A Knowledge Base For Improving Our Methods of Instruction

Charles M. Reigeluth and M. David Merrill

Brigham Young University

Abstract

This paper discusses the importance of developing the knowledge base (both scientific and technological) that is needed for improving our present-day methods of instruction. It proposes seven steps as being necessary to develop that knowledge base: (1) definition of concepts of instruction, (2) derivation of principles of instruction, (3) validation of those principles, (4) development of theories or models, (5) testing of those theories or models, (6) development of application procedures, and (7) testing of those application procedures. Related work done by M.D. Merrill's instructional research laboratory is outlined. Attention is drawn to some important areas that need much greater expenditure of effort and resources to develop the kind of scientific and technological knowledge base that can help us to improve our methods of instruction.

A Knowledge Base For Improving Our Methods of Instruction

In spite of a broad concern for improving the quality of public education, surprisingly little is being done to develop the knowledge base that is necessary for improving our methods of instruction, especially when considered in relation to the total resources devoted to education. The National Council on Educational Research (Note 1) states that about one-half of one per cent of the total annual expenditure on education was allocated for increasing education's knowledge base in 1976, compared with five per cent of the total for agriculture and ten per cent for industry. Of the total expenditure for increasing the knowledge base for education, a surprisingly small proportion is allocated to developing a knowledge base for improving our methods of instruction.

The Need

Certainly many things besides better methods of instruction are needed to improve the quality of public education: better training of teachers, better design of facilities and media, better home-study environments, better administrative procedures, and much more. But from a purely instructional point of view, the two most fundamental factors are: (1) improving what is taught, and (2) improving how it is taught. The first factor is most strongly influenced by subjective values. This paper addresses only the second factor—improving the methods of instruction—because the how can be, and

should be, most strongly influenced by an appropriate knowledge base.

But what is this knowledge base for improving the methods of instruction? And what kinds of knowledge are needed? We need knowledge about the kinds of methods that will make learning easier and more fun for students: methods that are more effective, efficient, and appealing. Such methods can be viewed as being built up from elemental "strategy components," and knowledge about these strategy components is what we need most.

For example, suppose we want to teach a student to classify unencountered examples and nonexamples of a concept; we want the student to learn to distinguish yawls from boats that are not yawls. It has been shown that presenting the student with examples that are widely different (divergent) from each other, such as large metal-hulled yawls and small wooden-hulled yawls, will help prevent the student from undergeneralizing; that is, it will help prevent the student from saying that a large metal-hulled yawl is not an example of the concept "yawl" when in fact it is. It has also been shown that presenting the student with a clearly labeled "matched nonexample" (i.e., something that is not an example of the concept but is very similar to one) together with the example to which it is matched, such as a ketch that is similar to a yawl in size, hull type, and color, will help prevent the student from overgeneralizing; that is, it will prevent the

student from saying that such a ketch is an example of a yawl.

Divergent examples and matched non-examples are two clearly defined, elemental, strategy components for which an investigator can identify reliable cause-and-effect relations. But such a "scientific approach" to understanding instruction should not be confused with a mechanistic or nonhumanistic approach to giving instruction. Such a scientific approach merely affirms that certain things a teacher or textbook can say will have certain predictable effects on students' understanding. Teachers can be just as warm and human, in fact they can be more so, when they understand what strategy components will help most to solve different kinds of student learning problems.

A fundamental assumption behind our discussion of a knowledge base for improving our methods of instruction is that different strategy components can have different and consistent effects on the outcomes of instruction. This is not to say that all strategy components do have different and consistent effects on instructional outcomes. In fact, one of the major tasks confronting us is to identify and to define clearly the strategy components that do have consistent effects (e.g., the use of matched nonexamples and divergent examples in the teaching of concept-classification tasks) and to reject those that do not have consistent effects ("effects" include interaction effects as well as main effects; see next paragraph).

A corollary of the fundamental assumption that different strategy components can have different and consistent effects on the outcomes of instruction is that different conditions (such as types of subject matter and kinds of students) can have consistent influences on those effects. Therefore, the knowledge base that is needed for improving how things are taught must include both the development of new strategy components (that have consistent effects) and the identification of any differences in their effects that may be caused by different conditions. These activities may be viewed as a science of instruction (see Reigeluth, Bunderson, & Merrill, 1978) because they entail the discovery of cause-and-effect relations, or principles of instruction, that relate conditions, methods, and outcomes of

instruction.

But another aspect of the needed knowledge base is the development of procedures for applying the principles of instruction (not to be confused with principles of learning) to the improvement of instruction. This activity may be viewed as a technology of instruction (technology being defined as "applied knowledge") because it entails the development of ways for using the knowledge of a science for solving real-world problems; it entails the development of application procedures for the principles of instruction.

There are as many types of application procedures as there are types of instructional problems, but some major types of application procedures include: (1) procedures for teaching and/or designing instruction effectively, (2) procedures for diagnosing weaknesses in existing instruction, (3) procedures for rating existing instruction (i.e., predicting its effectiveness), (4) procedures for improving existing instruction, and (5) procedures for teaching effective self-instructional strategies to students.

Developing the Knowledge Base

Every technology (e.g, medicine, engineering) is related to a science (e.g., biology, physics), which is comprised of clearly defined concepts and empirically validated principles (i.e., cause-and-effect relations among those concepts). Instructional technology is no exception. Because of this relation, and on the basis of our experience, we propose the following seven steps as a useful operating procedure for further developing the scientific and technological knowledge base for improving our methods of instruction.

1. Definition of Concepts

One of the greatest hindrances to deriving and communicating instructional principles and application procedures is the lack of an adequate and unambiguous classification of important concepts and variables, particularly those relating to methods of instruction. Therefore, a useful prerequisite for all other activities is the classification, precise definition, and unambiguous labeling of the phenomena related to methods of instruction.

But there are many ways in which such phenomena can be classified, just as noninstructional phenomena such as "trees" can be classified in different ways: according to age (e.g., seedlings and saplings), kind of leaf (e.g., pines and deciduous trees), or genus (e.g., oaks and maples). The ultimate value of any classification scheme that we adopt for instructional phenomena is determined by the stability and magnitude of the cause-and-effect relations that are found to exist among those categories. It is likely that many currently used concepts, such as "discovery," "deductive," and "discussion," will gradually be scrapped and more precise concepts and unambiguous terminology will gain increasing acceptance.

2. Derivation of Propositions

Having defined a vocabulary with which to describe the instructional process (step 1), it is possible to make more precise statements about relations observed in practice, about relations derived from descriptive principles, and about relations that seem to follow logically from the variable scheme defined. Therefore, the second step in developing a knowledge base for improving our methods of instruction is to derive propositions (hypothesized principles) that state prescriptive relations among strategy components (methods), conditions, and outcomes. Each of these propositions is a potential principle of instruction, but its validity as a principle must be demonstrated (step 3 below).

3. Validation of Principles

The third step is the testing of the propositions to find out whether each is a valid principle. Unless there is empirical support for the prescriptive relation described by each proposition, it is of little value. But there are two important kinds of empirical support that can be obtained (see Reigeluth, 1978): (1) support from laboratory experiments investigating the isolated effects of one, or at most just a few, strategy variables under conditions that are carefully controlled to reduce confounding variables, and (2) support from classroom experiments investigating the aggregate effects of complete sets of strategy variables under realistic conditions. In this step we are interested only in laboratory experiments, because we want to validate single principles (i.e., we want to test the effects of single strategy components). Complete sets of strategy components are tested later (step 5 below).

4. Development of Theories or Models

It is likely that some strategy components will have duplicate effects: When you have either of two components in the instruction, adding the other will contribute nothing. It is also likely that some strategy components will have interaction effects with some conditions. For instance, under a certain condition, a strategy component will have an opposite effect from under a different condition. For these reasons, it is important to develop models or theories that prescribe combinations of strategy components that will optimize given types of outcomes for given sets of conditions. There has been some controversy over the viability of generalizable theories of instruction, but it is likely that models or theories that take account of different conditions can have a large degree of generalizability across schools and across time (see Reigeluth, 1978). This step will often be conducted simultaneously with the next step.

5. Testing of Theories or Models

Like propositions, models and theories have little value unless empirical support can be obtained for them. Therefore, the fifth step is the testing (and revision) of theories and models. Unlike research on single principles of instruction, research on prescriptive instructional models and theories seldom attempts to show that a model or theory is valid or invalid. Rather, it is directed at identifying an optimal[1] set of strategy components for certain sets of conditions and desired outcomes. Reigeluth (1978) proposes a research methodology for doing this kind of research on instructional theories or models.

6. Development of Application Procedures

The sixth step is the development of

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[1] "Optimal" should be considered (in terms of) the effectiveness, efficiency, and appeal of the instruction. Efficiency refers to effectiveness in relation to cost: cost in both student learning time and in the monetary expense of the instruction.

procedures for applying theories and models of instruction to the solution of different kinds of problems. These kinds of problems may include: (1) the design of new instructional materials, (2) the rating of the effectiveness and efficiency of existing materials, (3) the diagnosis of weaknesses in existing materials, (4) the improvement of existing materials, and (5) the teaching of self-instructional strategies to students. Application procedures are like cookbooks: They provide a set of steps a person may follow in order to solve the problem.

7. Testing of Application Procedures

The seventh step is the evaluation (and revision) of the application procedures. This is done by trying out alternative procedures in real-world applications and by comparing their effectiveness and costs. Reigeluth and Merrill (Note 2) describe one possible methodology for doing this.

These seven steps represent ways to develop what appear to be the most important aspects of the knowledge base for improving our methods of instruction.

OUR RELATED WORK TO DATE

The authors' work on improving the methods of instruction is based on the assumption that different strategy components are optimal under different kinds of conditions and for different types of outcomes. Because of this assumption, our basic approach is to develop strategy components that will meet instructional needs for different kinds of instructional conditions. Over the past five years, M. David Merrill's laboratory (sponsored jointly by Brigham Young University and Courseware, Incorporated) has produced sizable efforts in literature review, original theory construction, and systematic research. The following is a summary of our work to date.

Basic Concepts and Variable Classes

The authors have done some extensive work in the area of taxonomy construction. Figure 1 shows the major categories of instructional variables and their major interrelationships as we currently conceptualize them. Briefly, all instructional variables belong to one of three categories: (1) methods, which an instructional designer or educator can manipulate in

order to achieve specified outcomes under given conditions, (2) conditions, which cannot be manipulated but which nonetheless influence the outcomes of methods by interacting with them, and (3) outcomes, by which methods can be evaluated under different conditions. The relations among the three categories are indicated by the arrows in Figure 1. (This figure does not depict the instructional process, nor does it depict the process of instructional design.)

Figure 1 also identifies major classes within each of these three categories. Methods are classified very differently from most current conceptualizations. Organizational strategy variables are components of different methods for organizing the subject-matter content (including skills) that is to be taught. Delivery strategy variables are components of different methods for conveying the instruction to the student. Management strategy variables are components of different methods for arranging the interaction of the students with the organizational and delivery strategy components. This classification of instructional variables is described in detail by Reigeluth and Merrill (Note 3).

Within this scheme, the authors have done extensive work only on organizational strategies, which can be further classified as presentation strategies and structural strategies. Presentation strategy variables are components of methods for organizing the instruction on a single "construct" (e.g., concept, principle, or procedure); structural strategy variables are components of methods for organizing (structuring) many related constructs. An extensive taxonomy of concepts related to presentation strategies is presented by Merrill and Wood (1974, Note 4), and a taxonomy of concepts related to structural strategies is presented by Reigeluth, Merrill, et al. (Note 5).

We believe that the effectiveness of a presentation strategy component depends primarily on the type of content involved and the level of behavior (task level) required of the student. We have identified five types of content—facts, subsets, concepts, procedures, and principles—and (with the exception of facts) five task levels for each of these types of content: remember verbatim examples, remember

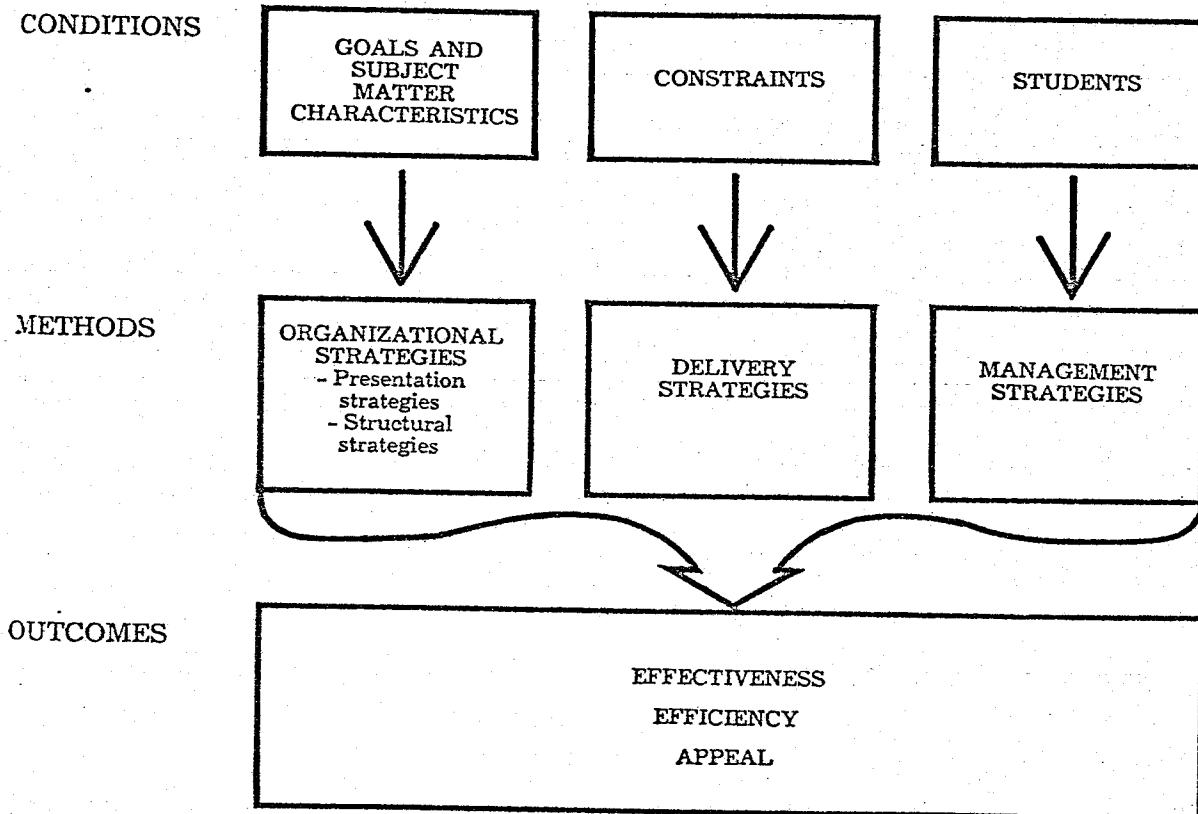# A KNOWLEDGE BASE FOR IMPROVING INSTRUCTION

CONDITIONS

| GOALS AND SUBJECT MATTER CHARACTERISTICS | CONSTRAINTS | STUDENTS |

METHODS

| ORGANIZATIONAL STRATEGIES
– Presentation strategies
– Structural strategies | DELIVERY STRATEGIES | MANAGEMENT STRATEGIES |

OUTCOMES

EFFECTIVENESS

EFFICIENCY

APPEAL

Figure 1. A model showing the major classes of instructional variables and the major interrelationships among those classes

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paraphrased examples, remember verbatim generalities, remember paraphrased generalities, and use generalities on newly encountered examples (such as using a definition to classify examples and non-examples of a concept). This task/content classification of subject matter is explained in greater detail by Merrill, Richards, Schmidt, and Wood (Note 6) and by Merrill, Reigeluth, and Faust (in press).

The task/content classification of subject matter is important for improving our methods of instruction, because it is the basis for predicting which presentation strategy components will be optimal under given kinds of instructional conditions. This advance, however, as important as it is, represents only one part of the knowledge base necessary to improve the presentation adequacy of instructional methods. The other major part is the development of highly effective presentation strategies for each task/content type of subject matter.

We believe that considerable progress has been made recently on presentation strategies. One of the major breakthroughs in the development of presentation strategies was the notion that all instruction can be broken down into different types of displays: the "elements" of instruction (see Merrill & Wood, 1974). The most important displays, referred to as "primary presentation forms" (PPF's), are: (1) generalities, such as definitions of concepts and statements of procedures and principles; (2) examples, such as instances of a concept and applications of a procedure or a principle; (3) generality practice, which is student recall or recognition of a generality; and (4) example practice, which requires the student either to remember an example or (a) to classify an example as an instance or a noninstance of a concept, (b) to perform an example of a procedure, or (c) to explain an example of a principle. These four primary presentation forms (PPF's) are described in greater detail in several of our publications, including Merrill, Reigeluth, and Faust (in press), Merrill, Richards, Schmidt, and Wood (Note 6), and Merrill and Wood (1974, Note 4).

Principles of Presentation Adequacy

The results of all these efforts has been the development of some prescriptive principles of instruction: principles that relate certain instructional outcomes to certain instructional conditions and strategies. The following is a summary of the major principles of presentation adequacy that we hypothesize to be valid for high school and college students.[2]

Presentation consistency. The instruction on a single topic should be at the same task/content level as the goals and objectives of that instruction. (The corresponding test items should also be at the same task/content level.)

PPF (Primary Presentation Form) selection. Instruction for remembering a verbatim example should be comprised of only two of the PPF's: the example and example practice. Instruction for remembering a paraphrased example also should be comprised of only the example and example practice. Instruction for remembering a verbatim generality should be comprised of only the generality and generality practice; instruction for remembering a paraphrased generality should be comprised of a reference example as well as the generality and generality practice. Finally, the instruction for using a generality should be comprised of only a generality, examples, and example practice.

PPF sequence. Instruction for remembering a verbatim example and for remembering a paraphrased example should begin with the example; instruction for the remaining task/content types should begin with the generality. Other than that, learners should be able to select the type of PPF that they think would be most helpful at any moment, including a review of the initial PPF.

PPF contents. The major components of each PPF should be: (1) a fairly concise statement or question (about the generality or the example) depending upon the type of PPF; (2) an alternate representation for the generality; (3) attribute isolation for the early examples and for all feedback at the use task level; (4)

separate helps for all four PPF's (e.g., mnemonics for the remember levels, a reference example with a description of its mapping to the generality for each generality at the use level, and a concise representation of the generality with a description of its mapping to the example for each example and for each example-practice feedback); and (5) a clear description of the kinds of variations in instances that a student must learn at the use level, such as a description of Markle's rational set (Markle & Tiemann, 1969) for concept learning or of variations in the application of a procedure to specific situations. (The contents of each of these major PPF components have also been researched and specified to a large degree, but those contents vary with the type of content, e.g., principles, concepts, etc. A description of those contents is beyond the scope of this brief overview; the reader is referred to Courseware's Author Training Course [Note 7] for a description of some of those contents.)

PPF quantity. Written instructional materials should contain more examples and example practice than any student will need. Learners should be permitted to select the amount of each that they feel is necessary to understand the topic. The effectiveness of this type of learner control depends on providing the students with the kinds of information necessary for them to make the proper decision, such as a clear description of the kinds of variations in instances that they must learn at the use level.

PPF isolation. Each PPF should be separate from the other PPF's and should be clearly identified as to which PPF it is. The same applies to the major components of each PPF.

Instance sampling and matching. Instances (both examples and example practice) at the remember-paraphrased levels and at the use level should be of a variety of representation forms and of a variety of difficulty levels. Instances at the use level should also be divergent on variable attributes that the student ought to learn, and examples should be matched with examples of common errors (e.g., matched nonexamples for concept learning and common misconceptions for principle learning).

Some of these principles are explained in greater detail in each of the following publications: Merrill and Goodman, Note 8; Merrill, Olsen, and Coldeway, Note 9; Merrill, Richards, Schmidt, and Wood, Note 6; Merrill and Tennyson, 1977; and Merrill and Wood, Note 10.

The derivation of these principles, which we refer to as theory construction, is obviously very important, but our efforts go considerably beyond this in two ways. We have devoted considerable effort to (1) validating those principles (step 3), primarily for high school and college students but to some extent for elementary and junior high school students also, and (2) developing procedures to facilitate the application of those principles to solving instructional problems (step 6).

One of our first major efforts to validate the above-mentioned principles of presentation adequacy was a review of research literature (Merrill, Olsen, & Coldeway, Note 9). Research already conducted by us includes: Coldeway and Merrill (Note 11); Gibbons and Boutwell (Note 12); McLachlan, Schmidt, and Merrill (Note 13); Merrill, Schmidt, and Norton (Note 14); Merrill and Tennyson (Note 15); Merrill and Tennyson (Note 16); Olsen, Reigeluth, and Merrill (1977); Reigeluth (1977); Reigeluth and Merrill (1977); Schmidt, Wood, and Merrill (Note 17); Tennyson (1973); Tennyson and Woolley (1971); Tennyson, Woolley, and Merrill (1972); Vance, Cropper, and Jensen (Note 18); Wilcox, McLachlan, and Merrill (Note 19); Wood, Gilstrap, and Merrill (Note 20); Wood, Richards, and Merrill (Note 21); Woolley (Note 22); and Young, Smith, and Merrill (Note 23).

In addition, about 25 research studies are in various stages of completion, including studies on the validation of the instructional strategy diagnositic profile, PPF sequence and instance number, generality and instance helps, practice feedback, attribute isolation, learner control, and PPF isolation.

In no case has any study contradicted any of our proposed principles; all studies have either supported them or have shown no significant differences.

Application Procedures for Presentation Adequacy

The other major extension of our work is the development of procedures to facilitate the application of the above-mentioned principles of presentation adequacy to solving instructional problems (step 6). The development of procedures requires a completely different effort (at the technologist or engineering level) than does the development of prescriptive principles of instruction (at the scientist level), just as the development of prescriptive principles in the science of instruction requires a completely different effort than the derivation of descriptive principles in the science of learning. Procedures are simple step-by-step applications of one or more principles.

We recently finished a project to develop procedures for the application of a limited set of principles. The principles concern presentation adequacy for high school and college students, and the application was for the diagnosis and rating of existing instruction. Instruction in this limited set of procedures is contained in The Instructional Strategy Diagnostic Profile Training Manual (Merrill, Richards, Schmidt, & Wood, Note 6). A major part of the procedures is a set of forms that are used to profile the presentation adequacy of the instructional materials and to rate their overall level of effectiveness with respect to presentation strategies. Lessons 4 and 5 show the kinds of step-by-step procedures that can be developed to implement some of the above-mentioned principles of presentation adequacy.

Another significant application of the above-mentioned principles of presentation adequacy is the instructional design procedures used by Courseware, Incorporated. These procedures are presented in Courseware's Author Training Course (Note 7) and Coursewriter's Workshop (Note 24), but more importantly, these procedures have been used extensively in the development of thousands of hours of written instruction. Although this does not represent a formal validation, it has provided extensive field testing of the procedures on many large (i.e., multimillion dollar) and small instructional development projects such as the Navy's S3A and P3 projects and the Air Force's F4, F15, and F16 projects.

The Instructional Strategy Diagnostic Profile Training Manual has undergone some formal validation studies (step 7) for the diagnosis and rating of existing written instructional materials (Wood, Richards, & Merrill, Note 21; Merrill, Wood, Baker, Ellis, & Wulfeck, Note 25). These studies and Courseware's extensive field testing have shown that the procedures as a whole are very useful, but they have also shown that much work remains to be done. (For a description of the nature of the work that we feel remains to be done, see "Remaining Needs" below).

Principles of Structural Adequacy

We have recently come to believe that principles of structural adequacy usually have a stronger impact on instructional outcomes than do principles of presentation adequacy. As a result of our previous and current work in the structural area, we believe that the effectiveness of a structural strategy component (e.g., a particular method of sequencing or a particular way of summarizing important constructs) depends primarily on the "orientation goals" of the instruction. We have identified three major types of orientation structures, which are selected on the basis of orientation goals. Within sections of an orientation structure, there are several kinds of supporting structures, which are selected on the basis of (a) secondary goals, (b) orientation structure, and (c) student entering knowledge or behavior. The type of structure provides the basis for prescribing optimal structural strategy components, similar to the way that the task/content combination provides a basis for prescribing optimal presentation strategy components.

Since these ideas have only recently been developed, the state of our knowledge is very much still in transition. Therefore, our description will be anything but definitive. First, we shall briefly describe the types of structures that are the basis for prescribing structural strategies. Next, we will describe the major kinds of structural strategies. Then we will describe some of the principles that we are in the process of deriving. Finally, we will indicate our premature impres-

sions of the kinds of procedures that might best implement those yet undeveloped principles of structural adequacy.

The following are the three types of orientation structures that we have identified and described: the procedural structure, the taxonomic or matric structure, and the model or theoretical structure. These three kinds of structures, plus learning structures and list structures, can also serve as supporting structures. (The nature and use of orientation and supporting structures are described below.)

The procedural structure shows the relations among steps in a procedure. There are two types of such relations, and they are both present in what is referred to as a flow diagram. One is a procedural-prerequisite relation, which specifies the order(s) in which different steps can be performed. The other is a procedural-decision relation, which shows the conditions necessary for deciding which procedure, subprocedure, or step to use in a given situation.

The taxonomic structure shows the superordinate, coordinate, and subordinate relations among related constructs in a subject matter. There are also two types of taxonomic relations. In a "kinds" taxonomy, a subordinate concept is a kind of the concept to which it is subordinate, such as a bear being a kind of mammal. In a "parts" taxonomy, a subordinate concept is a part of the concept to which it is subordinate, such as a circulatory system being a part of a mammal. Two or more taxonomic structures can be combined to form a matric structure, and many subject-matter areas can be usefully described with a kinds-by-parts matrix. Taxonomic and matric structures may often be referred to as conceptual structures.

The theoretical structure (or model) shows the interactions of cause-and-effect relations among concepts. These interacting cause-and-effect relations are referred to individually as principles, and basically they explain why something happens as it does. There are also two important kinds of theoretical structures (or models): those that describe natural phenomena, which are goal-free and therefore invariant, and those that de-

scribe ways to achieve some end, which are goal-oriented and therefore vary as goals vary.

The learning structure shows learning-prerequisite relations by describing what must be known before a given concept or principle can be learned. This is the widely misunderstood Gagné learning hierarchy, which is often confused with other kinds of structures, especially the procedural-prerequisite structure.

The list structure shows a linear (order) relation among its constructs. The nature of the linear relation may vary; for instance, countries may be listed in order of population, area, agricultural production, birth rate, or an almost infinite number of other characteristics.

These five kinds of structures are described in detail and illustrated by Reigeluth, Merrill, and Bunderson (in press). Each of these types of structures calls for the use of some different structural strategies, which are described next.

We have identified four major types of structural strategies: (1) selection strategies, for deciding which constructs to teach in a given subject-matter area, (2) sequencing strategies, for deciding the order in which to present those constructs, (3) synthesizing strategies, for deciding how and when to show the important relations among those constructs, and (4) summarizing strategies, for deciding how and when to preview and review those constructs and relations. It is beyond the scope of this overview to provide a detailed description of all the different strategy components we have developed to date. But as an indication, Figure 2 lists the major synthesizing strategy variables we have identified thus far. The strategy components and the types of orientation and supporting structures are the major components of the principles of structural adequacy, which are discussed next.

At the present time, the development of principles of structural adequacy is still in its initial stages. Nevertheless, we are confident that there are important principles in all four areas: selection, sequencing, synthesizing, and summarizing. The following are some preliminary and very tentative propositions; although

SSDP PROJECT

STRUCTURAL STRATEGY TAXONOMY

Synthesizing Strategy Variables

Purpose of a synthesizer
Parameters: internal, external

Timing of a synthesizer
Parameters: before, during (specify exactly when
during), after

Frequency of different synthesizers
Parameters: continuum from very infrequent to very
frequent

Level of a synthesizer
Parameters: continuum from general to detailed
or from simple to complex

Inclusiveness of a synthesizer
Parameters: number of related elements included

Form of a synthesizer
Parameters: literal, analagous

Representation of a synthesizer
Parameters: prose, schematic

Type of relation synthesized in a synthesizer
Parameters: procedural prerequisite, procedural
decision, parts taxonomic, kinds taxonomic, causal

Figure 2. The major synthesizing strategy variables that we have identified to date.

they are too general to be very useful, they do provide an indication of the kinds of relations we feel are likely to be important for improving our methods of instruction.

Initial synthesis principle. A general synthesizer, which shows the major parts of the subject matter and the major relations among those parts, should be presented at the very beginning of the instruction.

Gradual elaboration principle. The parts of the initial synthesizer should be gradually elaborated so that the sequence of the instruction proceeds (a) from general to detailed for conceptual orientation structures, and (b) from simple to complex for procedural and theoretical structures.

Periodic synethesis principle. A synthesizer should be provided after each elaboration (i.e., after each part of the initial synthesizer has been elaborated). Increasingly detailed or complex interrelationships are shown in each successive synthesizer to correspond to the detail or complexity of the parts that are taught in each elaboration.

Type of synthesizer principle. The following types of synthesizers should be used under the corresponding conditions: a conceptual structure (taxonomic or matric) for conceptual orientation goals, a theoretical structure for theoretical orientation goals, and a procedural structure for procedural orientation goals.

Periodic summary principle. A summarizer (e.g., a concise generality for each construct) should be provided after each elaboration but before the synthesizer for each respective elaboration.

Application Procedures
for Structural Adequacy

Finally, our preliminary impressions of the kinds of procedures that might best implement those yet somewhat poorly defined principles of structural adequacy are indicated by the following impressions for instructional design: (1) On the basis of goals select a kind of orientation structure for the subject matter to be presented in the textbook (conceptual, procedural, or theoretical), (2) Develop the orientation structure in the subject matter to be taught (this is a new form of task analysis), (3) Map out the high-level sequences, synthesizers, and summarizers for the text (this is like a blueprint of what the units and chapters of the textbook will be on), (4) Identify supporting structures within each part of the orientation structure on the basis of: secondary goals, type of orientation structure, and student entering behavior (this is like a blueprint of the contents of each chapter or each section of each chapter), and (5) Map out the middle and lower level sequences, synthesizers and summarizers on the basis of those supporting structures.

Since the type of structure is always the basis for specifying structural strategies, we envision the development of complete, integrated models for selecting, sequencing, synthesizing, and summarizing related topics of a subject matter, such that a different set of procedures would be used for each type of orientation structure and for each type of supporting structure. One such model, which we have named concept elaboration theory, is already at a fairly advanced stage of development (in fact, it was our first effort in the area of structural strategies). But revisions are sure to be made as we develop complete sets of principles (models) of structural adequacy. To a large extent the early development of this model was putting the cart before the horse, but it also helped considerably to show the horse what to do. For a more detailed description of application procedures for designing new instruction, see Reigeluth, Merrill et al. (Note 5).

REMAINING NEEDS FOR
THE KNOWLEDGE BASE

The work that we and others have done to date and are currently doing is an important step toward the goal of being able to improve our methods of instruction. But much remains to be done.

(1) **Definition of concepts.** In the area of presentation adequacy, it appears that many of the important variables have been precisely defined and clearly labeled. Much work remains to be done in the area of structural adequacy, however, especially in the development of elemental strategy components.

(2) and (3) Derivation and validation of principles. It also appears that many of the important principles have been identified in the area of presentation adequacy, but again much work remains to be done in the area of structural adequacy. Far more controlled experiments have been conducted in the area of presentation adequacy than in the area of structural adequacy, but the empirical support in both areas has not been consistent. This indicates a need to investigate the relative contribution to learning (both qualitatively and quantitatively) of each strategy component when in combination (interaction) with all the strategy components that contribute more than it does (see next paragraph).

(4) and (5) Development and testing of models or theories. Very little of what is needed has been done to develop models of optimal combinations of strategy components, and even less has been done to test such models. Reigeluth (1978) has described a research methodology that appears to be effective (a) for investigating the relative contribution (both qualitatively and quantitatively) of each strategy component when in combination with all the strategy components that contribute more than it does, and (b) for investigating the ways in which individual differences and subject-matter characteristics interact with those combinations of strategy components. Because of its greater external validity, this kind of research is much more important for improving our methods of instruction than are controlled experiments, and it deserves much greater effort and expenditure of resources in the immediate future.

(6) and (7) Development and testing of application procedures. This is almost completely virgin territory, except for one small section of presentation-strategy application procedures where The Instructional Strategy Diagnostic Profile Training Manual (Merrill, Richards, Schmidt, & Wood, Note 6) applies: diagnosis and rating procedures. Even this section needs much more testing and revision. Some

instructional design procedures have been developed, but they tend to have a very weak and piecemeal foundation in the scientific knowledge base of instruction. The same is true for revision procedures and for learning procedures (i.e., procedures for students to follow in order to increase the effectiveness and efficiency of their learning methods with poorly organized instructional materials). However, extensive work in this area will have to wait for more progress in the development of a scientific knowledge base for instruction, especially in the area of structural strategies.

Once such procedures have been developed, it will be important to evaluate the cost effectiveness of each part of each procedure (a part being those steps for the application of a single principle). This cost effectiveness must be evaluated both in student time vs. contribution to performance, and in professional time (e.g., the rater's time) vs. contribution to professional outcome (e.g., the accuracy of the rating). We anticipate that cost-effectiveness data will warrant the deletion of significant amounts of each set of procedures (diagnosis procedures, rating procedures, etc.), and it will also provide a sound basis on which to create "short-form" procedures for the best possible "quick and dirty" approach.

CONCLUSION

In conclusion, considerable progress has been made in the area of presentation adequacy, and we are very excited about our current progress on structural adequacy. Much work remains to be done in both areas, however, and the areas of delivery strategies and management strategies are even more wide open. It is our hope that this paper will help draw attention to the importance of developing the knowledge base that is necessary for improving our methods of instruction. We also hope it will draw attention to the need for much greater effort and expenditure of resources in this important endeavor.

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