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CHAPTER 10

INSTRUCTIONAL SCIENCE AND TECHNOLOGY: THEIR CONTEXT WITHIN EDUCOLOGY AND SOME IDEAS FOR THEIR FUTURE DEVELOPMENT

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TRANSITION: One category of knowledge about education that is possible is knowledge about effective practices in education. A possible name for knowledge about effective practice is 'praxiology'. And possible names for the concept of 'knowledge about effective educational practices' are: praxiology of education, educational praxiology, and praxiological educology. In the previous three chapters, arguments have been presented for the development of this category of knowledge, and explications have been given of some of the implications of the concept. In this chapter, Reigeluth and Merrill present the results of some of the empirical and conceptual work which they have conducted toward extending knowledge about effective practices in education.

In Chapter 10, the authors differ somewhat in their conception of praxiological educology from that of Brezinka, Maccia, Steiner, Christensen, and Perry. First, Reigeluth and Merrill do not distinguish clearly between (1) true statements (knowledge) about effective educational practices and (2) the effective educational practices themselves. Second, they conceive of science of education as generalizations and praxiology of education as applications of those generalizations. (In their conception of science of education, they thus use the term in a way that is close to Monshouwer's use.) Steiner et al. conceive of science of education to be generalizations and also praxiology of education to be generalizations; programs for action are not derivable from the generalizations of science, but they are from the generalizations of praxiology.

Thus, the conception of 'science of education' that is followed in Chapter 10 is closest in meaning to the concept of 'praxiology of education' that is followed in previous chapters. The sense of 'praxiology of education' that is followed in Chapter 10 is 'effective educational procedures', a concept close, but not identical in meaning to the concept of 'technics' developed by Monshouwer in Chapter 7. This concept is to be contrasted with Steiner's conception, for example, in which effective educational procedures are the actual programs derived from praxiological generalizations. Praxiology, in her conception, is the generalizations, and a program is an arrangment of a set of effective actions. 'Instructional science and technology' in Reigeluth and Merrill's usage is closest in meaning to 'intructional praxiology and programs' in Steiner, Brezinka, Maccia, Perry, and Christensen's usage, and to 'instructional technology and technics' in Monshouwer's usage.

TRUE GENERALIZATIONS ABOUT EFFECTIVE INSTRUCTIONAL ACTIVITY	ARRANGEMENTS OF EFFECTIVE INSTRUCTIONAL ACTIVITY
≃	≃
INSTRUCTIONAL SCIENCE (IN THE REIGELUTH-MERRILL CONCEPTION)	INSTRUCTIONAL PRAXIOLOGY (IN THE REIGELUTH-MERRILL CONCEPTION)
≃	≃
PRAXIOLOGY OF INSTRUCTION (IN THE STEINER ET AL. CONCEPTION)	PROGRAMS OF EFFECTIVE INSTRUCTION (IN THE STEINER CONCEPTION)
≃	≃
SCIENCE OF EDUCATION (IN THE MONSHOUWER CONCEPTION)	TECHNICS (IN THE MONSHOUWER CONCEPTION)
≃	≃
EDUCOLOGY (IN THE BIGGS CONCEPTION)	EFFECTIVE EDUCATIONAL PRACTICE (IN THE BIGGS CONCEPTION)

FIGURE 10.1
Differing Conceptions of Instructional Science and Technology

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INTRODUCTION

Instructional science and instructional technology are but two fields within the discipline of educology. They are both dedicated to improving the methods of instruction, and they do not in any way imply a "mechanistic" system of education in which no importance is attributed to human interaction, imagination, and creativity. *Instructional science* is a field dedicated to the discovery of principles and theories about methods of instruction. It is concerned with the identification of the causes of different instructional outcomes under different conditions and with the explanation of the effects of different instructional methods under different conditions.[1] *Instructional* technology is a field dedicated to the development of procedures for applying scientific knowledge of instruction to the solution of practical problems in education and training.[2] We will elaborate upon and illustrate these definitions below.

In this chapter, we will (1) discuss the *context* of instructional

science and instructional technology within the discipline of educology, (2) discuss the *importance* of instructional science and technology for improving the effectiveness, efficiency, and appeal of methods of instruction, (3) describe the fundamental *nature* of instructional science and of instructional technology (or praxiology), (4) propose *seven activities* as a *procedure* for the continuing development of instructional science and instructional technology, (5) describe some *related work* that authors have done in those seven activities, and (6) discuss some of the most important areas for work on further developing these important fields of educology.

THE CONTEXT

J. Christensen and J. Fisher have identified and described a variety of fields within the domain of educology.[3] They argue that educology implies: (1) analytic studies about education, which include history of education, analytic philosophy of education, and jurisprudence of education; (2) normative studies about education, which is normative philosophy of education; and (3) empirical studies about education, which include science of education, praxiology of education, and political praxiology of education. According to these categories, instructional science and technology (or praxiology) lie exclusively within the area of empirical studies about education.

However, instructional science and instructional technology are not the same as Christensen and Fisher's science of education and praxiology of education, respectively. Education is a broader term than instruction; hence the area of empirical studies about education includes other aspects of education (such as administration) besides instruction. Instructional science and technology lie exclusively within the area of empirical studies about *instruction*.

IMPORTANCE OF INSTRUCTIONAL SCIENCE AND TECHNOLOGY

The purpose of the science and technology of instruction is to improve the quality of *methods* of instruction that are used in education and training. In spite of a broad concern for improving the quality of education, surprisingly little is being done to develop the knowledge base that is necessary for improving the methods of instruction, especially when considered in relation to the total resources devoted to education. The National Council on Educational Research[4] states that 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 agriculture's total and ten per cent of industry's total being allocated to research. And of the total expenditure for increasing the knowledge base for education, a surprisingly small proportion is allocated to developing a knowledge base for improving the *methods* of instruction.

Certainly many things 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 discussion addresses only the second factor -- improving the methods of instruction -- because it can be, and should be, most strongly influenced by an appropriate scientific and technological *knowledge base*.

THE NATURE OF INSTRUCTIONAL SCIENCE AND TECHNOLOGY

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. But in order to develop better methods of instruction, we must seek *detailed knowledge* about methods. Too often researchers investigate methods on too high a level of generality, such as "lecture" vs. "discussion group," "inductive" vs. "deductive," and "discovery" vs. "reception." Methods at such a high level of generality often vary as much within each category as between categories. Therefore, it is important to break down such methods into their building blocks and to study the effects of each of those more precise and clearly defined *strategy components*, separately and in various combinations, and under a variety of different conditions.

For example, suppose we want to teach a student a concept. This means the student must learn to classify previously unencountered examples and nonexamples of that concept -- for instance, he or she must learn to distinguish cars from vehicles that are not cars. It has been shown that presenting the student with examples that are widely different (divergent) from each other -- such as big Cadillacs and little Renaults -- will help prevent the student from undergeneralizing -- that is, from saying that a little Renault is not an example of the concept of the term, 'car', 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) together with the example to which it is matched -- such as a pickup truck that is similar to a car in size and color -- will help prevent the student from overgeneralizing the use of a term -- that is, from saying that a pickup truck is an example of something that should be denoted by the term, 'car'.

Divergent examples and matched nonexamples are two clearly defined, elemental, strategy components for which an investigator can identify reliable cause and effect relationships. 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 that a teacher or textbook can say will have certain predictable effects on students' understanding. A

teacher can be just as warm and human, in fact he or she can be more so, when the teacher understands which strategy components will help most to solve different types of student learning problems or errors.

Therefore, a fundamental assumption behind our discussion of a scientific and technological knowledge base for improving our methods of instruction is that *different strategy components can have different and consistent effects on the outcomes of instruction*. We are not saying that *all* strategy components do have different and consistent effects on instructional outcomes. In fact, this is why one of the major tasks confronting us is to identify, describe, and clearly characterize the kinds of 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 reject those that do not have consistent effects.

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* can have consistent influences on those effects. An increasing amount of research is being done on the ways in which the effects of a method of instruction vary for the different *types of students*.[5] Unfortunately, most of this research is done on general methods rather than on more precise strategy components. But type of student is not the only kind of condition that influences the effects of instructional strategy components and methods, nor is it necessarily the most important kind of condition. *Type of subjectmatter content* shows indications of being just as important.[6,7] Unfortunately, relatively little work has been done in this area.

Therefore, the knowledge base that is needed for improving how things are taught must include both the identification of new strategy components (that have consistent effects) and the determination of any differences in their effects that may be caused by different conditions. These activities may be viewed as a *science of instruction* because they entail the discovery of cause and effect relationships, or principles and theories of instruction, which relate conditions, methods, and outcomes of instruction. But another aspect of the needed knowledge base is the development of procedures for applying the knowledge of principles of instruction (not to be confused with principles of learning) to the improvement of teaching.

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 instructional science for solving real world problems -- it entails the development of *application procedures* for the principles of instruction. The term 'technology', as used herein, is synonymous with 'praxiology' as used by Christensen and Fisher[8] and others in this volume.*

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*As already noted in the transition to Chapter 10, the editor disagrees with this assertion. It seems that Reigeluth and Merrill are among those whom Monshouwer has identified as scholars who do not distinguish between technology and technics.

All technologies (e.g., medicine, engineering) are related to a sci-nce (e.g., biology, physics), which is comprised of clearly defined con-epts and empirically validated principles (i.e., cause and effect re-ationships among those concepts). Those technologies are devoted to the levelopment of procedures (either methods or machinery) for applying sci-ntific principles. In instructional technology, there are as many types f application procedures as there are types of instructional problems. ut some major types of application include: (1) procedures for *teaching* r *designing* instruction effectively, (2) procedures for *diagnosing* weak-esses in existing instruction, (3) procedures for *improving* existing nstruction, and (4) procedures for rating existing instruction (i.e., redicting its effectiveness).

EVELOPING THE SCIENCE AND TECHNOLOGY OF INSTRUCTION

Instructional science and technology are in their infancy. They are ide open and exciting fields sorely in need of bright, imaginative, and reative young people; and there are only six or eight graduate programs n these fields in the country.[9] Since these fields are so new, we pro-ose the following seven activities as a useful operating procedure for urther developing the scientific and technological knowledge base for mproving methods of instruction.

1. *DEFINITION OF CONCEPTS.* One of the greatest hindrances to deriv-ng and communicating instructional principles and application procedures s the lack of an unambiguous definition of important concepts and vari-bles, particularly those relating to methods of instruction. Therefore, prerequisite to all other productive activities is the classification, recise definition, and unambiguous labeling of the phenomena related to nstruction.

But there are many ways in which instructional methods and conditions an be *classified*, just as noninstructional phenomena like trees can be lassified in different ways -- according to their age (e.g., seedlings nd saplings), their kind of leaf (e.g., pines and deciduous trees), heir genus (e.g., oaks and maples), etc. The ultimate value of any lassification scheme that we adopt for instructional phenomena is deter-ined by the stability and magnitude of the cause and effect relationships hat are found to exist among those categories. It is likely that progress n instructional science and technology will be related to the degree to hich many currently used concepts such as discovery, deductive, and dis-ussion, are replaced by more precise concepts and unambiguous terms. nfortunately, there is much resistance to such a change, for many people aively think that all that is being changed is names -- they do not recog-ize that there are and will be important new concepts for which there re no adequate names.

2. *DERIVATION OF PROPOSITIONS.* Having defined a vocabulary with hich to describe the instructional process (Activity 1), it is possible

to make more precise statements about relationships observed in practice, about relationships derived from descriptive principles of learning, and about relationships which seem to logically follow 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) which state prescriptive relationships 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 (Activity 3, below).

3. *VALIDATION OF PRINCIPLES.* The third activity is the testing of the propositions (derived from Activity 2) to find out whether or not each is a valid principle. Unless there is empirical support for the prescriptive relationship described by a proposition, it is of little value. But there are two important kinds of empirical support that can be obtained:[10] (1) Support from *laboratory experiments* investigating the isolated effects of one, or at the most just a few, strategy variables under conditions that are carefully controlled so as 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 activity we are interested only in laboratory experiments, because we want to verify individual, pure relationships (i.e., single principles). Complete sets of variables are tested later (Activity 5 below).

4. *DEVELOPMENT OF MODELS.* It is likely that some strategy components will have duplicate effects -- that is, when you have either of two components in the instruction, the other will contribute nothing. It is also likely that some strategy components will have interaction effects with other strategy components and/or with conditions -- for instance, adding one component may make another component have an opposite effect from before the former was added.

For these reasons, it is important to develop models (or theories) which 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) which take account of different conditions can have a large degree of generalizability across schools and across time.[11]

This activity will often be conducted simultaneously with, or even after, the next.

5. *TESTING OF MODELS.* Like propositions, models have little value unless empirical support can be obtained for them. Therefore the fifth activity is the testing and revision of the models. But, unlike research on single principles of instruction, research on prescriptive instructional

models seldom attempts to show that a model is or is not valid. Rather, it is directed at identifying an optimal[12] set of strategy components for certain sets of conditions and desired outcomes. The authors have proposed a research methodology for doing this kind of research on instructional models.[13]

6. *DEVELOPMENT OF APPLICATION PROCEDURES*. The sixth activity enters the field of instructional technology. It entails the development of procedures for applying the principles and/or models to the solution of different kinds of instructional 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 provide a set of steps that a person may follow in order to solve a specific problem.

7. *TESTING OF APPLICATION PROCEDURES*. The seventh activity is the evaluation and revision of the application procedures. This is done by trying out the alternative procedures in real world applications and by comparing their effectiveness with their costs.

We propose these seven activities as a highly effective way to develop a scientific and technological knowledge base for improving the methods of instruction.

OUR RELATED WORK TO DATE

Our basic approach to improving the methods of instruction is based on the assumption that different strategy components are optimal under different types of conditions and for different types of outcomes. Because of this assumption, our basic approach is to develop strategy components that will meet the instructional needs of different types of instructional conditions. Over the past five years (1973-78), M. David Merrill's laboratory (sponsored jointly by Brigham Young University and Courseware, Incorporated) has produced sizeable efforts in literature review, original theory construction, and systematic research. The following is a summary of our work to date.

1. *BASIC CONCEPTS AND VARIABLE CLASSES*. The authors have done some extensive work in the area of taxonomy construction. 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 can not 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. Figure 10.2 shows the major categories

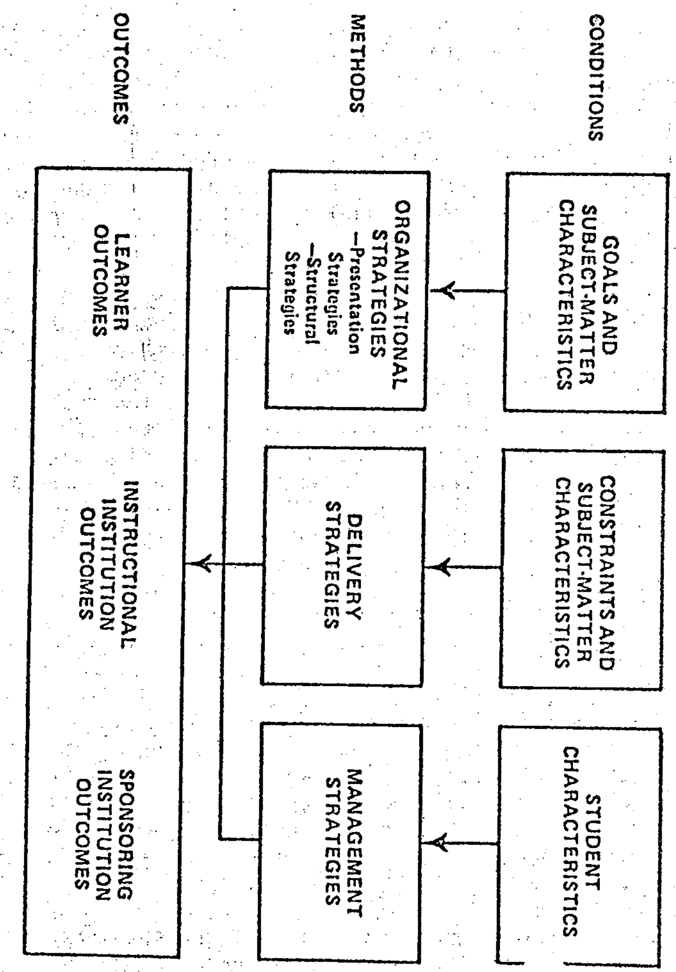

FIGURE 10.2

A model showing classes of instructional variables and the major relationships among them.

of instructional variables, and the major interrelationships among them, as we presently conceptualize them. (This figure does *not* depict the instructional process, nor does it depict the process of instructional design.)

Figure 10.2 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 methods for organizing the subject-matter content (including skills) that is to be taught. *Delivery strategy variables* are components of methods for conveying the instruction to the student. And *management strategy variables* are components of methods for arranging the interaction of the students with the organizational and delivery strategy components. This classification of instructional variables is described in detail elsewhere by the authors.[14]

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 concept, principle, etc.; and *structural strategy variables* are components of methods for organizing (structuring) many related concepts, principles, etc. An extensive taxonomy of concepts related to presentation strategies is presented by Merrill and Wood,[15,16] and a taxonomy of concepts related to structural strategies is presented by Reigeluth *et al.*[17]

2. *PRINCIPLES OF PRESENTATION ADEQUACY*. We believe that the effectiveness of a presentation strategy component depends primarily on the *type of content* involved and the *level of behavior* at which the student is to learn that content. We have identified five types of content -- facts, subsets, concepts, procedures, and principles -- and (with the exception of facts) three major task levels at which each of these types of content can be learned -- remember examples, remember generalities, and use generalities on newly encountered examples (such as using a definition to classify examples and nonexamples of a concept). This task-content classification of subject matter is explained in greater detail elsewhere.[18,19]

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 (i.e., methods for teaching a single concept) will be optimal under given types of instructional conditions. But this advance, 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 (i.e., strategies for teaching more than one concept, principle, etc.). 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.[20] A display is a piece of instruction that contains a single kind of information. The most important displays are referred to as "primary presentation forms;" and they are: (1) *generalities*, such as definitions of concepts, (2) *instances*, such as examples of a concept, (3) *generality practice*, which is student recall or recognition of a generality, and (4) *instance practice*, which may require the student to remember an instance or to classify an instance as an example or nonexample of a concept. These four primary presentation forms are described in greater detail in several of our publications.[21,22,23,24]

The result 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 which we hypothesize to be effective for *high school and college students*.[25]

i. Presentation Consistency. The instruction on a single topic should be at the same task-content level as the goals and objectives of that instruction. Also, the corresponding set of test items should be at the same task-content level.

ii. Primary Presentation Form Selection. Instruction for "remembering an instance" should be comprised of only two of the primary presentation forms: (1) the instance, and (2) instance practice. Instruction for "remembering a generality" should be comprised of only: (1) the generality, and (2) generality practice. And finally, the instruction for "using a generality" should be comprised of only: (1) a generality, (2) instances, and (3) instance practice.

iii. Primary Presentation Form Sequence. Instruction for remembering an instance should always begin with the instance; and the instruction for the remaining task-content types should always begin with the generality. Other than that, the learner should be able to select the type of primary presentation form (e.g., instance or instance practice) that he or she thinks would be most helpful at any moment, including a review of the initial primary presentation form -- the generality.

iv. The Contents of Each Primary Presentation Form. The major components of each primary presentation form should be: (1) a fairly concise *statement or question* about the generality or the instance; (2) an *alternative representation* for the generality (e.g., a diagram or picture); (3) *attribute isolation* (highlighting, arrows, etc.) for the early instances and for all feedback at the use task level; and (4) separate *helps* for all four primary presentation forms (e.g., mnemonics for the member levels, a reference instance with a description of its ipping to the generality for each generality at the use level, id a concise representation of the generality with a descrip-on of its mapping to the instance for each instance and for stance and for instance-practice feedback. The contents of ch of these major *PPF* (primary presentation form) components ve also been researched and specified to a large degree,[26,27] t those contents vary with the type of content, i.e., princi-es, concepts, etc.

v. Quantity of Instances and Instance Practice. Written structional materials should contain as many instances and much instance practice as the slowest student will need. e learner should be permitted to select the amount of each at he or she feels is necessary to understand the topic. The fectiveness of this type of "learner control" depends on pro-ding the student with the kinds of information necessary for m or her to make good decisions, such as a clear description the kinds of variations in instances that he or she must arn at the "use a generality" level.

vi. Isolation. Each primary presentation form should be parate from the others and should be clearly identified as which one it is (generality, generality practice, instance, instance practice). The same applies to the major components each primary presentation form -- such as, alternative re-esentations, helps, etc.

vii. Instance Sampling and Matching. Instances and instance actice at the "remember an instance" level and at the "use a nerality" level should be of a variety of representation forms d of a variety of difficulty levels. Instances at the "use generality" level should also be divergent on variable attri-tes that the student ought to learn, and instances should be tched with instances of common errors (e.g., matched non-amples for concept learning). Some of these principles are plained in greater detail elsewhere.[28,29,30,31,32]

e derivation of these principles is obviously very important, but orts go considerably beyond this in two ways. We have devoted rable effort to (1) *validating* those principles (Activity 3), pri-for high school and college students, but to some extent for ele- and junior high school students also, and (2) *developing procedures* litate the application of those principles to solving instructional s (Activity 6).

VALIDATION OF PRINCIPLES OF PRESENTATION ADEQUACY. One of our ajor efforts to validate the above-mentioned principles of pre-on adequacy was a review of research literature.[33] Also, we and our associates have completed over 20 empirical research studies, and about 25 more studies are in various stages of completion,[34] including studies on primary presentation form sequence, instance number, generality and instance helps, practice feedback, attribute isolation, learner con-trol, and primary presentation form 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.

4. *APPLICATION PROCEDURES FOR PRESENTATION ADEQUACY.* The other major extension of our work is the development of procedures to facili-tate the application of the above-mentioned principles of presentation adequacy to solving instructional problems (Activity 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 pre-scriptive 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 a limited application of a limited set of principles. The principles concern pre-sentation adequacy for high school and college aged students, and the application was for the diagnosis and rating of existing instruction. Instruction in this limited set of procedures comprises *The Instructional Strategy Diagnostic Profile Training Manual.*[35] A major part of the pro-cedures is a set of forms that are used to profile weaknesses in the in-structional materials and to rate their overall level of effectiveness with respect to presentation strategies. Lessons 4 and 5 in the manual show the kinds of step by step procedures that can be developed to imple-ment 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*[36] and *Coursewriter's Workshop*,[37] but more importantly these procedures have been used extensively in the development of thousands of hours of written instruction.

5. *TESTING OF APPLICATION PROCEDURES.* *The Instructional Strategy Diagnostic Profile Training Manual* has recently undergone some formal validation studies (Activity 7) for the diagnosis and rating of existing written instructional materials.[38,39] Also Courseware's use of instruc-tional design procedures has provided extensive field testing of the procedures on many large (i.e., multi-million dollar) and small instruc-tional development projects. The validation studies and Courseware's extensive field testing have shown that these 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 we feel remains to be done, see below.)

6. *CONCEPTS RELATED TO STRUCTURAL ADEQUACY.* We have recently come elieve that principles of structural adequacy (i.e., principles ı relate to teaching a number of related concepts, etc.) usually a stronger impact on instructional outcomes than do principles of ntation adequacy. As a result of our previous and current work in *tructural* area, we believe that the effectiveness of a structural egy component (e.g., a particular aspect of sequencing or of summari- important content) depends primarily on the type of "subject matter ture." We have identified two levels of subject matter structures: tation structures, of which there are three types, and supporting tures, of which there are five types. The type of structure pro- the basis for prescribing optimal structural strategy components, ar to the way that the task-content combination provides a basis for ribing optimal presentation strategy components.[40]

Since these ideas have only recently been developed, we have few ences to detailed explanations, and the state of our knowledge is much still in transition. Therefore, our description will be any- but definitive. In this section, we shall briefly describe the of structures that are the basis for prescribing structural stra- s, and we will describe the major kinds of structural strategies.

There is only one *orientation structure* for a course, but it may be f three types: a procedural structure, a conceptual structure, or oretical structure. These three kinds of structures, plus learning tures and list structures, can also serve as *supporting structures*, of which is nested within a part of the orientation structure. (The and use of orientation and supporting structures are described .)

The *procedural structure* shows the relations among steps in a pro- . A procedural structure could entail such things as a method of stical analysis, a method for trouble-shooting a defective television ı procedure for solving quadratic equations, or a procedure for de- ıg instruction. A procedural structure may specify the set of orders ch different steps can be performed, or it may show the conditions ary for deciding which procedure, sub-procedure, or step to use in n situation.

The *conceptual structure* shows the superordinate, coordinate, and linate relations among related constructs in a subject matter. There ıree types of conceptual structures. In a "kinds taxonomy" a sub- te concept is a *kind* of the concept to which it is subordinate, s a bear being a kind of mammal. In a "parts taxonomy" a subordinate t is a *part* of the concept to which it is subordinate, such as a atory system being a part of a mammal. Two or more taxonomic struc- can be combined to form a "matrix structure," and many subject matters usefully described with a kinds by parts matrix.

The *theoretical structure* (or model) shows the interactions or cause fect relations among concepts. These interacting cause and effect

relations are referred to individually as principles, and they basically explain why something happens as it does. A diagram which shows the cause and effect interactions among the supply, the demand, and the price of a good is a theoretical structure.

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 structure and the parts taxonomic structure.

The *list structure* shows a linear (order) relation among its concepts. 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 elsewhere.[41] 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 what content to teach, given the orientation goals and curriculum level of the course, (2) sequencing strategies, for deciding on the order in which to present the selected concepts, principles, etc., (3) synthesizing strategies, for deciding how and when to show the important relations among those concepts, principles, etc., and (4) summarizing strategies, for deciding how and when to preview and review those concepts, principles, etc., and the relations among them. It is beyond the scope of this overview to provide a detailed description of all the different strategy components that we have developed to date. But as an indication, Figure 10.3 lists the major synthesizing strategy variables that 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.

7. *PRINCIPLES OF STRUCTURAL ADEQUACY.* 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 they are too general to be very useful, they do provide an indication of the kinds of relationships that we feel are likely to be important for improving the methods of structuring instruction.

> *i. Initial Synthesis Principle.* A general synthesizer -- which shows the major parts of the orientation structure and the major relationships among those parts -- should be presented at the very beginning of the instruction. ('Should' means that doing so will result in the instruction being more effective, efficient, and appealing.)

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, ANALOGOUS

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 10.3

The Major Synthesizing Strategy Variables Identified to Date

ii. Gradual Elaboration Principle. A synthesizer (i.e., a subject matter structure) should be provided after each elaboration (i.e., after each part of the initial synthesizer has been elaborated), in order to teach the relations among the more detailed constructs that were just taught and to show the context of the elaboration within the epitome. The detail or complexity of the relations taught should correspond to the detail or complexity of the concepts, principles, etc. that are taught in each elaboration.

iii. Type of Synthesizer Principle. The following types of synthesizers should be used under the indicated conditions: a conceptual structure for conceptual goals, a theoretical structure for theoretical goals, and a procedural structure for procedural goals.

iv. Periodic Summary Principle. A summarizer (e.g., a concise generality for each concept) should be provided after each elaboration but before the synthesizer for each respective elaboration. This will facilitate synthesis and retention.

8. *A MODEL FOR STRUCTURING INSTRUCTION.* The authors have constructed a tentative model of the way that we presently expect that instruction should be organized with respect to structural strategies. We refer to it as the "elaboration model of instruction."[42] Although some aspects of the model vary depending upon conditions, there are also some basic, unvarying aspects of the model, and they are briefly described below by use of an analogy.

Taking a look at a subject matter "through" the elaboration model is similar in many respects to looking at a picture through a *zoom lens*. A person usually starts with a *wide angle view*, which shows the major parts of the picture and the major relationships among those parts (e.g., the composition or balance of the picture).

The person then zooms in on a part of the picture. One could be forced to zoom in on a certain part, or one could be given the option of zooming in on whatever part interests that person the most. Assume that instead of being continuous, the zoom operates in steps, or discrete levels. Zooming in one level on a given part of the picture allows the person to see more detail on the major subparts of that part and to see the major relationships among those subparts. At this point several options are available. The person could pan across at the same level of detail to another part of the picture. Or one could continue to zoom in another level for more detail or complexity on one of the subparts. Or one could zoom back out to the wide angle view to review the context of that part within the whole picture. Again, the person could be forced to follow a certain pattern, could be given the option of following any of a limited number of types of patterns, or could be given total freedom to follow any pattern that she or he chooses, as long as no subpart is inspected before it has been seen from the next higher level.

After viewing a set of details on a part of the picture (i.e., subparts directly below a given part), the person should zoom back out to revisit the whole part in order to synthesize that detail -- that is, to see with greater detail and understanding, the relationships among those subparts.

It must be remembered that the zoom lens analogy is just an analogy and therefore that it has non-analogous aspects. One such dissimilarity that all the detail of the picture is actually present in the wide gle view, whereas the detail is not there at all in the epitome. Also, tail is added in discrete steps in the elaboration model. Nevertheless, e similarities are many, and the analogy is insightful.

The elaboration model of instruction starts the student with a very oad, general view of the subject matter to be taught. Then it divides at subject matter into parts, elaborates on each of those parts, divides ose parts into subparts, elaborates on each of those subparts, and so until the knowledge has reached the desired level of detail and com- exity.

This general to detailed organization allows the learner to learn at level of detail that is most meaningful[43] to him or her at any given ate in the development of his or her knowledge. The learner is always are of the context and importance of the different topics being learned. is meaningful context improves student long-term retention and student tivation. Also, the learner never has to struggle through a series of arning prerequisites that are on too deep a level of instruction. As e learner works down to deeper levels of detail, increasingly complex erequisites will need to be introduced. But if they are only intro- ced at the level of detail at which they are necessary, then the learner ll want to learn those prerequisites because he or she will understand eir importance for learning at the level of detail that now interests n or her.

This elaboration model of instruction is described in greater detail sewhere.[44]

9. *APPLICATION PROCEDURES FOR STRUCTURAL ADEQUACY.* Finally, the llowing is a tentative six-step procedure for implementing the elabora- on model in the design of instructional materials (See Figure 10.4).

Step 1. Choose the Type of Orientation Structure. On the basis of the general goals of the instruction, select one of the three types of orientations: conceptual, procedural, or theoretical.

Step 2: Make the Orientation Structure. This content task analysis step requires the development of the most detailed or complex version of the orientation structure selected. Detailed procedures have been developed for doing this,[45] and they are very briefly summarized in Figure 10.4.

Step 3: Analyze the Orientation Structure. This step entails analyzing the orientation structure just created in order to identify which parts of it should be taught in the "epitome" and which should be taught in each level of elaboration. The epitome is a kind of overview that epitomizes the orientation structure -- it is an extract of the essence of the

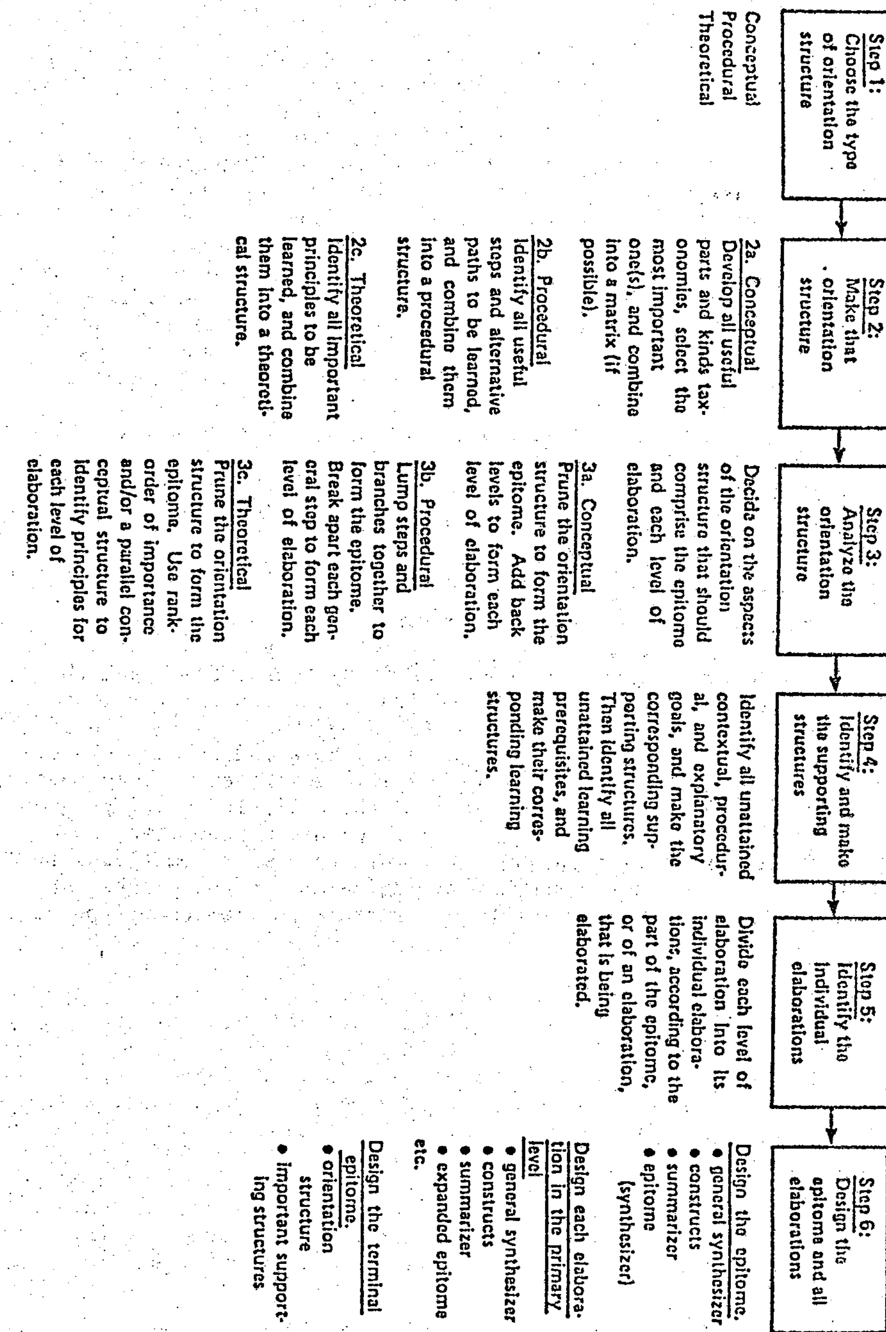

FIGURE 10.4

The six-step design procedure for structuring the instruction in any course entailing cognitive subject matter.

orientation structure. Again, detailed procedures have been developed for doing this,[46] and they are briefly summarized in Figure 10.4.

Step 4: Identify and Make the Supporting Structures. This content task analysis step requires identifying and making all the important supporting structures for the parts of the orientation structure in the epitome and in each level of elaboration. This step is basically the same regardless of the kind or orientation structure selected, and it is also briefly summarized in Figure 10.4.

Step 5: Identify the Individual Elaborations. This step entails allocating the subject matter content in each level of elaboration to the individual elaborations that comprise each level. The supporting structures and the parts of the orientation structure are allocated on the basis of the part of the epitome on which each elaborates.

Step 6: Design the Epitome and all Elaborations. The last step of the instructional design procedure is to make a "blueprint" of what the instruction (e.g., course, textbook, etc.) should look like. As for the other five steps, detailed procedures have been developed for doing this step,[47] and they are briefly summarized in Figure 10.4.

This is a very tentative procedure which, along with the elaboration model, requires much testing and improvement. Nevertheless, we are fairly confident that type of structure should be 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.

REMAINING NEEDS FOR THE KNOWLEDGE BASE

The work that we have done to date and are currently doing is a step toward the goal of being able to improve the 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. However, in the area of structural adequacy, much work remains to be done, especially with respect to the identification 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 points to the need for investigating the relative contribution to learning (both qualitatively and quantitatively) of each strategy component when in combination (interaction) with all the strategy components which contribute more than the one component does.

4 *AND* 5. *DEVELOPMENT AND TESTING OF MODELS OR THEORIES.* Very little of what is needed has been done with respect to developing models of optimal combinations of strategy components, and even less has been done to test such models. The authors[48] have described a research methodology which 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 which 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, 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. 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 evaluation procedures (both for diagnosis of weaknesses and for rating of effectiveness), 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.

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 terms of student time vs. contribution to performance, and in terms of 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 excited about recent progress on structural adequacy. But much work remains to be done in both areas, and the areas of delivery strategies and management strategies are even more wide open. It is our hope that this chapter will help draw attention to the importance of developing the knowledge base that is necessary for improving the methods of instruction. And we hope it will draw attention to the need for much greater effort and expenditure of resources in this important endeavor.

SUMMARY

First we discussed the *context* of instructional science and instructional technology within the discipline of educology. Instructional science and technology lie exclusively within the area of empirical studies about instruction.

Second, we described the nature of instructional science and instructional technology. The purpose of both is to develop methods of instruction that are more effective, efficient, and appealing. The importance of studying clearly characterized strategy components was discussed. And we described the concern of instructional science as being with the discovery of principles and theories of instruction, while the concerns of instructional technology is with the development of procedures for applying scientific knowledge to the solution of practical problems in instruction, such as diagnosing weaknesses in existing instruction and designing highly effective new instruction.*

Third, we proposed that seven activities are necessary if we are to develop adequately the scientific and technological knowledge base for improving methods of instruction. The seven activities are: (1) the precise definition and unambiguous naming of instructional concepts and variables, (2) the derivation of hypothesized principles, (3) the experimental testing of those principles, (4) the development of models (or theories) which prescribe "optimal" combinations of strategy components, (5) the experimental testing of those models, (6) the development of application procedures, and (7) the testing of those application procedures.

Fourth, we summarized our related work to date on those seven activities. (1) Some *basic concepts* were described, including a variety of kinds of methods (organizational, delivery, management) and strategies (presentation and structural). Some specific strategy components were described (generalities, instances, generality practice, and instance practice for presentation strategies; and synthesizers, summarizers, epitomes, and elaborations for structural strategies), and the conditions which are used as a basis for prescribing strategies were also described (content types -- facts, subsets, concepts, procedures, and principles -- and task levels -- remember examples, remember generalities, and use generalities -- for prescribing presentation strategies; and types of structures -- procedural, conceptual, theoretical, learning, and list -- for prescribing structural strategies). (2) Some *prescriptive principles* were described, both for presentation adequacy (presentation consistency; primary presentation form selection, sequence, contents, and isolation; quantity of instances and instance practice; and instance sampling and matching) and for structural adequacy (initial synthesis, gradual elaboration, type of synthesizer, and periodic summary). (3) Some *research* testing the principles of presentation adequacy was briefly mentioned. (4) A *model* for structural strategies was summarized (the elaboration model of instruction), and the zoom lens analogy was presented; (5) No *research* has been done on this model to date. (6) Some *procedures* for applying the above-mentioned models and principles were described, both for presentation strategies and for structural strategies. And (7) some *research and field testing* of the procedures in the area of presentation strategies were briefly mentioned.

Fifth and finally, we described what we believe are some of the most important remaining needs for the further development of the scientific and technological knowledge base for improving the methods of instruction. These remaining needs are far greater than the progress that has been made to date, and there is a strong need to attract bright young people and more consistent funding to help push back the frontiers of this tremendously important field of educology.

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*In this summary, Reigeluth and Merrill make it clear that they are using 'science' and 'technology' close to the way that Steiner uses 'praxiology' and 'praxis' and Monshouwer uses 'technology' and 'technics'.

INSTRUCTIONAL SCIENCE AND TECHNOLOGY

FOOTNOTES

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22. M.D. Merrill, R.A. Richards, R.V. Schmidt, and N.D. Wood, *Op. Cit.* (Note 18).

23. M.D. Merrill and N.D. Wood, *Op. Cit.* (Note 15).

24. M.D. Merrill and N.D. Wood, *Op. Cit.* (Note 16).

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46. *Ibid.*

47. *Ibid.*

48. C.M. Reigeluth, *Op. Cit.* (Note 10).