are therefore compatible instructional activities. Compatible instructional activities are in contrast to sequenced prerequisites which should not be undertaken at the same time. Some instructional activities may be useful in teaching toward more than a single objective, thus identifying these instructional objectives as compatible. Some instructional activities may be compatible and point to associated sets of compatible objectives. The concept of compatibility is useful in identifying clusters of objectives which might logically be taught together and may form a basis for establishing instructional topics within a program.

One form of incompatibility, that of prerequisites, has already been discussed. Instructional activities and related objectives may be incompatible for other reasons. Instructional activities may, for example, be designed for differing group sizes or instructional settings, making them inappropriate for teaching at the same time and thus incompatible. Further, objectives and instructional activities may be neutral with respect to compatibility, indicating that they may be taught at the same time, but without particular gain in efficiency.

An important step in the development of a system of individualized education is the specification of performance standards. Each goal or objective in the total system must be interpretable in terms of the behaviors necessary for its achievement. As mentioned earlier, these performance standards need not be common to all pupils, nor need they be rigidly applied without exception. Rather, these criteria may be

sufficiently flexible to allow for the wide range of individual abilities which generally exists in any group of pupils--but no objective should be without its associated achievement or performance criteria stated in specific behavioral terms.

Performance standards in systems of individualized education are frequently embodied in criterion-referenced tests. As the name implies, such tests contain a criterion, or a set of criteria, which a pupil must satisfy in order to attain the objective. These criterion-referenced tests, however, need not always be of the paper-and-pencil type; they may take other forms which involve oral as well as written skills and attainment of criterion may be determined through observation and performance testing. The task of establishing criteria is clearly made less complex when system goals or objectives have been carefully planned and specifically stated.

For some objectives, the criteria for attainment may be open-ended. Although specific behaviors to be attained are stated, a single observation will not suffice to determine that criterion has been reached; continuing demonstration over time is desired: This type of objective is likely to be included, for example, in a program in the affective domain.

In this section, the structural components of individualized educational programs, and the many ways in which these programs may differ have been identified. While all are based on mastery level objectives, they may differ relative to the sequencing or non-sequencing of objectives, on whether they require full or variable mastery, and on whether they include common or variable objectives. Instructional objectives and activities have been defined and the notion of performance standards as they relate to the mastery-level objectives has been discussed. The process of individualized instruction will be built upon these concepts in the next section.

III

THE PROCESS OF INDIVIDUALIZED INSTRUCTION

The first step in the implementation of an individualized instructional program is placing each student within the context of the instructional objectives. Usually this is accomplished through the use of a placement test or pretest. With the results of this test teachers can identify where each pupil should begin in the total network of objectives and can select a set of objectives from the total system which are realistic in terms of the pupil's likelihood of attaining them. With this information a teacher may effectively diagnose deficiencies in the pupil's progress toward the objectives in any given instructional area.

It is at this level of the system that significant advances are made toward individualizing instruction since the diagnosis which takes place is made in terms of the individual pupil's standing with regard to the specified instructional objectives and not with regard to the standing of other pupils. The objectives which have already been specified by the instructional program act as a framework within which each pupil proceeds; a variety of instructional objectives may be identified at any given time. Diagnosis, then, is not simply the identification through pretesting of a pupil's current deficiencies in a particular area; it includes a broader judgment about his standing within the total network of objectives.

A crucial component of any system of individualized education is the process of guiding or prescribing, for it is at this point that the instructional process is directly related to the individual needs of the student. Here the decision is made about how best to meet the instructional needs determined by the diagnosis. The guiding or prescribing process must take into account the structural characteristics of the program (common or variable objectives, full or variable attainment, and sequential or non-sequential instructional objectives) as well as such student characteristics as learning style, interest, and ability.

Individualized instructional programs differ in the way in which selected instructional activities are implemented, that is, in the way instruction takes place. Most individualized programs prescribe that the student work alone on the instructional activity--frequently on a work sheet or file folder. Individually Guided Education attempts to form large, medium, and small groups around specific instructional activities, the size of the group depending on the instructional activity and the requirements of the student group. A single student may work alone when this is deemed appropriate. The concepts of guiding and grouping students according to similar needs, as opposed to prescribing that students work independently all or most of the time, is an additional difference between types of individualized educational programs.

Following instruction, student performance is evaluated. A posttest is given to determine the degree to which a pupil has attained the prespecified objective; whether the level of attainment is satisfactory is dependent upon the success criteria which were also prespecified.

In essence, the total system has come full cycle at this point. Student achievement of a given objective necessitates the identification of a new objective, which may be dependent upon or unrelated to the achieved objective. Non-achievement may require that a different objective be set or the same objective may be retained, but a different set of instructional activities may be prescribed. The criteria for achievement may be altered to suit an individual case. Although objectives and the criteria for their attainment are prespecified, the system remains flexible in that either may be redefined as required. The process of goal-setting, pretesting, diagnosis, prescription, instruction, and assessment is thus simply a means to an end, and not an end in itself. Modification can and does occur as required at any stage of the process; the ultimate goal is to serve the needs of the individual pupil, not the needs of the system (Lindvall & Bolvin, 1970).

Basic to programs of individualized education, then, are the processes of pretesting or placement testing, diagnosing, guiding or prescribing, instructing, and posttesting. These processes are conducted relative to the individual needs, interests, and abilities of students. In addition to the structural differentiators of individualized programs identified in the preceeding section, this section has identified another basis for distinguishing between types of individualized programs. This difference is the emphasis the programs place on guiding students into learning groups as opposed to prescribing independent work for individual students.

IV

COMPUTER MANAGEMENT OF INDIVIDUALIZED INSTRUCTION

Up to this point the discussion of individualized education has been abstract. While the system seems logically sound and intuitively pleasing, many logistic problems arise with the actual task of implementing the system in a typical classroom. The problems relate, for the most part, to routine matters of record-keeping and information retrieval, but when these tasks are considered at each stage in the program of individualized instruction, they compound rapidly and soon become unmanageable. While the task of creating an initial list of goals or objectives for a particular curriculum area may be difficult, the job of keeping track of this list as objectives are added, modified, or replaced soon becomes overwhelming. As discussed earlier, a system of individualized education may include common or variable, sequenced or non-sequenced, and full or variable objectives. Several possible combinations of these objective types exist, and all may be used with each pupil at different times throughout the operation of the system. Keeping track of even a single student becomes a considerable clerical task, and one that prevents the classroom teacher from using time effectively on the more important matters of instruction and counseling.

Assessing level of performance and diagnosing the deficiencies of each pupil are no less time consuming. When the guiding or prescribing of instructional activities for each pupil follows these steps, the task confronting the teacher becomes very great. The instructional phase of the system followed by the criterion-referenced testing necessary to ascertain level of goal attainment further compound the teacher's task in managing the system effectively. Even if a teacher is capable of leading a class of pupils through one iteration of the system, subsequent feedback and further iteration would soon reduce the effectiveness and efficiency of the system.

During 1974, the Wisconsin Research and Development Center sought to identify strategic problems in implementing IGE/MUS-E in schools.[1] Consequently 130 teachers from seven schools took part in organized discussions utilizing the Delbecq Nominal Group Technique. Participants rated in order of importance the five highest organizational problems and the five highest personal problems they had encountered in implementing IGE in their schools. Analysis of the responses indicated six anticipated problem areas of which management of individualized instruction, including planning individualized programs, grouping students, diagnosis, remediation, and record-keeping, was rated the second most crucial problem to be solved.

Generally the data analysis revealed that considerable support in providing facilities and resources is required initially. It further revealed a continuing need for assistance in managing programs of individualized instruction.

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[1]This information was collected as part of the "Materials and Strategies for IGE Staff Development and Implementation" component of the Wisconsin Research and Development Center for Cognitive Learning.

The management of a comprehensive system of individualized education in a manual mode does not appear to be particularly viable. It seems evident that the support of computer systems--automated information storage, processing, and retrieval mechanisms--will be necessary to successfully implement programs of individualized education.

Most of the problems associated with control of an individualized system of education relate to the capture, storage, and retrieval of information. Lists of objectives for each instructional area need to be formulated, filed, and constantly updated and maintained. This set of objectives must be continually reviewed in terms of both group and individual progress. Pupil performance on assigned objectives must also be recorded and reviewed. A considerable amount of testing of pupils at both pre- and post-instructional stages is necessary. Scoring these tests, while not difficult, may be a time consuming task for the instructional staff. Possibilities for the machine scoring of tests exist and are particularly feasible and desirable for comprehensive placement tests. Perhaps most important of all, systems of computer managed instruction have the ability to provide rapid and frequent feedback in the form of reports to pupils, teachers, school administrators, and parents.

Fortunately, the current stage of computer technology makes automation of these tasks possible. Systems can be created where objectives and associated performance standards, once specified, can be permanently stored in computer memory and student achievement data can be related to it. Parts of the systems may be modified with a minimum of complications to other components in the system.

Tests for the assessment of a pupil's beginning level of performance may be constructed in machine-readable form. Scoring and recording of the data may then be done more efficiently. The classroom teacher can be relieved of most, if not all, of the burden of this activity. The system may be programmed to provide diagnostic reports, based upon matching test results with expected levels of performance. The system may also facilitate guiding and prescribing activities by suggesting groupings of students or by selecting particular instructional settings. Posttests may also be in machine-readable format, although many teachers prefer tests in formats which are not readily amenable to machine scoring. The results of testing, however, when recorded, stored, and matched against expected criterion levels, result in an achievement profile for each student. Such profiles would indicate the student's standing relative to the objectives included in the instructional program. Such profiles may serve as progress reports to administrators and parents, as well as to pupils and teachers.

Clearly, then, computer technology will greatly ease the burden of managing individualized educational programs. Without this technology, such systems will likely remain in the developmental stage and fail to become fully operational.

Some attempts to apply computer technology to individualized educational programs will now be reviewed. The extent to which each system incorporates the parameters of an individualized educational program will be noted.

V

A REVIEW OF COMPUTER MANAGED INSTRUCTIONAL SYSTEMS

A system of computer managed instruction (CMI) has as its objectives collecting and processing information on students and supplying this information at appropriate times and places so that it is directly applicable to instructional decision making. When the appropriate information is supplied to decision makers in a usable format, the efficiency of decision making and the quality of decisions should improve. Cooley and Glaser state: "The function of the computer in a CMI system focuses upon allowing better information flow to the complicated decision process on a continual basis [1968, p. 1]." The teacher, student, and administrator continuously need information for evaluating alternatives and making decisions.

Bolton and Clark state that the "concept and the function of CMI extend beyond traditional student accounting. This is a result of the growing mass of evidence which states that the true potential of management systems lies in allowing school systems to change their instruction procedures while maintaining the needed control [1973, p. 5]." It is, then, the function of a CMI system to utilize the computer to optimize the learning environment for each child and to maximize the efficient use of school resources, both human and material. Constructed as a "man-machine system focused well beyond the limited scope of personnel and administrative systems, CMI combines the data-manipulation power of current hardware with the functional flexibility of instructional software to generate a demonstrably effective and efficient tool for the individualized school system [Bolton & Clark, 1973, p. 5]."

Many research groups across the country conceptualized CMI systems almost concurrently. Baker (1971) reviewed the characteristics of these systems and noted a great deal of similarity among them. This survey showed that generally each of the various CMI systems studied was built around units of instruction specified in terms of educational objectives, desired student behavior, levels of competence, or concepts to be learned. Associated with each instructional unit are criterion-referenced tests which assess level of mastery for each objective in that unit. Typically, such tests are administered as pretests to determine a student's current level of achievement and as posttests to determine if specific objectives have been achieved.

Baker (1971) reports that in each of the systems four major functions are performed by computers: test scoring, diagnosing, prescribing, and reporting. The major CMI projects differ primarily in the emphasis placed upon the major functions performed by the system as related to the instructional program(s) being supported.

A REVIEW OF MAJOR COMPUTER MANAGED INSTRUCTIONAL (CMI) SYSTEMS

Since 1968, when the first major CMI system, known as IMS or Instructional Management System (Silberman, 1968), became operational through the efforts of the Systems Development Corporation of Los Angeles, several similar systems have been developed. These include a Teaching Information Processing System (TIPS) (Kelley, 1968) and a Computer — Managed System for Mathematics (CMS) (DeVault, Kriewall, Buchanan, & Quilling, 1969), both developed at the University of Wisconsin, the latter system being no longer operational; a Management Information System designed by the Pittsburgh Learning Research and Development Center to operate a program of Individually Prescribed Instruction (IPI/MIS) (Cooley & Glaser, 1968); Project PLAN (Flanagan, 1971), developed initially by the American Institutes for Research and now supported by Westinghouse Learning Corporations; AIMS (Lekan, 1971), a CMI system developed at the New York Institute of Technology; MICA (Baker, 1971), a CMI system operating at the Sherman School in Madison, Wisconsin; the Wisconsin System of Instructional Management (WIS-SIM) (Belt & Spuck, 1974), developed by the Wisconsin Research and Development Center for Cognitive Learning to provide instructional support to programs of Individually Guided Education (IGE); and the Comprehensive Achievement Monitoring (CAM) system, developed at the University of Massachusetts under a grant from the Kettering Foundation. While these systems vary in subject areas supported and approaches to individualizing education, all have addressed the primary characteristics of computer managed instruction in a similar fashion.

As noted, the basic prerequisite for any CMI system is the existence of a set of well-defined goals and objectives, stated in terms of the performance levels necessary for attainment. Kelley's TIPS program (1968), for example, is based upon an economics syllabus, the goal being mastery of the primary concepts of the course. Specific objectives are derived from syllabus components. Project PLAN (Flanagan, 1971) supports curricula in language arts, mathematics, social studies, and science, and it will also accommodate instructional objectives which are specified by the local school or district. The IPI/MIS (Cooley & Glaser, 1968) system is similarly based on a predefined elementary school curriculum designed for individualized learning. In the CMS system (DeVault, Kriewall, Buchanan, & Quilling, 1969), which deals with an individualized mathematics program, one objective is to actually teach pupils how to plan objectives; these outputs then become inputs to the system. The AIMS system (Fritz & Levy, 1972) was designed so that any set of linearly sequenced behavioral objectives could be incorporated. It is presently supporting instructional programs at both the elementary and secondary level. The MICA system is based on an objectives module and allows for 250 objectives in the instructional program. Currently this system is supporting a linearly sequenced elementary mathematics program. The WIS-SIM system (Belt & Spuck, 1974) supports the objective-based curriculum materials in the Individually Guided Education programs of the Wisconsin Design for Reading Skill Development (WDRSD) and Developing Mathematical Processes (DMP).

Basic to all the systems presented is the principle that a prespecified set of objectives exists. While curriculum content may vary and while

formulation of objectives may involve different persons, each system requires the delineation of the objectives in the data base. Also included in the data base is the sequencing (linear, network, or non-sequenced) of the objectives.

CMI systems must also be concerned with the specification of performance standards required to obtain objectives. In fact, statements of performance standards are best incorporated within the statement of objectives. The CMI systems differ primarily with regard to how the personnel are involved in the decision-making process. It is implied within the TIPS system that the course professor specifies the required level of attainment. IPI/MIS, however, has a comprehensive, predefined, elementary curriculum as the systems base and implies the involvement of many persons, which may include school administrators, teachers, pupils, and parents. Performance standards in the IGE program of WIS-SIM are usually set by the developers of the instructional programs, but may be altered at the school or district level in accordance with the desires and needs of the local schools. Not all objectives in IGE programs are assessed quantitatively through paper-and-pencil tests. Some assessment is based upon work samples, performance tests, and teacher observation.

A basic element of many programs of individualized education is pretesting to establish the current standing of students relative to the total network of objectives. Most CMI systems operating at the elementary school level process specific pretest results. Pretesting of each pupil for each instructional topic is a basic component of both IPI/MIS and MICA. Placement testing in IGE (WIS-SIM) programs frequently covers an entire instructional level and is usually conducted at the beginning of the school year and at other times desired by the individual schools. CAM provides its users with statistical item analysis information useful in test construction and refinement.

Test scoring and test reporting have been variously automated in the several systems. Currently, PLAN represents the highest level of automation. Placement tests, achievement tests, and instructional objective tests are optically scanned on-line by a mark-sense reader and the response pattern is transmitted to the computer where it is stored in a file for subsequent batch processing.

In CMS, placement tests were machine scored off-line and resulting scores were entered in a batch mode from magnetic tape or punched cards. The posttest results for single instructional objectives in CMS were machine scored and the scores entered interactively by teletype.

IMS machine scores tests off-line with mark-sense readers and the scores are entered into the computer in batch mode. In WIS-SIM, placement tests are machine scored and the results are entered in batch mode either from cards or tapes. The criterion-referenced, instructional objective tests are manually scored and the scores are entered manually on mark-sense sheets or cards. Depending upon the computer configuration utilized, the mark-sense forms are entered on-line or in a batch mode. In MICA, tests are comments manually scored and the results are entered interactively through a CRT terminal.

On the basis of the test results, educational need may be diagnosed to identify those instructional objectives which the student has not mastered, but for which the student has satisfied the prerequisites.

CAM employs a system wherein the identification of learning deficiencies is based upon a computer analysis of wrong response patterns. Some instructional programs, such as those supported by MICA and IPI systems, have instructional objectives which are sequenced linearly, so that the objective which follows the last objective mastered is the next to be undertaken; diagnosis, then, is the identification of the next non-mastered objective. In PLAN, the decision about which track or level is most appropriate for an individual child is based on the placement test. Objectives within each level of the reading and mathematics programs within PLAN are then linearly sequenced and diagnosis is carried out in a manner similar to the CMI system. WIS-SIM advances the notion of comparison between actual and expected performance over time to identify potential teaching/learning problems. The AIMS system produces a "pupil profile" which contains student achievement data and demographic information, as well as clinical case information. From this, the teacher assesses student instructional needs.

It is at the prescriptive stage where CMI systems possibly differ the most. The TIPS system, for example, has a variable prescriptive format, depending upon the degree of discrepancy between test results and criterion levels. Prescriptive activities may include homework exercises, attendance at alternative lectures, or group work. Such activities may be optional or required, depending upon the level of mastery identified by testing. Unlike other CMI systems, TIPS presents prescriptions to students in paragraph format rather than referring the student to a numbered work folder. The CMS project, on the other hand, does not generate specific prescriptions; it simply lists the tasks which a given pupil has completed. The process of prescription in CMS involves teacher-pupil discussion concerning the next task to be completed. CMS differs slightly from other CMI systems in that pupil involvement at this stage is quite pronounced. Prescription in Project PLAN is more broadly based in that all available data supplied by the student, and his parents and teachers, is utilized by the computer in recommending a specific program of studies. This is similar to CMS, in that the level of pupil involvement is high, but differs from it in that extensive computer assistance is required to "solve" a long set of decision rules. Typically, prescription in Project PLAN results in the selection from among several alternative teaching-learning modules.

IPI/MIS, AIMS, and MICA, being based upon predefined elementary curricula, are quite specific with regard to prescriptions. In general, these systems generate prescriptions which refer the student to programmed materials, workbooks, file folders, or texts. In some cases students are referred to teacher-led seminars. These systems also provide for student involvement at this stage. IPI lists prescriptions for an individual pupil along with summary achievement reports. MICA allows for the generation of prescriptions instantaneously through the use of interactive terminals. WIS-SIM focuses on providing teachers and students with information to assist in grouping students on the basis of common instructional needs. A variety of instructional activities is available and specific activities are selected by the teachers and/or students on the basis of the learning needs represented in the group.

The implementation of prescribed instruction is the next stage in a system of individualized education. Typically, the computer plays little

or no role in instruction, a fact which separates CMI systems from CAI (Computer Assisted Instruction) systems. This is not to say, however, that a CAI activity could not be utilized within a CMI framework. None of the systems discussed in this paper appear to utilize the computer in the implementation of prescribed activities. Following instruction, posttests are generally given. As described earlier, tests may be administered and scored either by machine or manually. Test results are then stored in the computer and compared with criterion performance standards. Such comparisons provide the data necessary to ascertain whether or not a pupil has achieved the particular objective. Most systems allow for the production of reports containing the updated achievement information. In WIS-SIM, for example, these records are labeled performance profiles.

TIPS and CAM both provide summary information which is useful in evaluating the teaching/learning process. TIPS presents information based on group performance which assists in identifying instructional units in which students have experienced difficulty. CAM allows the production of summary performance profiles based upon student characteristics such as ethnic type, sex, or socio-economic status. This information allows for the evaluation of the effectiveness of instructional programs for students in various groups.

SUMMARY OF CMI SYSTEMS

CMI is a management information system which provides instructional managers with information required for decision making in individualized educational programs. The major processes specified in CMI systems include test scoring (placement or posttest), achievement profiling, diagnosing, and prescribing. The major systems examined in this review share much in common; they differ in the emphasis on and reporting formats for each of the four process areas. A variety of approaches to test scoring are taken, from hand scored, batch oriented systems to machine scored, on-line systems. No system at present has integrated on-line test scoring with an interactive reporting capability. There is no reason to conclude that any one approach to test scoring is best for all instructional environments and programs. Each approach must be assessed in terms of meeting decision-making requirements within existing cost constraints.

While all CMI systems provide diagnostic and prescriptive information, the actual information provided varies greatly with the structure of the instructional program being supported. A difference in prescriptive reporting is evident between CMI systems which encourage students to work alone (e.g., IPI) as contrasted with those programs which support instructional grouping (e.g., IGE/WIS-SIM and PLAN). Diagnosis and prescription within the systems examined is not highly developed at the present time. A noticeable step forward is the diagnostic function of comparing actual performance with expected performance included in WIS-SIM. None of the systems examined appear to provide diagnostic and prescriptive information in any systematic way based upon learner characteristics other than past achievement. Varying instructional activities according to student preferences, interests, abilities, or learning styles appears to be left to the teacher's ability to recall the student characteristics and appropriately associate them with

instructional activities. CMI systems seem to have greatest potential in the area of management of instructional resources in the prescriptive process and diagnosis of student instructional needs. These areas have only barely been touched in system development to this date.

Few researchers have addressed the problem of curriculum management and CMI at the conceptual level. Notable efforts in this direction are those taken by Cooley and Glaser (1968), Baker (1971), DeVault and Kriewall (1967), Belt and Spuck (1974), and Spuck and Owen (1974). None of these models has been translated into a generalized CMI system which accounts for the basic structural differences between different programs of individualized education.

VI

THE WISCONSIN SYSTEM FOR INSTRUCTIONAL MANAGEMENT (WIS-SIM) MODEL

In this section, the processes of computer managed instruction are integrated into a generalized model which will account for the major structural and process delineations of programs of individualized education. The model is an extension of earlier considerations presented as the Wisconsin System for Instructional Management (WIS-SIM) (Belt & Spuck, 1974).

Systems of computer managed instruction are designed to provide management information to school personnel as required for instructional decision making. The main function of an instructional management information system is to improve decision making about the instructional program of the school, leading to maximized educational benefits for each child while making efficient use of the available human, material, and financial resources. The objectives of such a system are as follows:

1. To identify decisions which are related to the instructional process.
2. To determine what information would be most useful to decision makers involved with the decision.
3. To arrange mechanisms to capture required data.
4. To summarize the data in a form most usable to the decision maker.
5. To arrange for the timely delivery of appropriate information to the decision maker.
6. To evaluate the utility of the information to the decision process.

Teachers in classrooms or instructional units are decision makers who have frequent need for information; theirs is the ultimate responsibility for planning and implementing an instructional program suitable for each student. The individual student may also be a significant decision maker since the student may be involved with his teacher in establishing specific instructional objectives for himself. Thus, he should have feedback as to his progress toward attainment of initial and long-term goals. It is important that feedback about progress for young children be fairly immediate in order to yield maximum motivational value. Parents have a key role in influencing pupil motivation and learning and therefore may also be involved in establishing instructional objectives and monitoring their attainment. It is necessary to make appropriate and timely information available to these decision makers in order to establish optimum learning environments and maximize use of school resources.

The basic structure of programs of individualized education, as derived in the earlier discussion of this topic, leads to the following basic assumptions concerning instructional programs to be supported by a generalized system of computer managed instruction:

1. There exist instructional missions and goals which are reduced to sets of measurable instructional objectives.
2. Testing instruments and/or procedures are available to assess mastery of the instructional objectives.
3. Level(s) of mastery or performance standards are specified for each child and for each instructional objective (full mastery--variable attainment).
4. Objectives which are to form a part of each student's instructional program are delineated (common objectives--variable objectives).
5. Dependencies existing between objectives are specified (sequenced objectives--non-sequenced objectives).
6. Normative information exists, as required, for specifying long-range performance expectations.
7. Educational activities and materials exist which provide individualized instructional experiences toward the accomplishment of the specified instructional objectives.
8. It is possible quantitatively and/or qualitatively to assess those individual characteristics of students which are essential to individualizing instructional activities.
9. It is possible quantitatively and/or qualitatively to assess the resource implications of alternative educational experiences.

THE INSTRUCTIONAL CYCLE

The instructional cycle in programs of individualized education may be depicted as in Figure 4. Five processes (P 1-5) and two decision (D 1-2) areas are included in this representation. Initially, testing (P-1) takes place; this provides information as to the placement of students within the instructional program. These placement or break-in tests are scored during a process (P-2) called test scoring. Results from the tests are compared with mastery or performance levels which have been specified for each student and for each instructional objective. It should be noted that the testing and subsequent test scoring need not refer solely to paper-and-pencil tests, although this format is common, particularly in break-in or placement testing. Other forms of testing which might be utilized are performance tests, work samples, and teacher observation.

On the basis of information derived from test scoring, it is possible to determine for each student his status within the instructional program; that is, a determination of those objectives which have been mastered and those objectives which have not been mastered. The process of di[illegible]osing (P-3) provides information leading toward identifying instructi[illegible]needs (D-1). For each student and for each student's program, those objectives which have not yet been mastered, but for which he has met all prerequisites, may be determined. Thus, need is assessed by comparing the actual performance of the student with the performance expectations which have been established for him. Since more than a single objective may be identified in the diagnostic process, it may be necessary for the student and/or the teacher to determine which objective represents the greatest need at that time.

The teacher may compare the instructional need of the individual student with the instructional activities which are available to assist

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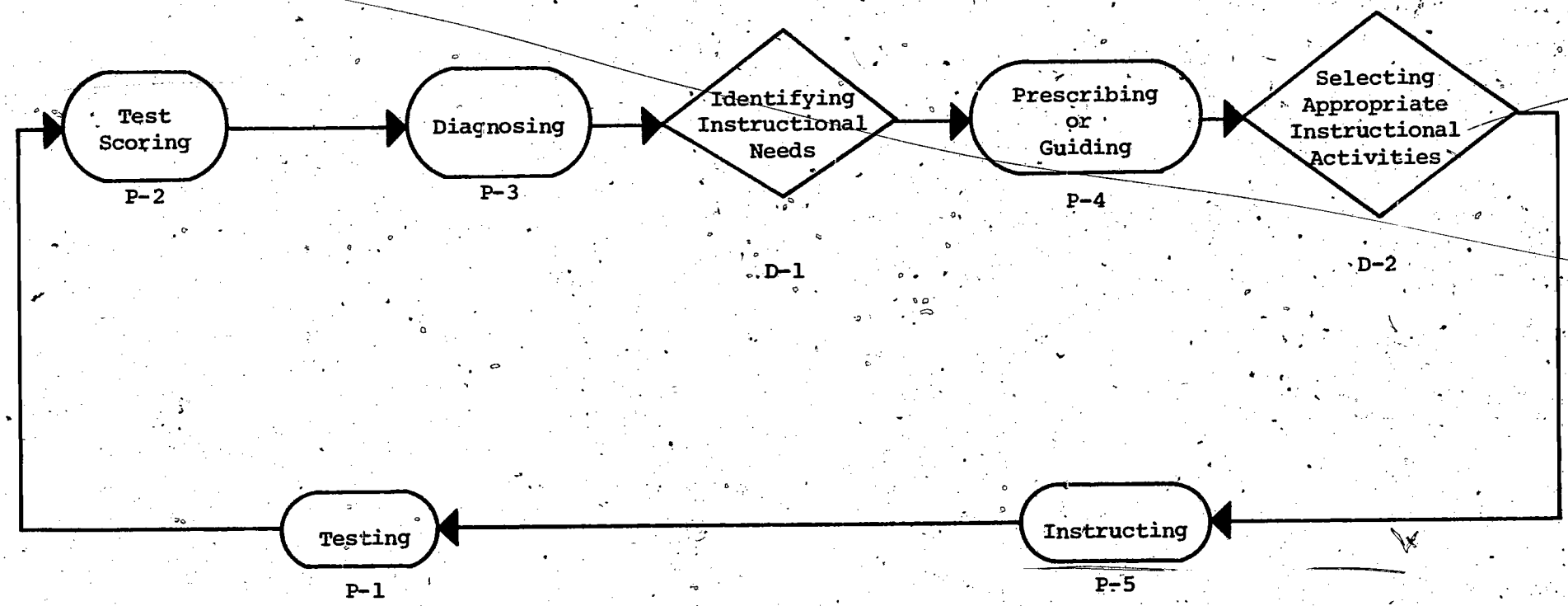


Figure 4. The instructional cycle in individualized education.

the student in learning the content of that objective. Prescribing or guiding (P-4) is a process designed to provide information useful in selecting those instructional activities (D-2) which are most appropriate for meeting the student's instructional needs. The selected activities are carried out during the instructing process (P-5), after which testing again takes place to assess whether the student has met the instructional objectives. This test is scored and the cycle is repeated.

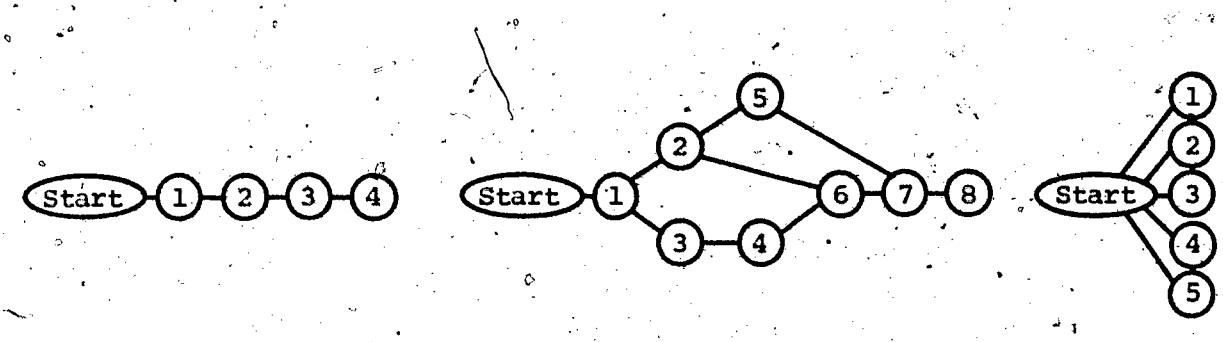
While not explicitly presented in Figure 4, feedback within the instructional cycle is possible. If, for example, during the instructing process, it becomes evident that the selected instructional activity is not, in fact, appropriate, a new instructional activity may be selected without repeating the entire cycle.

DEFINING THE INSTRUCTIONAL PROGRAM

A first step in implementing any computer managed system is to define the data bases required by that system. Two data bases are fundamental to the concept of instructional management, although these may be divided further for technical reasons on the operational level. The first required data base must define the individualized program to the automated system. This data base will be denoted here as the Program Data Base (PDB). The educational program of the school was described earlier in terms of instructional programs, instructional areas, instructional units (content/process or level/grade), instructional topics, and instructional objectives. The PDB should contain the information which relates the given instructional objective to the instructional program in terms of the intervening descriptors of areas, units, and topics. Also contained within the record for each objective might be additional descriptive information such as the name of the objective, a short description of it, and any required internal or external labeling.

Three structural continua have been discussed earlier: sequenced or non-sequenced objectives, common or variable objectives, and full mastery or variable attainment. It is assumed that the sequencing of objectives is the same for all students, so that an objective will have the same prerequisites when included in one student's instructional program as when included in any other student's program. Since the sequencing of objectives for the program does not vary, it may be defined within the Program Data Base, rather than the Student Data Base (SDB), which will be discussed later.

The type of sequencing to be defined may form a line, or a network, or be non-sequenced, as depicted in Figure 5. When the objectives form a line, Figure 5a, the sequencing of instruction is such that when a student completes a given objective, he then moves on to the next objective in the line. In a network the sequencing is more complex. An objective may have more than a single objective as a prerequisite. For example, objective six in Figure 5b has as prerequisites objectives two and four; objective six is in turn prerequisite to objective seven along with objective five. The linear form is clearly a special case of the network form. Figure 5c shows the non-sequenced case. Here, no objective is dependent upon, or prerequisite to any other objective. When and if sequences of objectives exist, they must be coded and included as a part of the PDB.



a. linear b. network c. non-sequenced

Figure 5. Sequencing of objectives.

It should be noted that some instructional programs define prerequisites at the topic level rather than the instructional objective level.

Also of relevance here is the concept of compatibility of objectives. As discussed earlier, this concept is an extension of the concept of prerequisites and refers to objectives which may be efficiently taught together. Information related to the compatibility of objectives needs to be included in the PDB. This topic will be discussed later in the paper.

When the instructional program is to be implemented as a full mastery program, that is, when the same level of mastery is to apply to each student, then this level of performance needs to be specified as a part of the PDB. No special coding is required as a part of the PDB to indicate whether common objectives define the instructional program. Figure 6 summarizes the content of the Program Data Base and includes fields containing labels and descriptors, prerequisites, mastery levels, and objective compatibility. As objectives are added, deleted, or modified, the PDB will need to be updated to reflect these changes. Mastery levels, compatibility codes, and prerequisites may also change, necessitating further change in the PDB. Historical information contained within the CMI system may be useful in examining the prerequisite structure of objectives within the program area. A separate PDB or section of the PDB is required for each instructional program needed to fulfill the school's missions.

Identifiers, Labels, and Descriptors	Prerequisites	Mastery Levels	Objective Compatibility

Figure 6. Program Data Base.

DEFINING INDIVIDUAL STUDENT RECORDS

The information contained in the Program Data Base (PDB) defines the instructional program in a generic way. It establishes a framework within which individualization can take place. If the program is to be defined on an individual level, a Student Data Base (SDB) must be established to specify the instructional program of each child. The information contained in the SDB may be discussed in terms of student identification, demographic information, individual profiles, instructional program, performance expectations, and performance information. Student identification refers to a student number as well as to the name of the student. Demographic information includes background and program factors as may be required for program management and evaluation: teacher or unit name, room number, instructional programs in which the student is enrolled, age, sex, date of enrollment in school, home address, and so forth. Student identification and demographic information must be reviewed for accuracy at least annually.

Individual profile information is included as required for making instructional decisions concerning the individual child. Included within the scope of individual profile information would be the results from standardized achievement and aptitude tests, personality and interest inventories, and descriptions of learning styles. This information is included in the student register as required for instructional decision making for the individual student. The exact information included would be decided in accordance with district policy, federal and state laws, and the needs of the student's teacher or unit.

As was indicated, the PDB establishes a general framework for the instructional program. Any modifications required in the framework to meet the needs of the individual student must also be included in the instructional program. If the instructional programs include the concepts of variable objectives and variable mastery, then these parameters need to be specified. Those objectives for which the student is or is not to be responsible need to be identified to operationalize the concept of variable objectives. Similarly, the mastery level expected of each student for each objective needs to be specified in the SDB along with any specific performance goals which the student is expected to accomplish over a period of time. This last concept will be discussed more completely in that part of the paper dealing with specifying performance expectations and the process of diagnosis.

The last category of information included in the SDB is labeled performance information. The student's actual achievement is recorded in this section of the data base. At the least, a record is kept of those objectives which the student has mastered and those objectives which the student has still to master. The SDB may also include additional information required for instructional reporting and decision making, such as the actual percentage/raw scores achieved on tests assessing mastery, number of attempts on the objective prior to mastery, the date of the last attempt, and even the instructional activity(ies) used. The performance information would need to be updated frequently during the course of the student's instructional program, presumably at the conclusion of each unit of instruction.

The SDB, then, contains a comprehensive, historical record of student learning. Because performance information and instructional program information are specific to a particular student's instructional program, a separate section of the SDB must be included for each instructional program for which the student is responsible. The content of the Student Data Base is summarized in Figure 7.

Student Identification and Description	Demographic Information	Individual Profile Information	Individual Program Information	Instructional Expectations	Performance Information

Figure 7. Student Data Base.

THE WIS-SIM MODEL: AN OVERVIEW

As Bolton and Clark (1973) pointed out, systems of computer managed instruction should provide the means for constant data flow and collection, diagnosis, test scoring, historical analysis, and information availability. That is, CMI systems should have a "total systems approach." Figure 8, which presents the WIS-SIM model in diagrammatic form, illustrates such a total system. This figure incorporates the process and decisions shown in Figure 4, the instructional cycle in individualized education, but adds the process of achievement profiling and the data bases described in the preceding sections. Processes are represented by the rounded-rectangle symbol, decisions by the diamond symbol, and the data bases by the computer tape symbol. Rectangles are used to indicate information which flows into or out of the system. Information resulting from system processes is usually in the form of reports which are subsequently used as input to instructional decisions. A new major decision area, specifying performance expectations, which was not present in the instructional cycle model (Figure 4), has been added. This decision results in a set of expectations for each student's instructional program. In the sections which follow, each of the major processes indicated in the WIS-SIM model will be discussed along with the associated information flow.

TESTING AND TEST SCORING

Testing begins and ends the instructional cycle. Testing as a preassessment or placement process determines whether a student has met the performance standards associated with a given objective or set of objectives prior to the beginning of the instructional cycle. Preassessment generally

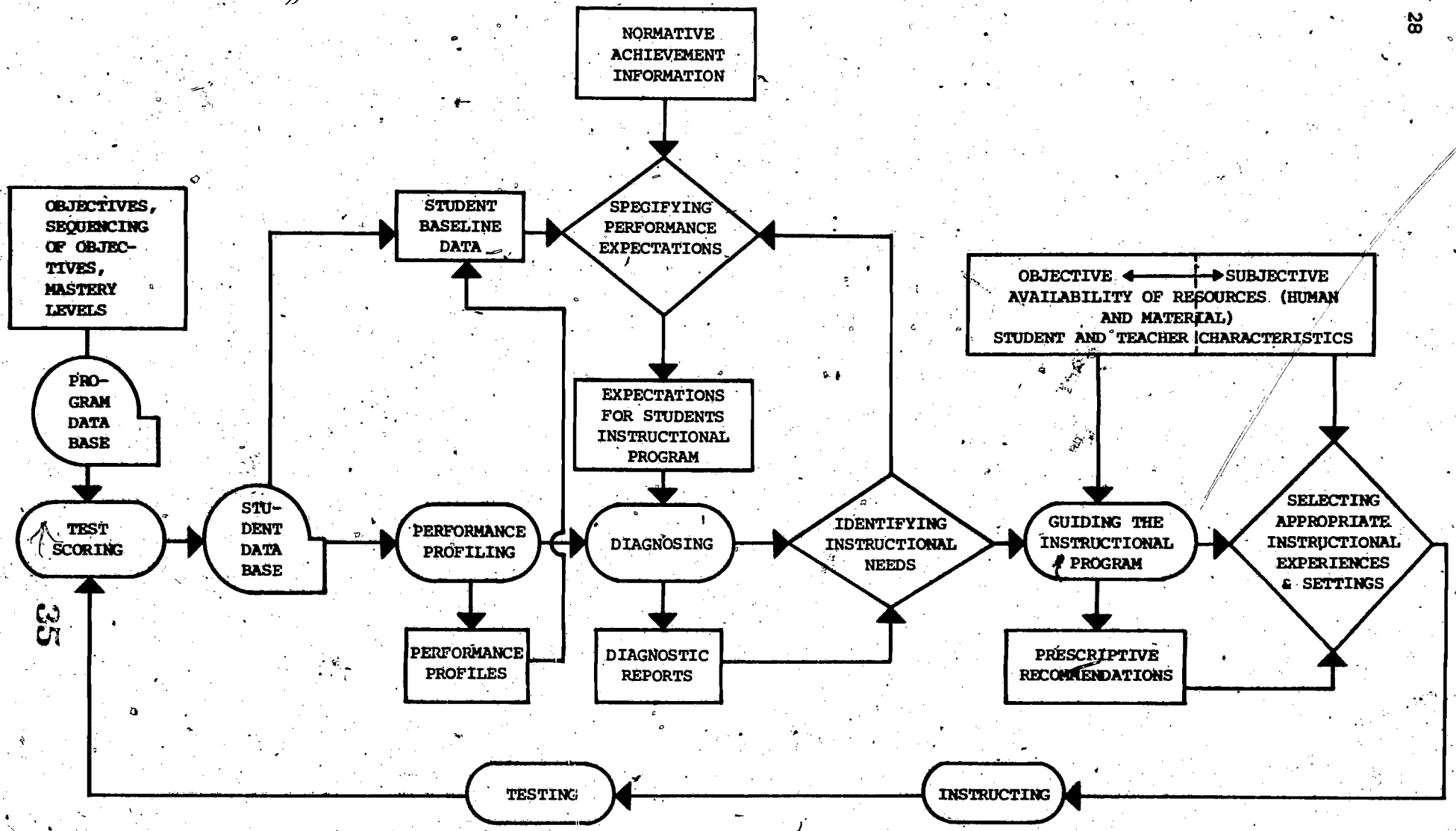


Figure 8. Wisconsin system for instructional management (WIS-SIM) model.

refers to testing on a small number of objectives, while placement testing covers a broader range of objectives and is used for identifying starting points for the student in a program. Placement testing may occur when a student first enters an instructional program and at additional appropriate times such as at the beginning of each school year.

At the end of the instructional cycle, testing takes place to determine whether a student has mastered the content of a particular set of objectives. At the end of an instructional unit, tests broader in scope than the post-assessment instruments may be used to ensure that students have mastered the larger aggregate of objectives.

Tests must be scored. Test scoring is a process wherein responses to test items are compared with the mastery levels or performance standards which have been set for that test and for that student. As noted previously, not all tests need be of a paper-and-pencil variety. Other forms of testing which could be utilized are performance tests, work samples, and teacher observation/certification. In any testing situation, however, it is essential that the mastery level or performance standards be explicitly defined. Since test results need to be entered into the data base in order to be utilized in an automated instructional management system, machine scoring can save considerable time in updating student records. Machine scoring can either eliminate or automate the intermediate steps of scoring, transcribing, and keypunching.

As a result of the variety of types of testing which may take place, it is reasonable to conclude that not all tests are machine scorable. Performance tests, work samples, and teacher observations are not usually conducive to machine scoring. Further, certain paper-and-pencil tests are not as efficiently scored by machine as they are by hand. Hand scoring may be more efficient when the number of items to be scored is small, when the response sheet cannot be easily read by scanning equipment, or when suitable scoring equipment is not readily accessible.

Figure 8 shows the objectives, the sequencing of objectives, and the mastery levels as input to the Program Data Base. Placement of the PDB at this point in the model is symbolic in the sense that information contained in it is utilized in processes other than test scoring. Once the information is entered into the system, it is available throughout the system. Additionally, feedback loops for the update or modification of the data base are not indicated in the model but are recognized and implied.

Also illustrated in the figure is the Student Data Base (SDB). Again the placement of this data base in the model is symbolic; information contained in this data base is also available throughout the system. Also certain parts of the SDB are updated from other points within the system as will be discussed later. Since the SDB contains each student's performance information, results from the test scoring process are catalogued in the SDB for use in the production of management reports. If individual mastery levels have been set, this information must be available at the time of test scoring.

PERFORMANCE PROFILING

Performance profiling is the next process in the WIS-SIM model. Profiles are reports of either individual or group achievement with regard

to a set of objectives included in the instructional program. Considerable flexibility in the production of these reports is generally provided by the system, thus allowing for freedom to define the group or individual to be profiled and the range of objectives to be included. Performance profiles may be used by teachers to derive an overall assessment of the placement of students within the instructional program, or as achievement reports which could be sent to parents or utilized in parent-teacher or student-teacher conferences. Profiles could also be performance summaries of classroom, unit, or school over a period of time for review by decision makers at these levels.

SPECIFYING PERFORMANCE EXPECTATIONS

The first of the three decision processes included in the model is specifying performance expectations. Through this process, goals are set for each student's instructional program for short or long periods of time, as is appropriate. Information input includes student and normative baseline data. Algorithms may be built into the system which are based on such individual profile information as past achievement, personal factors related to the student's learning, and performance profiles. Normative information, which also may result from achievement profiles aggregated at the unit, school, or district levels, may be supplied. Performance expectations take the form of specific objectives and the number of objectives within an instructional program to be achieved over a fixed period of time. When the individual expectations for a student have been set, they must be included as a part of the student data base, so that they will be available as required. Specifying performance expectations involves tailoring the instructional program to the needs of the student as required in programs involving variable mastery and variable objectives. The formulation of expectations leads to the specification of an individual instructional program for each child.

Teachers are considered as the primary decision makers in decision areas outlined in this model. Specifying performance expectations, however, provides an excellent opportunity for parents and the students themselves to be involved in the instructional decision-making process.

DIAGNOSING AND IDENTIFYING INSTRUCTIONAL NEEDS

The purpose of any system of individualized education is to serve the educational needs of individual pupils. In essence, the identification of needs is synonymous with the process of locating current weaknesses or problem areas in the total configuration of a pupil's knowledge within an instructional program. The process of diagnosis, as shown in the WIS-SIM model, results in the identification of such needs.

As Figure 8 indicates, the diagnostic function of the WIS-SIM model is based upon two sets of inputs: prespecified expectations as they relate to a given objective set, and the data provided by the performance profiles. In general, diagnosis occurs through the comparison of actual performance

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with performance expectations. While criterion-referenced testing remains the basis of the diagnostic process, subjective inputs of both teacher and pupil can and do become incorporated. The output of the diagnostic process may be a diagnostic report which presents the degree of discrepancy between expected and attained results.

Figure 9 shows the section of the total WIS-SIM model which is most directly related to the identification of instructional need. Expectations which were formulated as a result of specifying performance expectations are compared with actual student performance in an instructional program. Discrepancies as they are identified are reported and the teacher utilizes this information to make decisions concerning instructional needs.

Diagnostic reports of the type described are produced only when performance deviates from expectations by a prespecified amount; they are therefore viewed as exception reports. These exception reports may be used to identify students needing extra consideration in the form of one-to-one instruction, or help from supportive personnel such as speech therapists or social workers. Diagnostic reports could be used to identify students who are likely candidates for use as tutors or who might benefit from tutoring. Alternatively, the teacher may decide that the discrepancy between expected performance and achievement is the result of inappropriately set expectations rather than over or under achievement. The expectations, then, would be modified, leading to a change in the Student Data Base.

Diagnosing is a process designed to identify and report information which is helpful to teachers in determining instructional need. In addition to the reports suggested above, it is possible that through diagnosis some types of instructional activities and/or learning styles will be identified as more or less beneficial than others, or that particular categories of objectives will prove to present learning problems to the student. Such diagnostic information could lead to the early remediation of learning problems.

GUIDING THE INSTRUCTIONAL PROCESS AND SELECTING APPROPRIATE EDUCATIONAL EXPERIENCES AND SETTINGS

The WIS-SIM model is conceptualized so as to take into account a wide range of both subjective and objective information when determining appropriate educational experiences and settings to meet instructional needs. Factors which influence the selection of instructional activities are such teacher variables as skill in teaching and preference for teaching certain instructional activities; such student factors as aptitude, learning style and learning handicaps; and such interactive factors as personality conflicts between students or between a student and a teacher. As the WIS-SIM model shows, a very important consideration is the availability of both human and material resources. This is frequently overlooked in the literature on CMI systems. The diagnosis may suggest certain types of activities but few or none may be possible within the bounds of existing resources. It is important then that CMI systems take account of all factors so that decision makers are aware of the ramifications of each process for every other process. Components of the system may be modified until optimum operating levels are achieved.

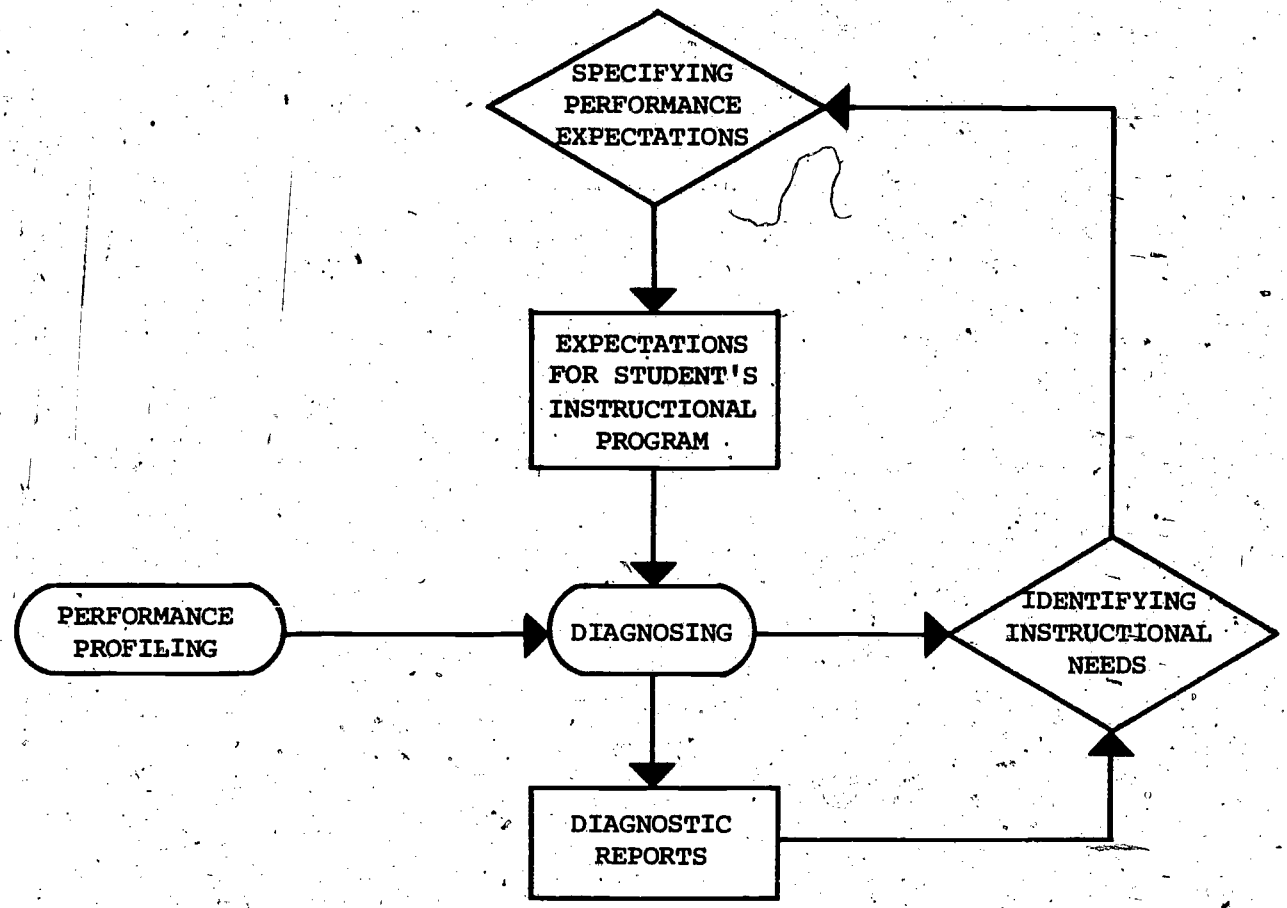

Figure 9. Diagnosing and identifying instructional needs.

In an earlier section, it was suggested that the Student Data Base could contain information on the individual factors affecting the selection of instructional activities or settings, such as individual, small, medium, or large group instruction. Additional data bases could be included in the system: an instructional materials data base, an instructional and non-instructional equipment data base; an instructional facilities data base, and a personnel data base for teacher characteristics and availability. An integrated system which links these data bases not only potentially provides for better instructional decision making and more effective utilization of resources at the instructional classroom or unit level, but additionally provides the basis for an accurate programmatic accounting of instructional costs per student per objective. This latter information would assist in school or district-wide decision-making pertaining to the allocation of resources to district-wide programs.

The contents of each of the data bases mentioned above could be detailed; however, since the concept of an Instructional Activity Data Base (IADB) is central to selecting decisions, it will be discussed further here. The primary purpose of this data base is to index and allow for the retrieval of instructional activities which can be used to assist a student in learning the content of a particular objective. Figure 10 outlines the content of this data base.

As with the other data bases, the Instructional Activity Data Base (IADB) contains information which identifies and describes the indexed resources. both internally to system software and externally to the actual resources which were inclined. A primary linkage to be defined is between the instructional resource and the objective or objectives to which it relates. If a particular objective is to be taught, this index may be used to determine those instructional resources which might be used to teach the objective.

Instructional activities may be coded along a variety of dimensions, such as appropriateness to learning or physical handicaps, learning style, motivational levels, and degree of student independence required. Codes such as these facilitate the selection of appropriate instructional resources. They may be compared with similar codes which exist in the Student Data Base.

Additional information contained in the IADB could identify tests or procedures which are appropriate for assessing performance levels or mastery on a particular objective or instructional activity. Those instructional materials required to support the activity and the equipment and space requirements should be noted as well. This information may be presented to the instructional manager directly or it may also be linked to other data bases ~~within~~ the system, specifically, the equipment and facilities data bases.

Instructional Activity Identification, Labels, and Descriptions	Associated Objectives	Characteristic Codes	Associated Performance Tests	Resource Requirements (Equipment, Settings, and Materials)	Summary of Usage	Availability Information

ure 10. Instructional Activity Data Base.

The next informational element noted in Figure 10 is the "summary of usage." An historical record may be kept of the student experience with a given instructional activity. This record could be summarized as a part of the IADB, taking into account such student characteristics as may be appropriate to later evaluation of the activity, such as its appropriateness for use with students with particular learning disabilities.

The Instructional Activities Data Base can meet two different informational needs. The first is to answer general inquiries as to what instructional activities (materials) are commercially or noncommercially available to meet certain instructional constraints (objectives, learning styles, etc.). These materials may not all be available in the district at the time of the request, but presumably could be obtained if desired. The second is to answer inquiries about what instructional materials are currently available within the school district. The IADB should act as an index to the availability of instructional resources within the school or district.

Many of the human and material factors mentioned so far can be quantified and included in an integrated system, but other factors do not lend themselves directly to such an approach. Also, even if quantifiable factors are entered into a system, in many cases it would be difficult to develop and to obtain agreement upon decision rules to be utilized in programming these constraints. Therefore the selection of appropriate instructional activities and settings will remain the teacher's decision--not the computer's. To emphasize and legitimize the teacher's subjective input in the decision-making process and recognizing that it is ultimately the teacher and/or student who makes the decisions, the process in the WIS-SIM model is denoted "guiding the instructional program" rather than prescribing, as it is in many other systems. The model presented in Figure 8 specifies the objective-subjective continuum as a source of information. Even though the subjective element is acknowledged, many of the factors can be quantified and decision rules can be formulated. The prescriptive reports which result are used to help select appropriate instructional experiences and settings. A variety of instructional activities may be recommended and it is then up to the teacher to determine which is optimal at a given time.

Some individualized instructional programs in the past have had linearly sequenced objectives with only a single instructional activity available to teach each objective. In such programs, the successful completion of a given objective leads naturally to the prescription of the next objective. As is evident from the earlier sections of this paper, this linear sequencing is indicative of only a small number of programs. In many programs the successful completion of a given objective leads to a variety of potential decision alternatives. Additionally, classical models of individualized education also stressed instructional settings wherein students worked autonomously on instructional activities. Some programs now emphasize the utilization of small, medium, and large group instruction, along with one-to-one and independent study. Prescriptive recommendations must now be responsive to the need for information about optimal groupings of students, taking into account student and teacher characteristics, as well as resource constraints.

It is easy to anticipate that if several individualized instructional programs are being implemented at once, the problems of testing, test scoring, diagnosing, and guiding or prescribing could easily consume as much time as the related instructional activities. Systems of computer managed instruction can greatly reduce this time through providing better information, more efficiently than can manual systems.

An additional concern is the amount of time spent on diagnosing and regrouping. A question which arises is how often can the students in an instructional unit regroup before many of the advantages of individualized education are lost? This paper does not directly address the question, but rather suggests that the duration of a grouping may be extended if it is established on the basis of more than a single objective. At this point the idea of the compatibility of objectives, introduced early in this paper, becomes important. Student groups may be established on the basis of these compatible objectives. It was suggested earlier that an index of objective compatibility be included in the objective data base. This index may be best expressed in matrix form specifying the compatibility or non-compatibility of each objective with every other objective.

INSTRUCTING AND TESTING

As Figure 8 indicates, selection of appropriate educational experiences and settings precedes the instructional process. The selected instructional activities should be implemented in a manner which reflects the individualized concern of the WIS-SIM model. Teachers need to be sensitive to the progress of students and be assured that the selected activities and settings are facilitative of students' mastery of the objective. If problems are identified it is clearly desirable that the instructional approach be modified, as possible, to alleviate these problems. Once instruction on an instructional objective is completed, the total cycle is repeated. Results of a posttest are compared with expected performance standards. Attainment of the objective leads to consideration of a new objective. Failure to attain the objective may result in a repeat of the cycle for the same objective, or it may, as stated previously, result in the selection of a more realistic objective. In either case, the relevant data are stored, to be available as necessary for the generation of reports within the system.

DECISIONS CONCERNING MODIFICATIONS TO THE INSTRUCTIONAL PROGRAM

The model of computer managed instruction presented here is focused upon the student and clusters of students in the processes of testing, test scoring, achievement profiling, diagnosing, and guiding the instructional program. It is also possible to view these processes as a means of providing information regarding the instructional program being implemented to educational decision makers. The instructional activities and the program itself then become the focus of the examination.

The most important steps in this WIS-SIM model are the processes of achievement profiling, diagnosing, and guiding the instructional program.

Achievement profiles may be produced which reflect the current status of performance relative to unit, building, or district goals which have been formulated for an instructional activity or a set of instructional activities. If these goals are not achieved, it is reasonable to question the appropriateness of the instructional activities. Diagnosis then becomes a process for identifying problems within the structure or content of the instructional program. As was noted in the discussion of the Instructional Activities Data Base, information concerning the utility of each instructional activity for different types of students may be summarized from the student performance records.

The process of guiding the instructional program is still viewed as leading to the decision of "selecting appropriate instructional experiences and settings." As a result of this decision, instructional activities for a particular instructional objective may be added, modified, or deleted, or the sequencing of these objectives may be altered. The Program Data Base will need to be updated to take into account such changes in the instructional program. Other data bases, as they exist, may also need to be revised to reflect these changes. In extreme cases the instructional program may be replaced in its entirety.

The WIS-SIM model, then, unlike many of the CMI systems reviewed earlier, is a "total system" approach designed to have direct utility at the classroom, building, and district levels. In a real sense, it is a model for making decisions about the instructional program as well as a model of individualized instruction. The utilization of this model would have the very direct result of assisting in the effective implementation of an individualized program of learning for each student, through assisting in the identification of the instructional needs and selection of appropriate instructional experiences and settings for each student. The model also has a less direct, positive impact on the student's learning through the continual monitoring and refining of the school's instructional program.

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