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ABSTRACT

The Structural Strategy Diagnostic Profile Project developed the elaboration model of instruction as a superior alternative to standard instructional sequencing based on hierarchical task analysis. The theory construction phase, the first of two phases, identified the instructional variables, postulated cause-effect relationships, and proposed optimal configurations of instructional conditions and methods through the construction of a model (or theory); the second phase included the application of the instructional model to the design of a course in a subject-matter area and the development of procedures for implementing this model in the design of new instruction. Four major products of the project are described: (1) an instructional model for sequencing, synthesizing, and summarizing related parts of a subject matter; (2) a taxonomy of the variables that are included in the model; (3) a set of procedures for designing instruction, based on the instructional model; and (4) a 'blueprint' illustrating the application of those procedures for the redesign of the Navy's Basic Electricity and Electronics course. (RAO)

FINAL REPORT ON THE STRUCTURAL STRATEGY DIAGNOSTIC PROFILE PROJECT

REPORT NO. UDI-H-704

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This final report is a summary of NPRDC task number 31 on the Structural Strategy Diagnostic Profile Project, in completion of a contract (No. N00123-76-C-0245, CW-0245-31) with the Navy Personnel Research and Development Center (NPRDC) in San Diego, California.

This report is not intended for practitioners. It describes a pioneering effort to find better ways to structure (i.e., to sequence and synthesize) instruction. Much work remains to be done to validate the instructional model and to field test the instructional design procedures developed in this project.

There are four sections in this summary report. The first section describes the procedures that were used in the project, and it summarizes the nature of the products of the project. The second section is an in-depth description of the results of the project. The third section discusses the applicability of the results to Navy training. And the fourth section indicates some areas which we feel have the most urgency for further investigation.

SECTION 1

PROCEDURES AND PRODUCTS

This section describes the procedures that were used in the Structural Strategy Diagnostic Profile Project, and it summarizes the nature of the products of the project.

Procedures

There were two major phases to the project: a theory-construction phase and an application phase. The theory-construction phase entailed three distinct yet interrelated activities (see Figure 1): (1) the identification of the instructional variables (i.e., concepts) that are of importance for sequencing, synthesizing, and summarizing related parts of a subject matter; (2) the postulation of cause-and-effect relationships (i.e., principles) among those variables; and (3) the construction of a model (i.e., theory) that proposes optimal configurations of instructional conditions and methods, based largely on those principles.

Insert Figure 1 about here

These three activities of the theory-construction phase were cybernetically related as is indicated by Figure 1. Therefore, they did not comprise a purely linear sequence, as is common in many procedures. For instance, in identifying useful instructional variables, there are many ways in

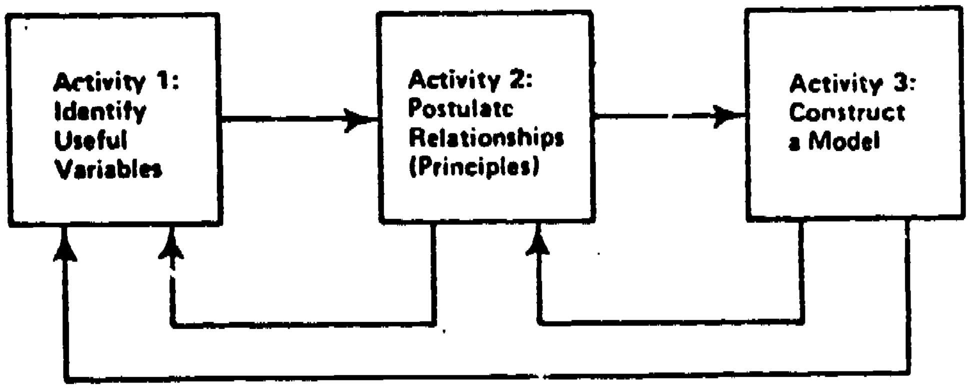


Figure 1. The three activities comprising the cybernetic, theory-construction phase of the project.

which one can classify a given set of instructional phenomena. One could classify methods of instruction according to the kind of subject matter being taught (e.g., methods for teaching mathematics, methods for teaching reading), according to the medium of instruction (e.g., lecturing methods, tutoring methods), according to the nature of the students (methods for early childhood, methods for "special" children, methods for the disadvantaged), etc., etc. The usefulness of the way in which we conceptualize or classify instructional phenomena depends upon the stability, magnitude, and importance (meaningfulness) of the cause-and-effect relationships that are found to exist among those concept classes. Hence, the results of postulating principles (activity 2 in Figure 1) lead to the acceptance, rejection, or modification of the variable scheme developed (activity 1 in Figure 1). In a similar way, the construction of an instructional model (activity 3) can lead to the recognition of important principles and/or variables that were overlooked.

The application phase, which was the second of the two major phases of the project, entailed two distinct but again related activities: (1) the application of the instructional model to the design of a course in a subject-matter area, and (2) the development of procedures for implementing the instructional model in the design of new instruction. This phase was also a cybernetic process. It began with the theoretical development of procedures based upon logic. Those procedures were then tried out on designing the course, which led to modification and elaboration of the procedures, which in turn were reapplied to the design of the course, etc.

Products

There were four major products of the project: two for each phase. The theory-construction phase resulted in the production of (1) a description of an instructional model (or theory) for sequencing, synthesizing, and summarizing related parts of a subject matter, and (2) a description and classification (i.e. a taxonomy) of those concepts or variables which are included in that model. An additional but minor product of this phase was a list of postulated principles which guided the construction of the model.

The application phase of the project resulted in the production of (1) a set of procedures for designing instruction, based on the instructional model, and (2) a "blueprint" showing the result of using those procedures for the redesign of the Navy's Basic Electricity and Electronics course. An additional but minor product of this phase was a comparison of this "blueprint" with the old structure of the same course.

SECTION 2

RESULTS OF THE PROJECT

This section of the final report presents the four major products mentioned above: (1) a description and classification of instructional concepts or variables that are included in the instructional model, (2) a description of the model for sequencing, synthesizing, and summarizing related parts of a subject matter, (3) a set of procedures for designing instruction according to the model, and (4) a "blueprint" of a course derived from the use of those procedures. The two minor products are also presented herein: (1) a list of postulated principles which guided the construction of the model and (2) a comparison of the "blueprint" with the old structure of the same course. This section is comprised of slightly modified versions of the three progress reports for this project. (Note: we say three progress reports because the fourth report is a revised version of the third report.)

SECTION 2, PART 1

CONTEXT OF STRUCTURAL STRATEGIES

The following is a general-level classification scheme that we believe to be very valuable as a framework for conceptualizing and investigating the effects of different methods of instruction under different conditions.

Because our goal is to prescribe optimal methods of instruction, our first classification is the division of the world of instruction into three categories: conditions, methods, and outcomes (see Figure 2).

CONDITIONS: Factors that (a) influence the outcomes of one or more methods of instruction by interacting with that or those methods and (b) cannot be manipulated by the instructor or textbook writer.

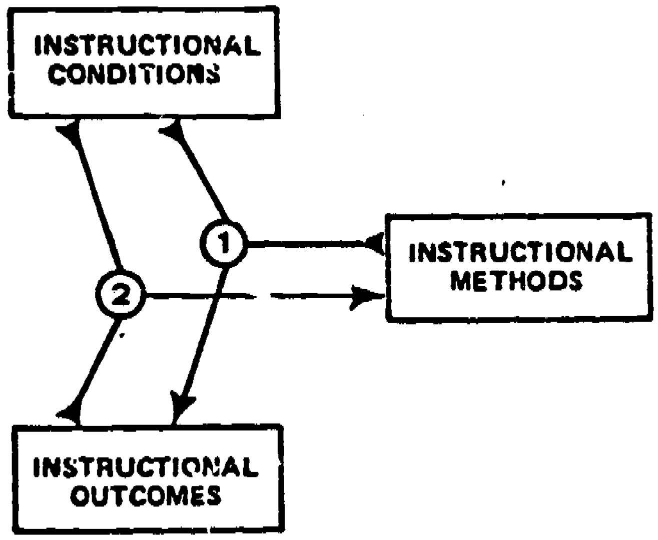
METHODS: Ways to achieve certain outcomes under certain conditions. If a "method" cannot be manipulated in a given situation, it becomes a condition.

OUTCOMES: The various effects that can result from the use of instructional methods and which provide a basis for measuring the value of alternative methods.

Insert Figure 2 about here

Methods can be of three kinds: methods for organizing instruction, methods for delivering the instruction to the learner, and methods for managing the interaction of the learner with the instruction (see Figure 3).

ORGANIZATIONAL STRATEGIES: Methods for deciding how to organize the material that has been selected for instruction. "Organize" refers to such things as choice of words, diagrams, format, and student response possibilities.



① For an instructional researcher the condition variables and the method variables are independent variables; and their parameters may interact to produce fairly consistent effects on the outcome variables, which are dependent variables.

② For an instructional designer (e.g., a professor or textbook writer) the desired outcomes and the conditions are independent variables which may also interact; and their parameters are used to prescribe good methods of instruction which are the dependent variables.

Figure 2. Three categories of instructional variables, and two sets of interrelationships among those categories.

DELIVERY STRATEGIES: Methods for conveying the content of the instruction to the learner and/or for receiving and responding to input from the learner. Delivery systems are the agents which convey, receive, and/or respond to the learner.

MANAGEMENT STRATEGIES: Methods for arranging the interaction between the learner and the other method variables—the organizational and delivery strategy components.

Insert Figure 3 about here

Next, conditions may be grouped according to which ones have the major influence on each of the three classes of methods.

GOALS AND SUBJECT-MATTER CHARACTERISTICS: Instructional goals are statements about what the results of the instruction should be. Subject-matter characteristics are aspects of all subject-matter areas which provide a useful basis for prescribing structural strategies.

CONSTRAINTS: Limitations of resources that influence the choice of methods in one way or another. Time, equipment, personnel, and money are the most obvious constraints in instruction.

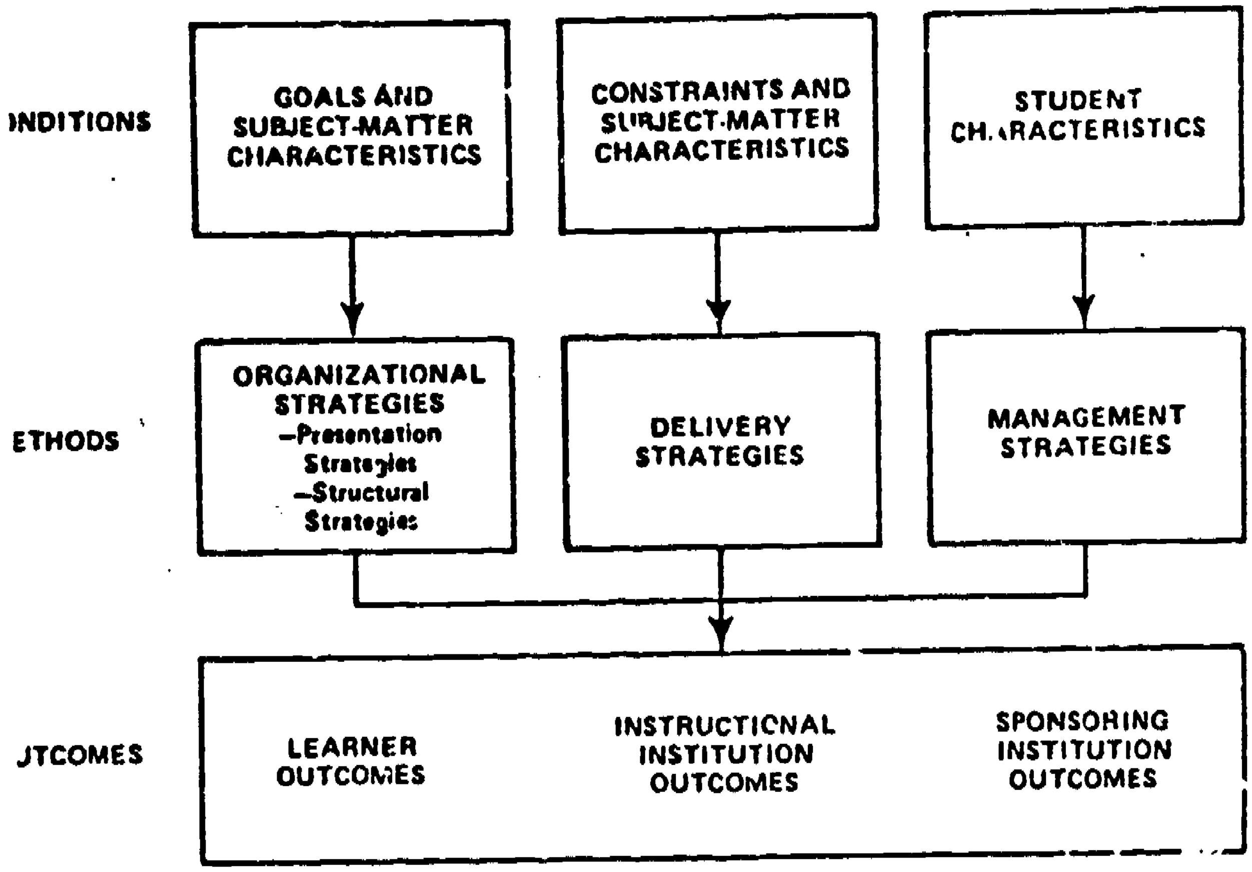


Figure 3. A model showing classes of instructional variables and the major relationships among them.

STUDENT CHARACTERISTICS: Qualities or aspects of an individual student that interact with methods to affect learning outcomes. These include ability, motivation, self-concept, and handicaps.

Thirdly, instructional outcomes may be divided into three categories: learner outcomes, instructional institution outcomes, and sponsoring institution outcomes.

LEARNER OUTCOMES: All those outcomes which impact upon the learner. They include the effectiveness, efficiency, and appeal of the instruction.

INSTRUCTIONAL INSTITUTION OUTCOMES: All those outcomes which impact upon the institution providing the instruction. They include learner outcomes, monetary costs, management demands, and appeal to personnel.

SPONSORING INSTITUTION OUTCOMES: All those outcomes which impact upon the institution that pays for the instruction. They include learner outcomes, monetary costs, and the appeal of the objectives attained to the sponsor.

These general classes of instructional variables tend to interact with each other in fairly consistent ways, as indicated by the arrows in Figure 3. But those are by no means the only ways in which they interact. For instance, some student variables may interact with some organizational strategy variables.

Within this broad framework of instructional variables, we are currently concerned only with those variables which relate to organizational strategies--primarily the variables in the left-hand column in Figure 3. However, there are two important kinds of organizational strategies: presentation strategies and structural strategies.

> PRESENTATION STRATEGIES: Organizational strategies which are methods for organizing the instruction on a single construct.
>
> STRUCTURAL STRATEGIES: Organizational strategies which are methods for organizing aspects of instruction that relate to more than one construct (i.e., to structures).

For our present purposes, we are only interested in (1) structural strategy variables and (2) in those condition variables which interact with structural strategy variables. The following section is a taxonomy of the important concepts and variables related to structural strategies.

A TAXONOMY OF VARIABLES RELATED TO STRUCTURAL STRATEGIES

In order to talk in any detail about sequencing and synthesizing subject-matter content, a number of new concepts relating to instruction and some unambiguous labels for familiar concepts need to be introduced. The purpose of this part of Section 2 is to introduce the basic set of concepts and terminology that will be used throughout the rest of this report in discussing content structure and its related instructional strategies.

We are interested in developing methods of instruction that are highly effective under different conditions. But the way we conceptualize and categorize those conditions and methods can have a large impact on the stability and usefulness of the relationships that are identified between those conditions and methods. Therefore, a matter of great importance is the manner in which we define and classify all the methods and conditions that we wish to investigate; and the ultimate value of any classification scheme that we adopt is determined by the stability, magnitude, and importance (meaningfulness) of the cause-and-effect relationships that are found to exist among those categories.

There are two factors that can influence the stability and magnitude of those cause-and-effect relationships: (1) the preciseness of definition of the categories and (2) the nature of the categories. The nature of the categories is determined by the way in which referents (objects, symbols, and events) are classified. For instance, trees may be classified according to their age (e.g., seedling, sapling), their kind of leaf (e.g., pine, deciduous), or their genus (e.g., oak, maple). The instructional world can also be "sliced" in different ways. Practically all classification schemes improve our understanding of the objects, symbols, or events being categorized; but some of them will have high predictive value, while others will have virtually no value for predicting the outcomes of instruction.

With respect to the preciseness of definition, many categories of methods that are frequently used in research and theory construction are not very useful because the stability of their cause-and-effect relationships is jeopardized by the looseness or the high level of generality of their definition. For instance, "lecture" vs. "discussion group", "inductive" vs. "deductive". and "discovery" vs. "reception" may often vary more within each category than between categories. In such cases, it is necessary to break down these "methods" into their building blocks, and to base one's research and theories on those more precise and clearly-defined strategy components.

In this taxonomy of variables related to structural strategies, we will first describe and categorize the condition variables that we feel are likely to interact with structural strategies. Then we will describe and categorize the structural strategy variables as we currently conceptualize them.

Condition Variables

The two important classes of condition variables that interact with the structural strategy variables are subject-matter characteristics and instructional goals.

SUBJECT-MATTER CHARACTERISTICS: Aspects of all subject-matter areas which provide a useful basis for prescribing structural strategies.

INSTRUCTIONAL GOALS: General statements about what the results of the instruction should be (Objectives are far more detailed than goals.)

We shall discuss subject-matter characteristics first. But in order to proceed with this taxonomy of conditions related to structural strategies, we must first introduce some prerequisite concepts. All subject matter has its origins in referents. A REFERENT is an object, event, or symbol which exists in our real or imagined environment. For convenience, referents are grouped together into concepts. A CONCEPT is a set of referents which are grouped together on the basis of one or more common characteristics, which are referred to as "critical attributes". As referents are the atomic particles of subject matter, so concepts are the elements with which all subject matter is constructed; and subject matter does not exist except as we create it from referents and concepts.

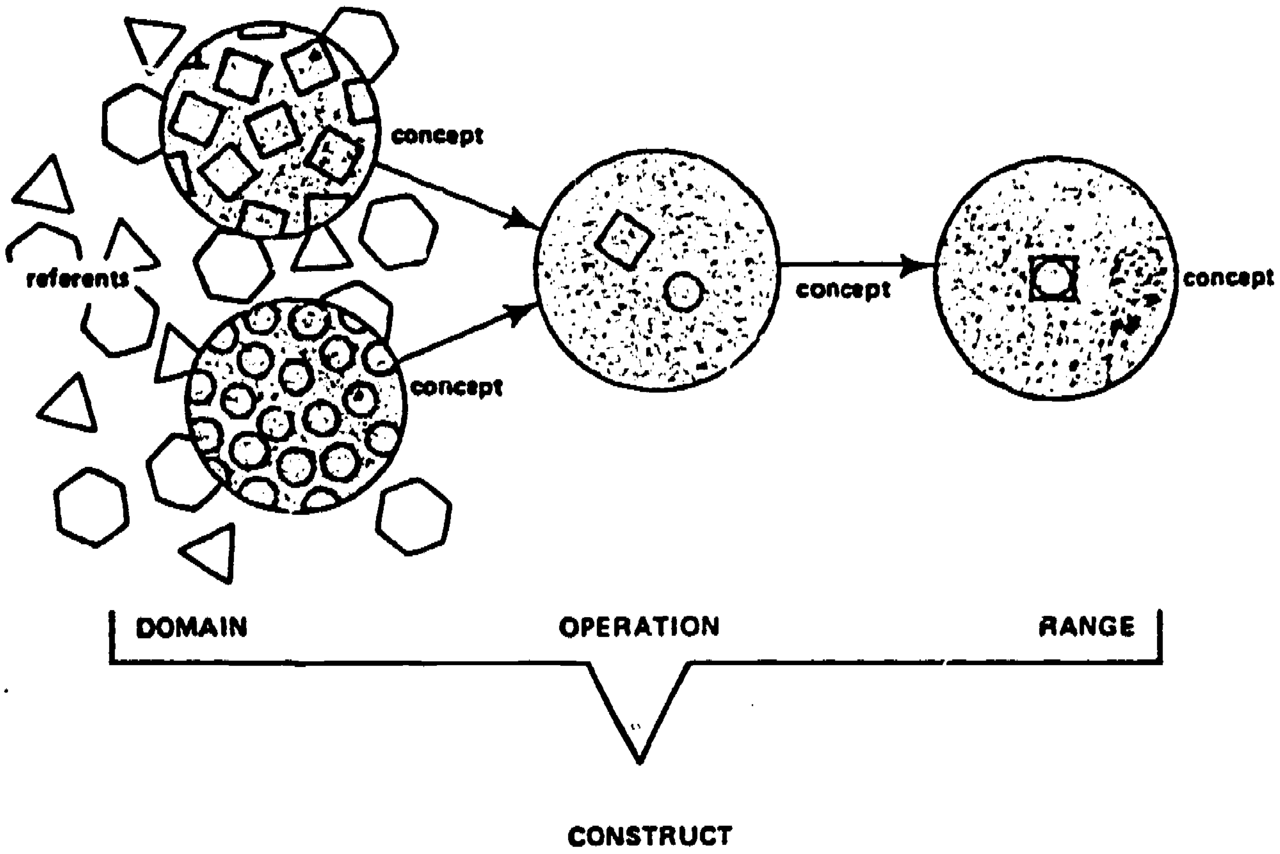
All subject-matter components can be conceptualized as having three parts: a domain, an operation, and a range (Merrill, 1973; Merrill & Wood, 1975a, 1975b; Reigeluth, Merrill, & Bunderson, 1978; Scandura, 1968, 1970). A DOMAIN is comprised of one or more referents of one or more concepts, hereafter referred to as "domain concepts". A

RANGE is also comprised of one or more referents of one or more concepts, hereafter referred to as "range concepts". And an OPERATION describes a particular mapping between a domain and a range. An operation, when applied to instances of the domain concept(s), results in the selection of corresponding instances of the range concept(s). (See Figure 4). The overall construction (i.e., the domain, operation, and range taken together) is referred to as a content construct. It will become apparent from the examples provided below that constructs are in effect made up of other constructs, for domain and range concepts are themselves constructs, having their own domain, operation and range.

Insert Figure 4 about here

However, in addition to comprising other constructs, constructs may be grouped into a structure on the basis of a single pervasive relation among those constructs (Reigeluth, Merrill, & Bunderson, 1978). This single pervasive relation is similar to an operation except that (1) the range of one construct serves as the domain of another construct and (2) the pervasive relation serves as the operation for all constructs in the structure. Examples of structures are also provided below.

COMPONENTS OF SUBJECT MATTER



REFERENT (INSTANCE). A referent (or instance) is an object, event, or symbol which exists, or could exist, in our real or imagined environment.

CONCEPT. A concept is a set of common characteristics (attributes) referenced by a particular name or label, that can be applied to a set of referents (instances of that concept).

OPERATION. An operation is a function set or a set of operators which specifies a particular mapping between a domain and a range.

DOMAIN. A domain is a set of referents upon which the operation acts or to which it is applied.

RANGE. A range is a set of referents which results from the application of an operation to a domain.

CONSTRUCT. A construct is a structure consisting of a domain, an operation, and a range.

Figure 4. The composition of a content construct

Returning to our taxonomization for <u>subject-matter characteristics</u>, the above-described conceptualization of subject matter leads to its classification as constructs, structures, and multi-structures.

CONSTRUCT: A single domain, operation, and range taken as a unit.

STRUCTURE: A "multiple-construct" in which the range of one construct is the domain of another construct having the same kind of operation. This single, pervasive kind of operation is referred to as a <u>relation</u>.

MULTI-STRUCTURE: A "multiple-structure" in which the relations among two or more structures are shown.

The major kinds of <u>constructs</u> (which seem to have the most utility for prescribing organizational strategies) are: facts, concepts, subsets, principles, and steps of procedures. (See Reigeluth, Merrill, & Bunderson, 1978, for a more detailed description.) Figure 5 illustrates these five kinds of constructs.

FACT: A one-to-one mapping between two referents (a domain and a range), such as "Columbus discovered America in 1492." A common type of fact is an <u>identity</u>, in which one referent is equivalent to the other.

CONCEPT: A class of referents (the range concept) which are grouped on the basis of certain common characteristics (the domain concepts). The operation specifies either a union ("and") or an intersection ("or") relationship among the domain concepts to form the range concept.

SUBSET: A set of concepts which are parts or kinds of a single (superordinate) concept. The operation specifies that referents of the subordinate concepts (the domain concepts) are either parts or kinds of the referents of the superordinate concept (the range concept).

PRINCIPLE: The operation specifies a cause-and-effect relationship among several event concepts. The event concept that is the cause is the domain concept, and the effect is the range. There may be more than one concept on the cause and/or the effect side.

STEP: The specification of specific actions to take in order to execute some clearly defined behavior or achieve some clearly defined objective. The domain concepts are event concepts which represent the actions to be taken; the range concept is the objective; and the operation is the order in which the actions should be taken.

Insert Figure 5 about here

The major kinds of <u>structures</u> which seem to have the most relevance for organizational strategies are: lists, learning structures, conceptual structures, theoretical structures (or models), and procedural structures. (See Reigeluth, Merrill, & Bunderson, 1978, for a more detailed description.)

LIST: A structure showing 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. See Figure 6 for an example.

Insert Figure 6 about here

LEARNING STRUCTURE: A structure showing learning-prerequisite relations among its constructs (i.e., it shows the critical components of principles--which are concepts--it shows the critical components or attributes of those concepts--which are also usually concepts--and so on.) These are often referred to as learning hierarchies, but other kinds of structures (e.g., parts-type taxonomic structures and procedural-prerequisite structures) are often confused

CONSTRUCT

Fact

The symbol shown is used to represent a vacuum tube on a schematic diagram of an electronic circuit.

Subset

Parallel circuits, series circuits, and combination circuits are three kinds of circuits.

Concept

A circuit is at resonance when reactive capacitance and reactive inductance are present in equal amounts (in a series RLC circuit).

Step

To "zero" the ohmmeter:
1. Turn range selector to desired setting.
2. Touch probes together.
3. Adjust ohms control until a zero reading is achieved.

Principle

An increase in frequency in a AC circuit produces a decrease in total current and an increase in total impedance.

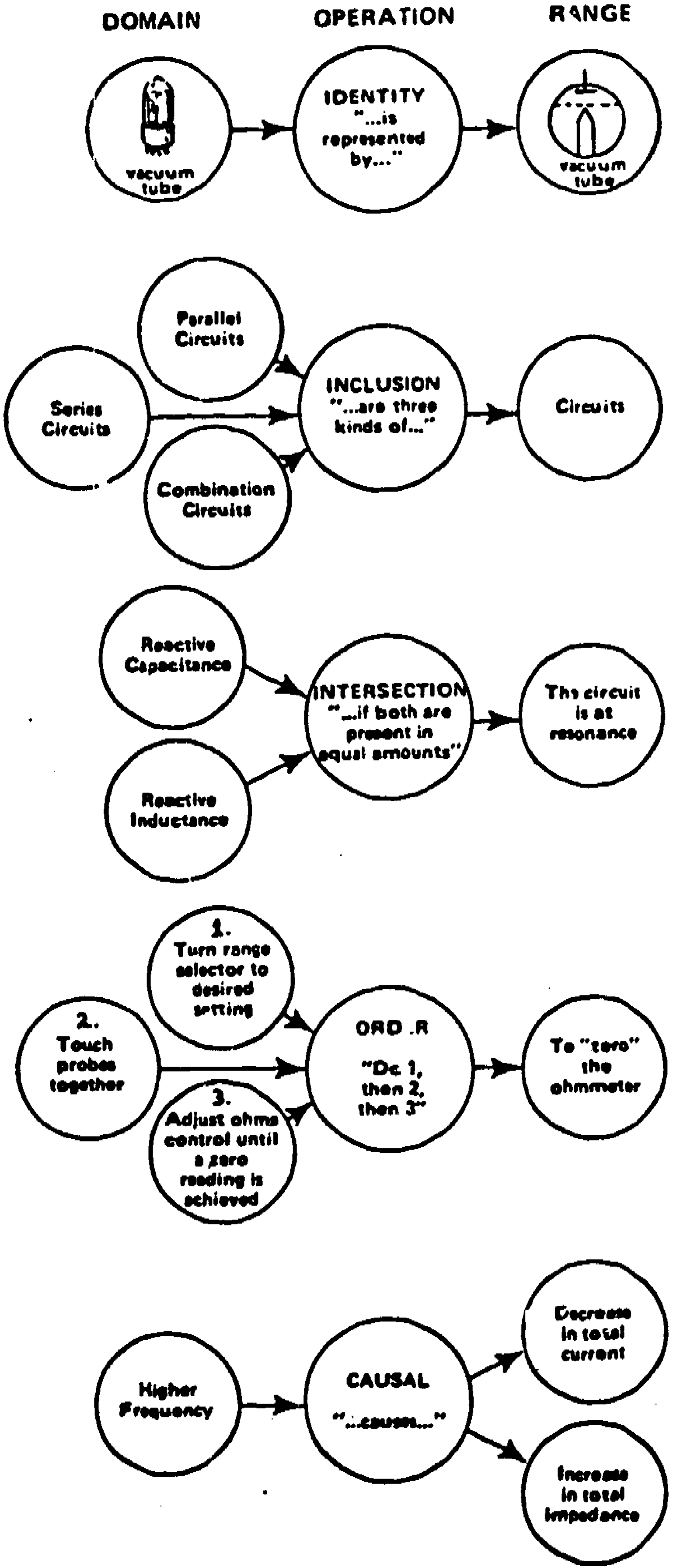


Figure 5. An example of each of the five kinds of constructs.

Important terms in electronics.

AMPERAGE

CAPACITANCE

CURRENT

FREQUENCY

IMPEDANCE

INDUCTION

POWER

REACTANCE

RESISTANCE

Key: the items in the list are arranged in alphabetical order.

Figure 6. An example of a list structure.

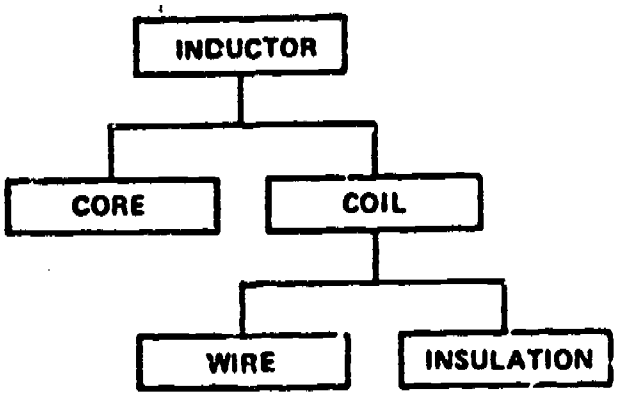
with learning hierarchies. See Figure 7 for an example.

Insert Figure 7 about here

CONCEPTUAL STRUCTURE: A structure showing superordinate/coordinate/subordinate relations among constructs. There are three important types of conceptual structures: parts taxonomies, which show constructs that are components of a given construct; kinds taxonomies, which show constructs (usually concepts) that are varieties of a given construct; and matrices (or tables), which are combinations of two or more taxonomies. See Figures 8, 9, and 10 for examples of these three kinds of conceptual structures.

Insert Figures 8, 9, and 10 about here

THEORETICAL STRUCTURE: A structure showing change relations among constructs. The most common kind of theoretical structure, or model, is that which shows empirical relations (see Figure 11). Another important kind is one which shows logical relations (see Figure 12). Klausmeier (1977) identified three kinds of empirical relations: cause and effect, correlation, and probability. He also labeled logical relations as



Key: The line between two boxes on different levels means that the lower box is a part of the higher box.

| = relation (all lines represent the same relation in a structure)

☐ = construct

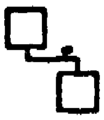
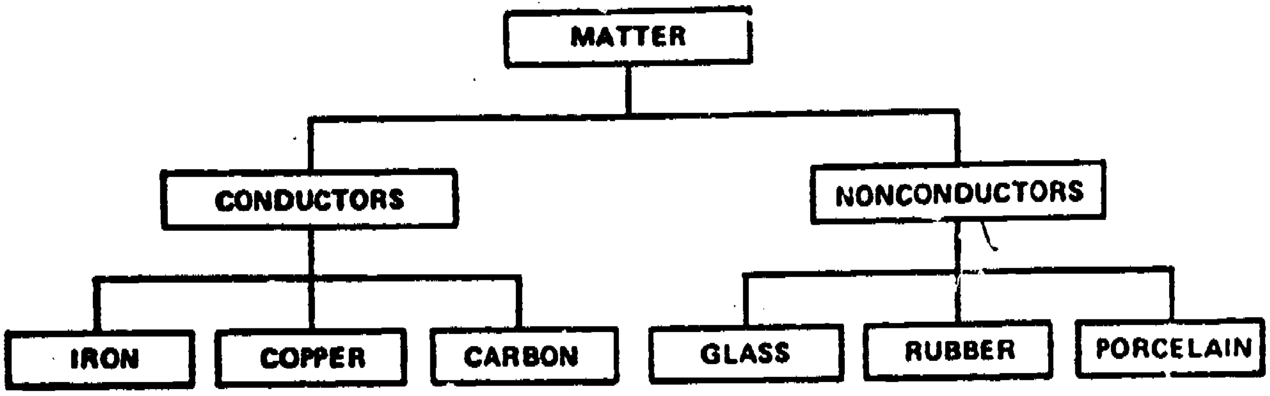
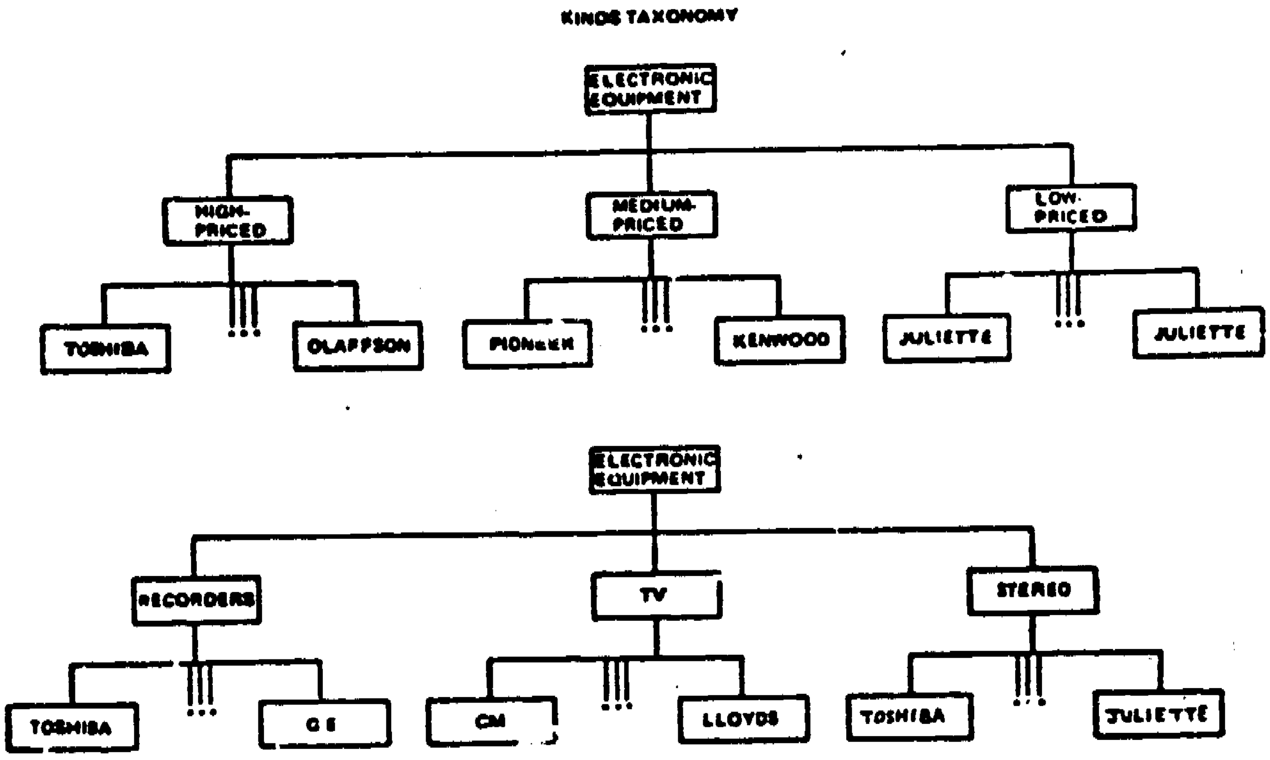
NOTE:  is also a construct, in which case the relation becomes an operation.

Figure 8. An example of a parts-taxonomic structure.



Key: The line between two boxes on different levels means that the lower box is a kind of the higher box.

Figure 9. An example of a kinds-taxonomic structure.



	TAPE RECORDERS	TELEVISION SETS	STEREO SYSTEMS
HIGH-PRICED	TOSHIBA SONY	CURTIS MATHUS SONY	TOSHIBA OLAFFSON
MEDIUM-PRICED	PIONEER PANASONIC	QUASAR HITACHI	YAMAHA KENWOOD
LOW-PRICED	JULIETTE GENERAL ELECTRIC	FLEETWOOD LLOYDS	SOUNDESIGN JULIETTE

Key: Each box contains instances of both its row heading and its column heading.

Figure 10. An example of a kinds-by-kinds matrix structure (or table). The parts of the two kinds taxonomies from which the matrix was constructed are shown at the top.

axiomatic. One of the major tasks of any dicipline is to discover or create logical structures which are isomorphic with empirical structures.

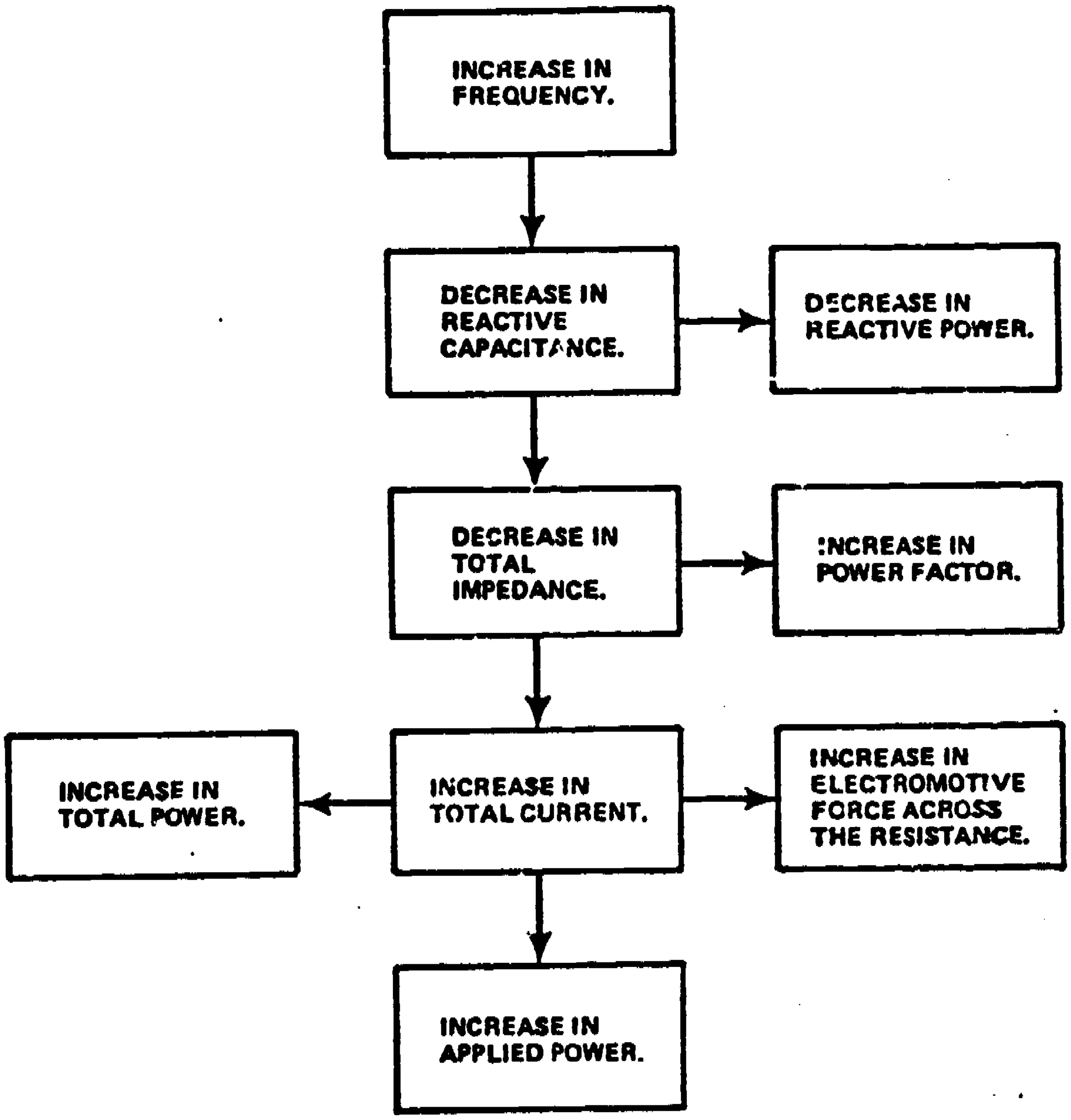
Insert Figures 11 and 12 about here

PROCEDURAL STRUCTURE: A structure showing procedural relations among constructs. There are also two important kinds of procedural structures: those which show procedural-prerequisite relations, which specify the order(s) for performing the steps of a single procedure, and those which show procedural-decision relations, which describe the factors necessary for deciding which alternative procedure or sub-procedure to use in a given situation. See Figures 13 and 14 for examples.

Insert Figures 13 and 14 about here

There is another valuable way in which content structures can be classified. They may be orientation structures or supporting structures (see Figure 15).

ORIENTATION STRUCTURE: A structure which is highly inclusive in that it subsumes all or most of the subject matter to be taught. It may be conceptual, procedural, or theoretical.



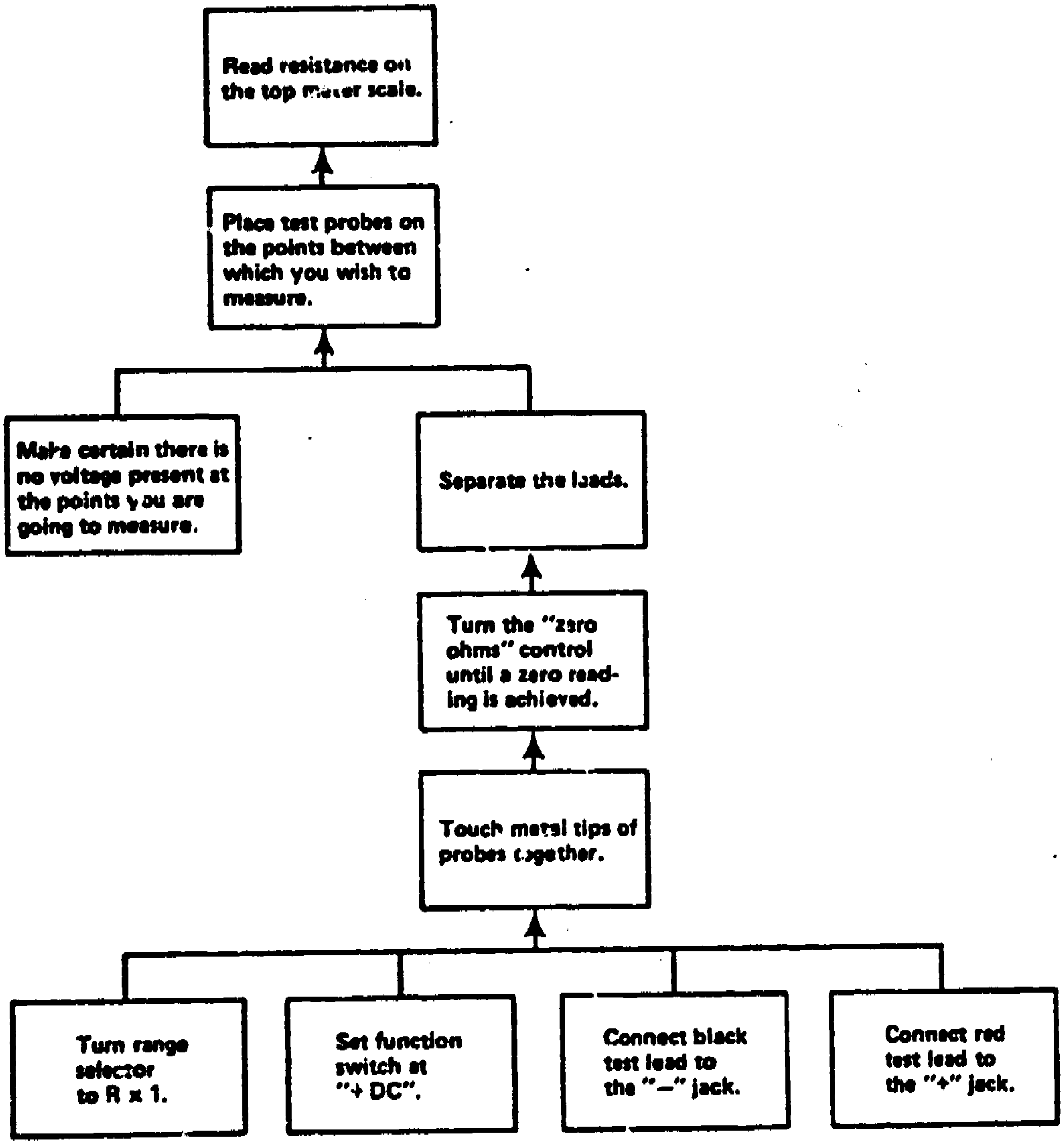
KEY: THE ARROW BETWEEN TWO BOXES MEANS THAT THE CHANGE IN ONE BOX CAUSES THE CHANGE IN THE OTHER BOX TO OCCUR.

Figure 11. An example of an empirical-theoretical structure.

$$R = \frac{E}{I}$$

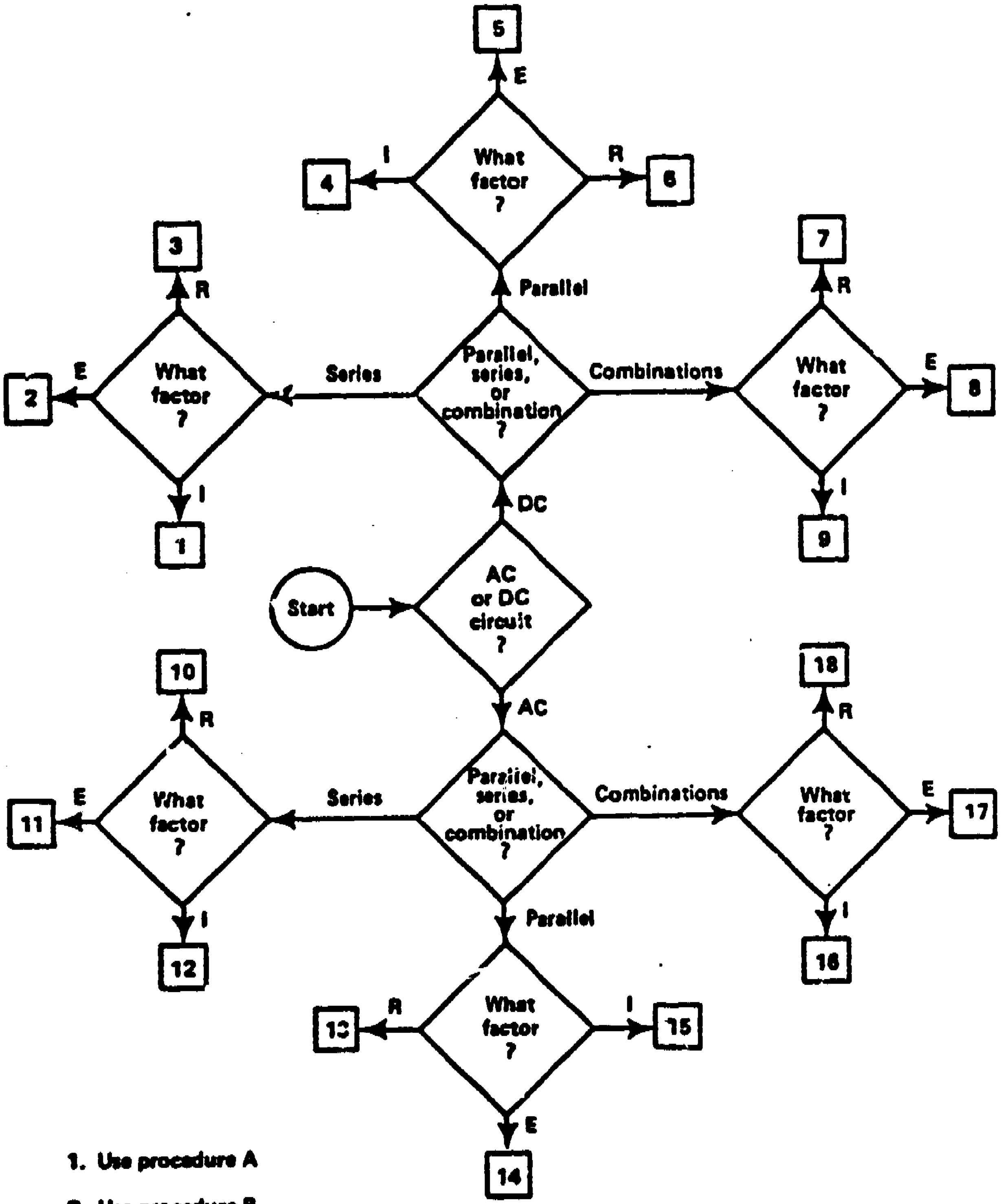
KEY: THE MATHEMATICAL SYMBOLS SHOW THE LOGICAL-THEORETICAL RELATIONS BETWEEN RESISTANCE (R), ELECTROMOTIVE FORCE (E) AND CURRENT (I) IN A SIMPLE SERIES DC CIRCUIT. EMPIRICALLY DETERMINED VALUES MAY VARY SLIGHTLY FROM THE LOGICAL.

Figure 12. An example of a logical-theoretical structure.



Key: The arrow between two boxes on different levels means that the lower box must be performed before the higher box can be performed. Boxes on the same level can be performed in any order.

Figure 13. An example of a procedural-prerequisite structure.



1. Use procedure A
2. Use procedure B
3. Use procedure C
Etc.

Key: Each diamond represents a decision point in the selectionof the appropriate procedure for measuring an aspect of electricity in a circuit.

Figure 14. An example of a procedural-decision structure.

SUPPORTING STRUCTURE: A structure which is much less inclusive than an orientation structure and is nested either within an orientation structure or within a more inclusive supporting structure. It provides knowledge which supports an understanding of the structure within which it is nested.

Insert Figure 15 about here

In reality, the difference between constructs and structures is not clear-cut; it is more like a continuum with a fuzzy boundary between the two sides. In addition, the "push-down principle" (see Merrill, 1971; Reigeluth, Merrill and Bunderson, 1978) can move the boundary along the continuum (toward the construct side) as the learner deepens his understanding. Nevertheless, given its variation with the learner's level of knowledge, the distinction between constructs and structures is a useful one for prescribing different types of organizational strategies.

There are at least two kinds of <u>multi-structures</u> that are important for specifying structural strategies: nested and parallel.

NESTED MULTI-STRUCTURE: A multi-structure comprised of structures which have a construct in common. For example, imagine a theoretical structure in a horizontal plane. Each construct in that theoretical

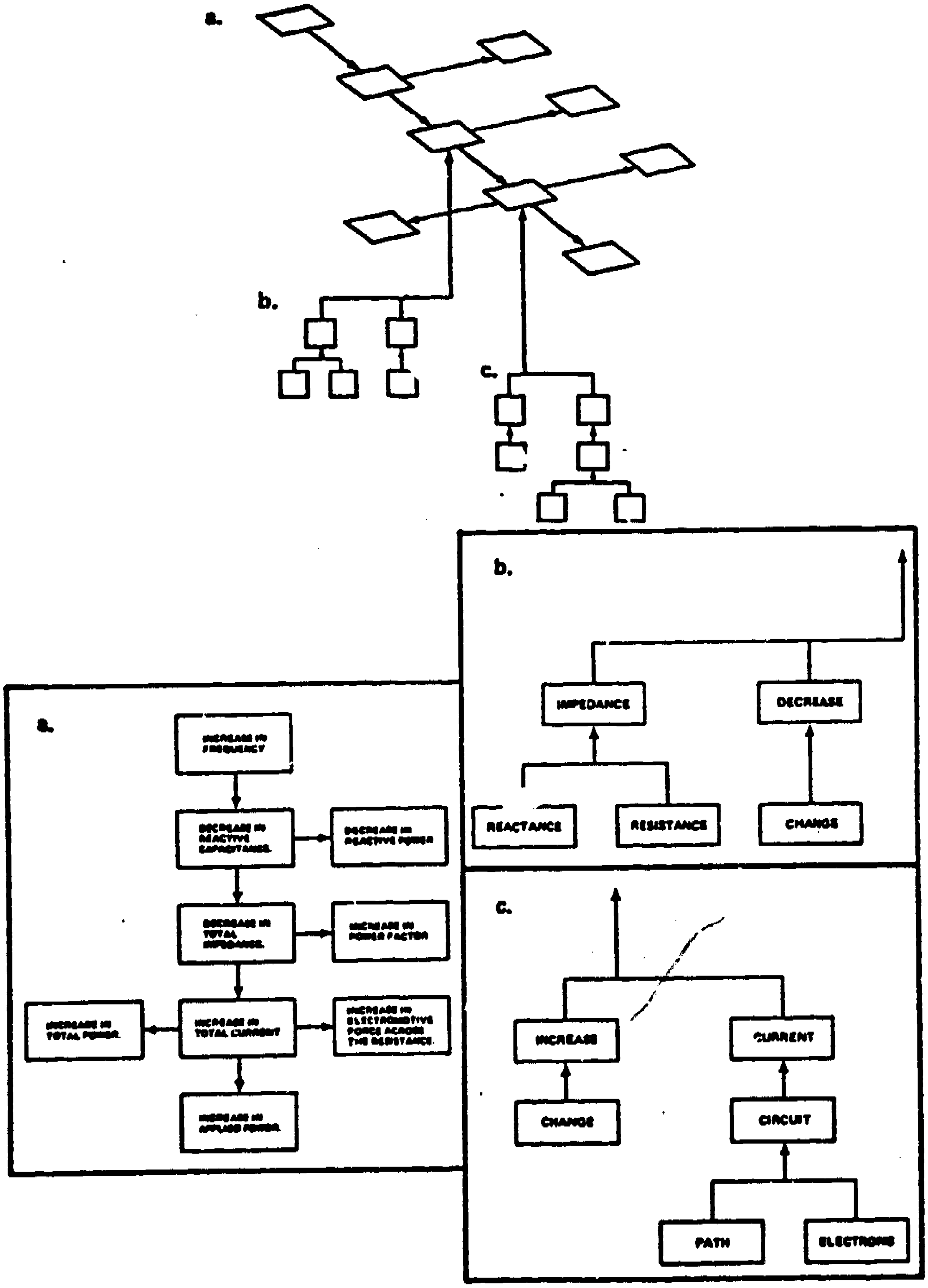


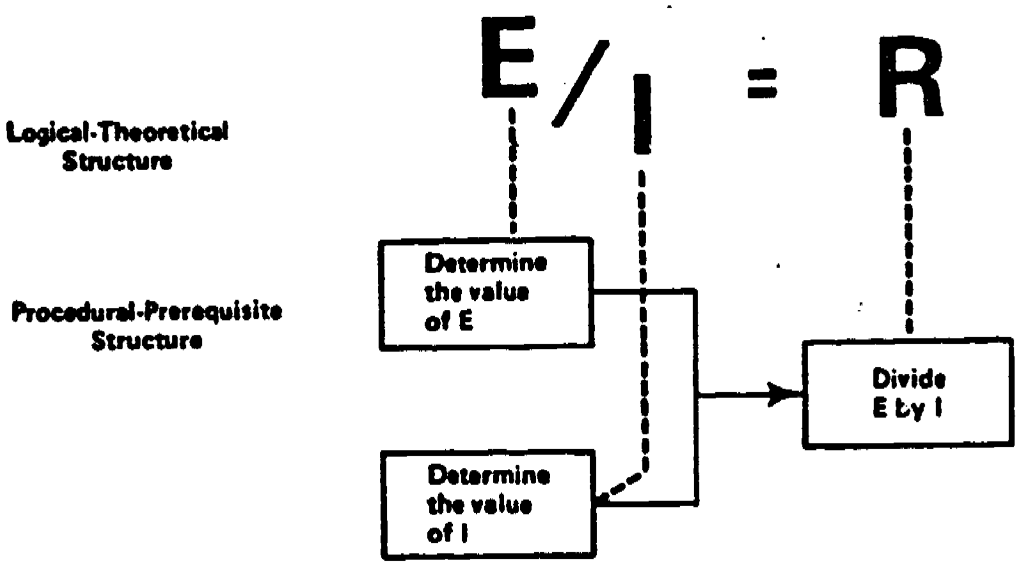
Figure 15. Part of a nested multi-structure showing two learning prerequisite structures as supporting struct es for a theoretical orientation structure.

structure could be the top box in a different learning structure. See Figure 15 for an example.

PARALLEL MULTI-STRUCTURE: A multi-structure consisting of two or more structures which have no concepts in common, but which have consistent relations between their respective concepts. For example, imagine a theoretical structure and a procedural structure in parallel planes. Each step in the procedural structure is related to (and in fact was probably derived from) a corresponding principle in the theoretical structure. See Figure 16 for an example.

Insert Figure 16 about here

Figure 17 summarizes and synthesizes the conditions which are classified as subject matter characteristics. The other important class of conditions relating to organizational strategies is instructional goals. Goals and objectives lie on a continuum from very general to very detailed. For our purposes, we are not interested in detailed goals, although Merrill's task/content classifications (Merrill, Richards, Schmidt, & Wood, 1977; Merrill and Wood, 1974, 1975b) provide useful categories of such objectives for presentation strategies.



Where E = Electromotive force

I = Current

R = Resistance

Figure 16. An example of a parallel multi-structure.

Insert Figure 17 about here

We believe that there are two kinds of general goals that have particular value for prescribing structural strategies: orientation goals and supporting goals.

ORIENTATION GOALS: The major emphasis of the instruction, with respect to how the student will use the subject-matter content.

SUPPORTING GOAL: A specification of subject-matter content and student behaviors that will enable or facilitate the achievement of the orientation goals.

The parallel between structures and goals continues even further because we propose that it is useful to classify all orientation goals as conceptual, procedural, and theoretical.

CONCEPTUAL ORIENTATION GOAL: The major emphasis of the instruction is for the student to gain a firm understanding (a) of the important concepts in a subject matter and (b) of the important taxonomic relations among those contepts. This is in essence a "general education" approach.

PROCEDURAL ORIENTATION GOAL: The major emphasis of the instruction is for the student to learn to perform a procedure or a set of procedures.

CONDITIONS

SUBJECT-MATTER CHARACTERISTICS

Constructs

Facts
Concepts
Subsets
Principles
Steps

Structures

Lists
Learning structures
Conceptual structures
Theoretical structures
Procedural structures

Orientation structures
Supporting structures

Multi-Structures

Nested
Parallel

INSTRUCTIONAL GOALS

Orientation Goals

Conceptual
Procedural
Theoretical

Supporting Goals

Enabling
Contextual
Procedural
Explanatory

Figure 17. A summary of the classifications of the condition variables that influence the use of structural strategies.

THEORETICAL ORIENTATION GOAL: The major emphasis of the instruction is for the student to understand the important change relations in a subject matter. This type of orientation goal may also be performance-oriented, but the performance entails broad transfer to unfamiliar situations that only a fundamental understanding of underlying processes would be adequate to cope with.

Supporting goals, which are less general than orientation goals, may be classified as enabling, contextual, procedural, and explanatory.

ENABLING SUPPORTING GOAL: A supporting goal which indicates what a student must know (or be able to do) in order to learn (or be able to do) a part of the goal which it supports. An enabling goal identifies learning prerequisites.

CONTEXTUAL SUPPORTING GOAL: A supporting goal which requires showing the context of a part of the goal which it supports. This context is in relation to subject-matter content which is super/co/subordinate to it.

PROCEDURAL SUPPORTING GOAL: A supporting goal which requires showing a standard procedure related to the goal which it supports. Landa's (1974) identificational and transformational algorithms usually satisfy this kind of supporting goal.

EXPLANATORY SUPPORTING GOAL: A supporting goal which requires showing the underlying processes upon which the procedural goal it supports is based.

Figure 17 summarizes all the condition variables that influence the use of structural strategies.

Method Variables

With respect to method variables, we mentioned above that we are only interested in structural strategies, a subset of organizational strategies. Structural strategies may be classified as "the four S's": selection, sequencing, synthesizing, and summarizing.

SELECTION STRATEGIES: Methods for deciding what parts of a subject matter to teach.

SEQUENCING STRATEGIES: Methods for arranging the order in which the constructs and relations selected will be presented to the student.

SYNTHESIZING STRATEGIES: Methods for teaching subject-matter structures (i.e., for teaching the relations among constructs).

SUMMARIZING STRATEGIES: Methods for previewing or reviewing the constructs and relations selected.

It would be possible to continue to breakdown each of these kinds of structural strategies into components. For instance, synthesizing strategies can be broken down into such components as: (1) frequency of synthesizers (how often they appear in instruction of a given length), (2) timing of each synthesizer (exactly when it is presented during the instruction), (3) level of each synthesizer (which is on a continuum from very general or simple to very detailed or complex), (4) [illegible]iveness of a synthesizer (the amount of material that is synthesized, with respect to both depth and breadth of material), (5) type of synthesizer (which is basically the type of relation shown, i.e., parts taxonomic, procedural prerequisite, etc.), (6) form of the synthesizer (which could be either literal or analogous), and (7) representation of the synthesizer (which could be prose, graphic, or diagramatic). However, for our present purposes, we feel that such a detailed analysis of strategy components must wait for a more extensive research effort.

There are two other ways of classifying all <u>structural strategies</u>. One is to classify them as either systematic or unsystematic.

SYSTEMATIC STRUCTURAL STRATEGIES: Structural strategies that are generated systematically from principles or a theory.

UNSYSTEMATIC STRUCTURAL STRATEGIES: Structural strategies that are not generated systematically from principles or a theory, such as structural strategies that are intuitively generated.

The other is to classify all structural strategies as either macro-level or micro-level.

MACRO-LEVEL STRATEGIES: Strategies for structuring the major sections of a course. For instance, they would include strategies for selecting, sequencing, synthesizing, and summarizing the units of a textbook.

MICRO-LEVEL STRATEGIES: Strategies for structuring the parts of the major sections of a course. For instance, they would include strategies for selecting, sequencing, synthesizing, and summarizing the sections of each chapter of a textbook.

Rather than being dichotomous, macro-level and micro-level strategies lie on a continuum.

As far as the systematic/unsystematic distinction is concerned, we are only interested in systematic strategies. Systematic strategies can in turn be built up into different strategy models (complete sets of strategy components) based on each of the different kinds of orientation structures. Such models will be described in some detail in the next part of Section 2.

There are two more concepts which we would like to describe: epitome and elaboration.

EPITOME: A synthesizer which epitomizes the subject-matter content to be taught in a course. It portrays only the most important parts of the content and the most important interrelationships among those parts. For example, for a procedural orientation goal, the epitome would be a very general-level procedure that subsumes all of the alternative sub-procedures which the student needs to learn (see Figure 18).

Insert Figure 18 about here

ELABORATION: A portion of instruction which provides more detailed or complex information about a part of the content to be taught. A first-level elaboration elaborates on an epitome; a second-level elaboration elaborates on a first-level elaboration; and so on.

Figure 19 summarizes these classifications of structural strategy variables.

Insert Figure 19 about here

SUMMARY OF THIS PART

First, the context of structural strategies was described by means of a general framework for conceptualizing and studying the effects of different methods under different conditions. This general-level classification scheme divided the world of instruction into conditions, methods, and outcomes. Methods were classified as organizational, delivery, and management; conditions were classified as goals and subject-matter characteristics, constraints, and student characteristics; and outcomes were classified as learner, instructional institution, and

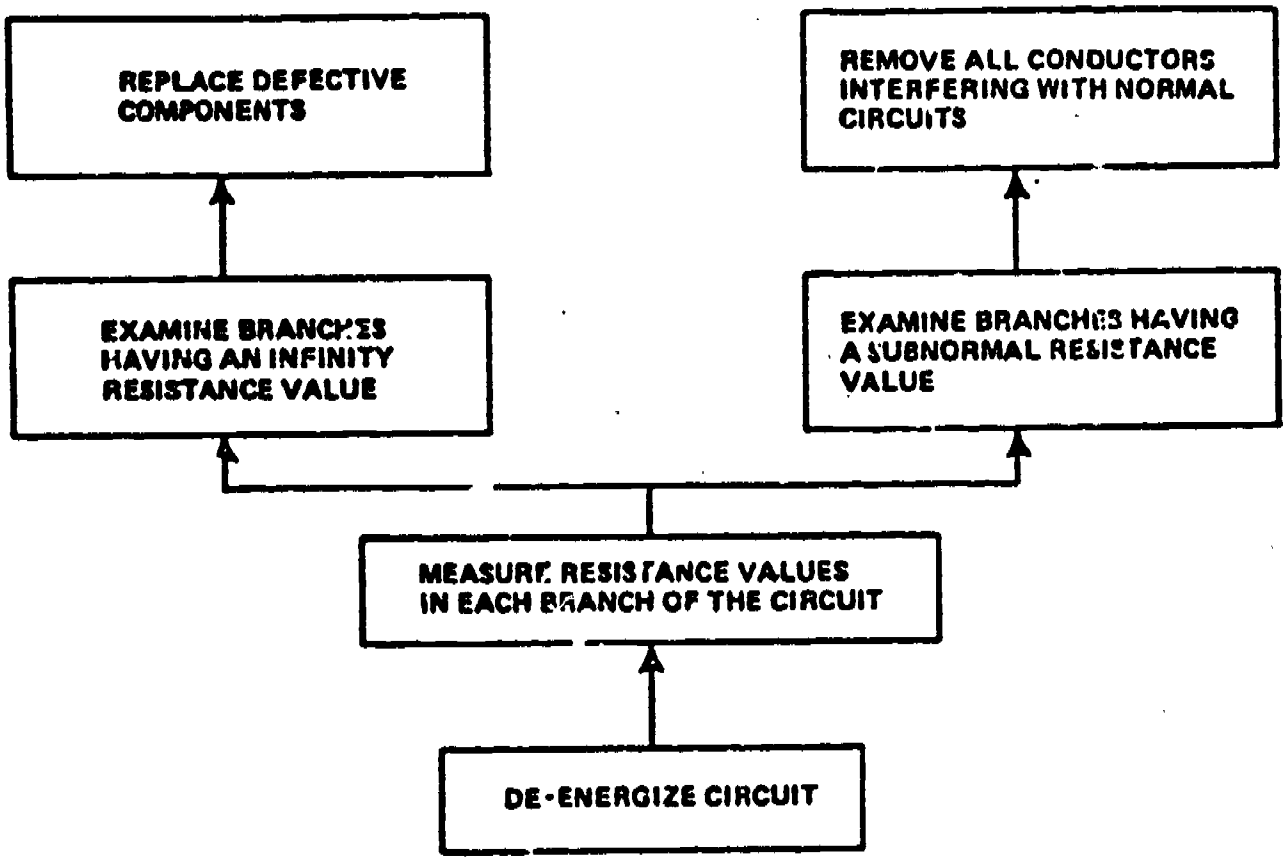


Figure 18. A procedural epitome for a course in electronics troubleshooting.

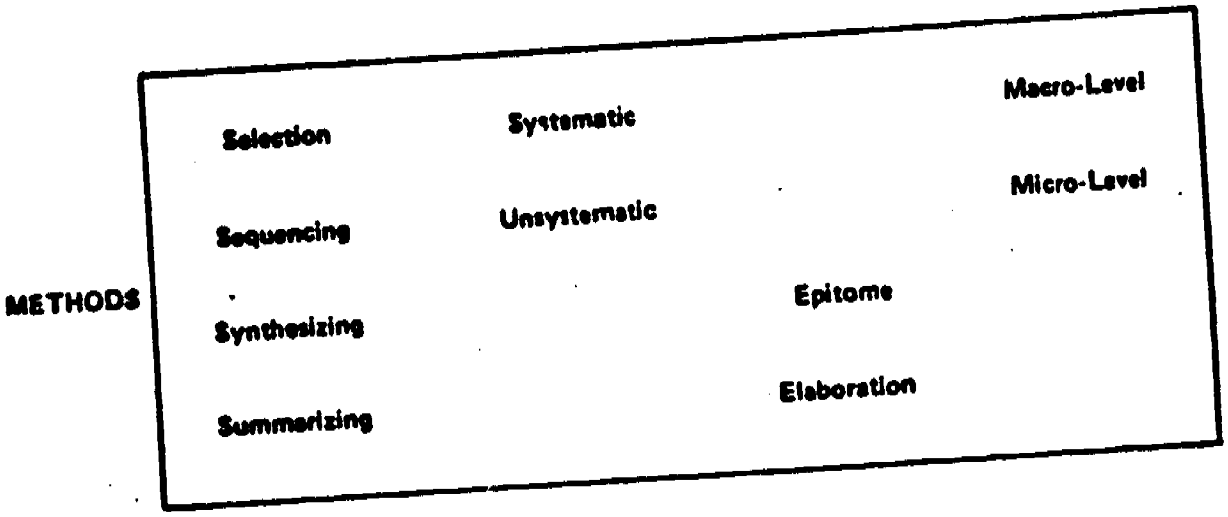


Figure 19. A summary of the classifications of the method variables that relate to structural strategies.

sponsoring institution outcomes. Organizational methods were also classified as presentation strategies and structural strategies. It was stated that we are only interested in structural strategies and the conditions (goals and subject-matter characteristics) which relate to them.

Second, the importance of clearly defining and classifying instructional variables and concepts was emphasized. It was indicated that the nature of the classifications and the preciseness of their definition will have a large impact on progress in developing better methods for sequencing and synthesizing instruction. An important requirement for such progress is to break down methods of instruction into their building blocks, and to base one's research and theories on those more precise and clearly-defined strategy components.

Finally, the variables relating to structural strategies were defined and classified. They are summarized in Figure 20.

Insert Figure 20 about here

In the next part of Section 2, we will use these concepts and variables to develop, and to create prescriptions for the use of, whole models for structuring instruction (i.e., integrated sets of structural strategy variables).

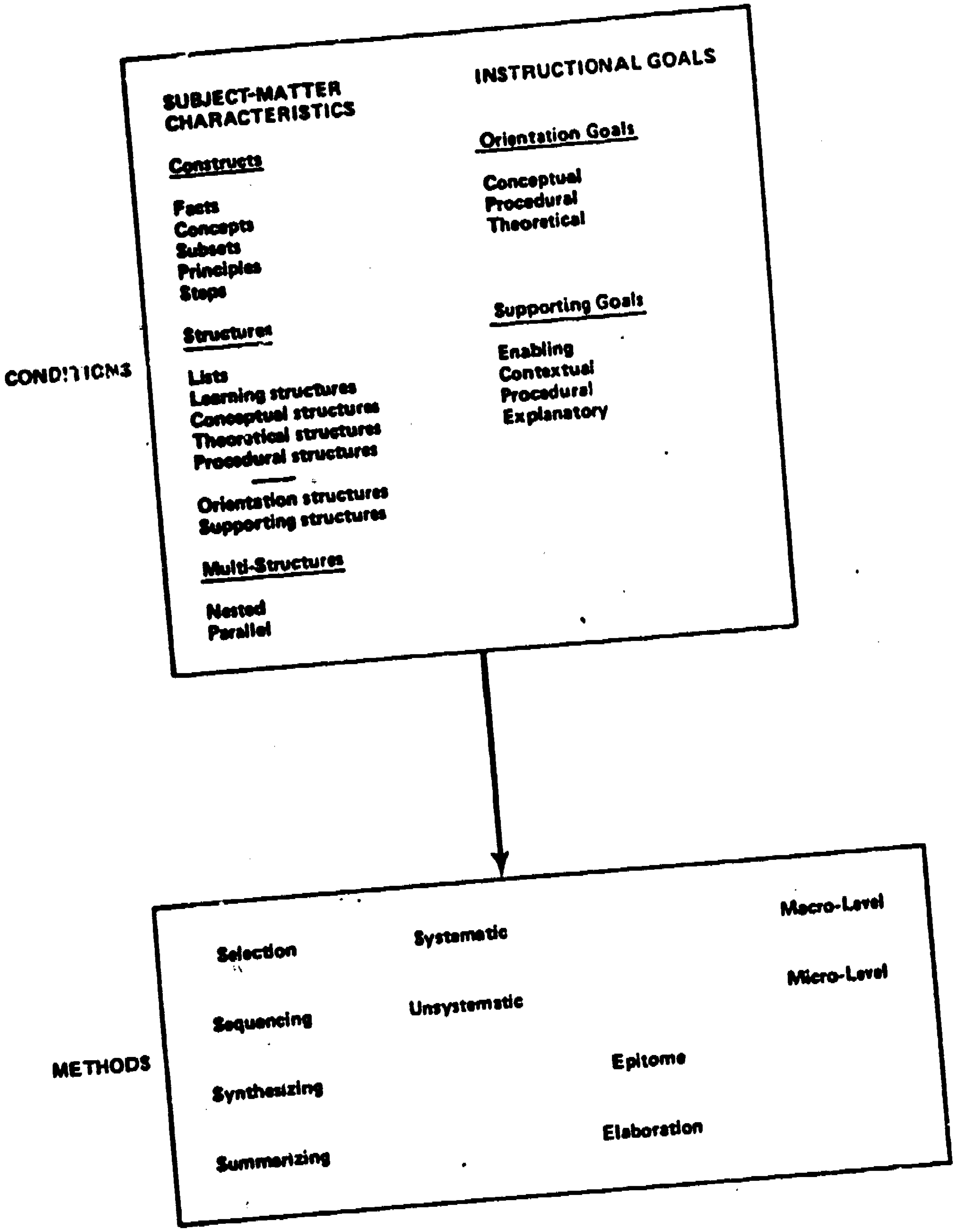


Figure 20. A summary of the classifications of variables that relate to structural strategies.

SECTION 2, PART 2

THE ELABORATION MODEL OF INSTRUCTION

This part of Section 2 describes the elaboration model for sequencing and synthesizing instruction. All of the concepts whose interrelationships are described by the model are defined in the previous part of this section.

Models

Models show how things work. One can conceptualize models as being of two kinds: those which describe natural phenomena, which are invariant, and those which describe ways to achieve some end, which are goal-oriented and therefore vary as goals vary. This distinction parallels the difference between descriptive sciences, such as the science of learning, and prescriptive sciences, such as the science of instruction (Reigeluth, Bunderson, & Merrill, 1978; Simon, 1969). The elaboration model of instruction is prescriptive--it describes ways to achieve given ends.

There are two aspects of the ends of instruction. One aspect is the nature of the general goals of a course of instruction. In the previous section we classified them as effectiveness, efficiency, and appeal. These ends are fairly uniform for all instruction--that is, one wants the students to enjoy the instruction (appeal), one wants to achieve a given level of learning with a minimum of student time and monetary expenditure (efficiency), and one wants the instruction to be effective. Since these goals do not vary much from course to course, the model is fairly constant with respect to them.

The other aspect of the ends of instruction is the nature of the particular goals of a given course of instruction. In the previous section we classified them as conceptual, procedural, and theoretical. Since these goals vary from course to course, the model must vary with each of these goals. In this report we will describe the aspects of the model which do not vary from course to course. Then we will describe aspects which do vary from course to course.

Principles

First, however, since all models portray a conglomerate of principles, it may be helpful if we describe some general principles of instruction upon which the elaboration model is based. These hypothesized principles are likely to be valid only for teaching a fairly large number of interrelated constructs. For a small number of constructs, sequencing and synthesizing strategies probably do not make much difference. In effect, the following seven hypothesized principles are parts of a more general "elaboration principle"; and each of these seven could in turn be broken down into more specific parts--more detailed principles.

1) Initial synthesis principle. A general synthesizer--which shows the major parts of the subject matter 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.)

2) Gradual elaboration principle. The parts of the initial synthesizer should be gradually elaborated so that the sequence of the instruction proceeds from general to detailed or from simple to complex.

3) "Most important first" principle. Whatever one judges to be the most important part of an epitome should be elaborated first. Importance is estimated by a subject-matter expert on the basis of such factors as contribution to understanding the whole orientation structure, frequency of use in the real world, or the seriousness of the consequences of inadequate use in the real world. The rationale for this principle is that the sooner a part of an epitome is elaborated the better it will be learned, because the learner will gain more practice in doing and integrating that part by the end of the instruction.

4) Optimal size principle. Each elaboration should be short enough that its constructs can be recognized comfortably by the student and synthesized comfortably by the instruction, yet long enough that it provides a good amount of depth and breadth of elaboration. This optimal size is related to the limits of short-term memory; but it is also likely that it is influenced by cognitive processing abilities (which are probably a function of mental maturity)

and by certain subject-matter characteristics (such as the novelty of the items and the type of relation being synthesized).

5) Periodic synthesis principle. A synthesizer should be provided after each elaboration 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 with the detail or complexity of the constructs taught in the elaboration.

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

7) Periodic summary principle. A summarizer (e.g., a concise generality for each construct) should be provided before each synthesizer and before each expanded epitome. This will facilitate synthesis.

An Analogy

In order to understand the nature of the elaboration model of instruction, an analogy may be helpful. Taking a look at 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. He could be forced to zoom in on a certain part, or he could be given the option of zooming in on whatever part interests him 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 the major subparts of that part and 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 he could continue to zoom in another level for more detail or complexity on one of the subparts. Or he 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, he could be given the option of following any of a limited number of types of patterns, or he could be given total freedom to follow any pattern he chooses.

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 part in order to synthesize that detail--that is, to see with greater detail and understanding, the relationships among those subparts.

It is also important that the viewer proceed from the top down. In other words, no subpart should be inspected before it has been seen from the next-higher level.

In a similar way[1], the elaboration model of instruction starts the student with a very broad, general view of the subject matter to be taught. Then it gradually divides that subject matter into parts, elaborates on each of those parts, divides those parts into subparts, elaborates on each of those subparts, and so on until knowledge has reached the desired level of detail and complexity.

This general-to-detailed organization allows the learner to learn at the level of detail that is most meaningful (Ausubel, 1968) to him at any given state in the development of his knowledge. The learner is always aware of the context and importance of the different constructs he is learning and of the important relationships among the constructs that he has learned. And the learner never has to struggle through a series of learning prerequisites that

---

[1] It must be remembered that the zoom-lens analogy is just an analogy and therefore that it has non-analogous aspects. One such dissimilarity is that all the detail of the picture is actually present in the wide-angle view, whereas the detail is not there at all in the epitome. Also, detail is added in discrete steps in the elaboration model.

are on too deep a level of detail to be interesting or meaningful at the initial stages of instruction. As he works his way to deeper levels of detail, increasingly complex prerequisites will need to be introduced. But if they are only introduced at the level of detail at which they are necessary, then the learner will want to learn those prerequisites because he will understand their importance for learning at the level of detail that now interests him.

Unfortunately, up to now the zoom lens has hardly been used at all in instruction. Most instructional sequences begin with the "lens" zoomed all the way in at one corner of the "picture" and proceed--with the "lens" locked on that level of detail--to systematically cover the entire scene. This has had unfortunate consequences both for synthesis and for motivation.

The lack of utilization of a zoom lens in instruction, in spite of the important pioneering work of Ausubel over two decades ago, may be due primarily to Ausubel's emphasis on the science of learning. Our present efforts are an attempt to develop the counterpart of those ideas in the science of instruction. The following is a description of some details of the elaboration model of instruction.

THE ELABORATION MODEL

Keeping in mind the foregoing analogy of the zoom lens, the following is a general description of the elaboration model of instruction (see Figure 21). The technical terms used herein are defined in the previous section.

Insert Figure 21 about here

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1) The instruction begins with an <u>epitome</u>, which provides a general overview of the major aspects of the orientation structure.

2) The instruction provides a <u>primary-level elaboration</u> on each part of the epitome, beginning with the "most important" part. Importance is estimated by a subject-matter expert on the basis of such factors as contribution to understanding the whole orientation structure, frequency of subsequent use, or seriousness of consequences of a mistake. Each primary-level elaboration adds detail or complexity to the general understanding of each part of the epitome.

3) At the end of each primary-level elaboration, the instruction provides a <u>summarizer</u> followed by an <u>expanded epitome</u>. The summarizer gives a concise generality of each construct that was taught in the elaboration, and the expanded epitome shows (a) the important relationships among

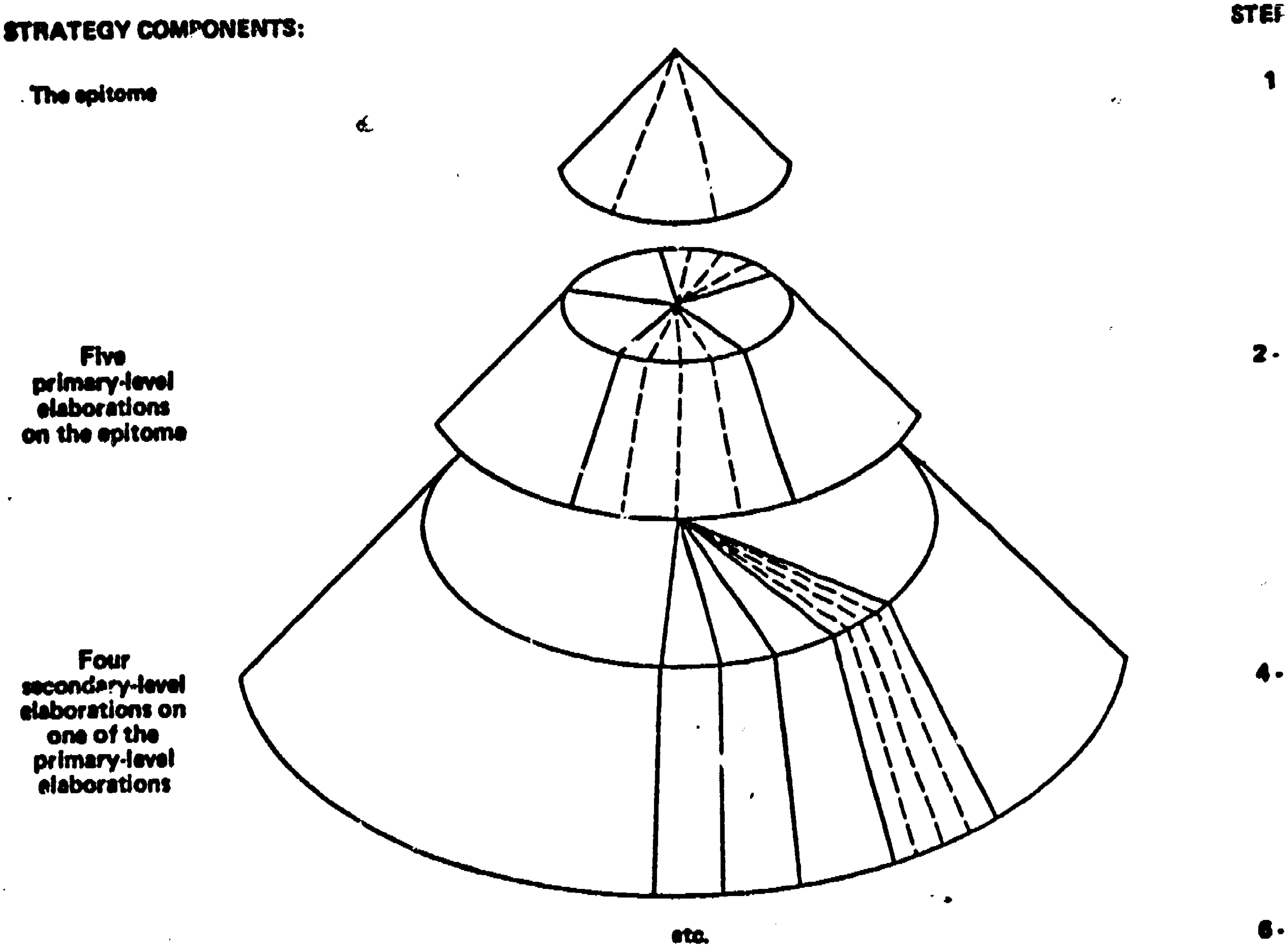

Figure 21. The major conceptual relationships among the parts of the elaboration model of instruction

the subparts comprising the elaboration and (b) the context of the elaborated part within the epitome.

4) After all of the primary-level elaborations/ expanded epitomes (see Figure 22), the instruction provides secondary-level elaborations, which usually elaborate on each primary-level elaboration rather than on the epitome --if such is necessary to bring the student to the depth of understanding specified by the objectives of the instruction. Sometimes, however, the secondary-level elaborations elaborate on a different dimension of the orientation structure (see next part of this section).

Insert Figure 22 about here

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5) At the end of each secondary-level elaboration, the instruction provides a summarizer and an expanded epitome, similar to those at the end of each primary-level elaboration.

6) After all of the secondary-level elaborations that are needed have been presented and shown in expanded epitomes, then the pattern is repeated for tertiary-level elaborations, fourth-level elaborations, etc., if such are needed to bring the student to the depth of understanding specified by the objectives of the instruction.

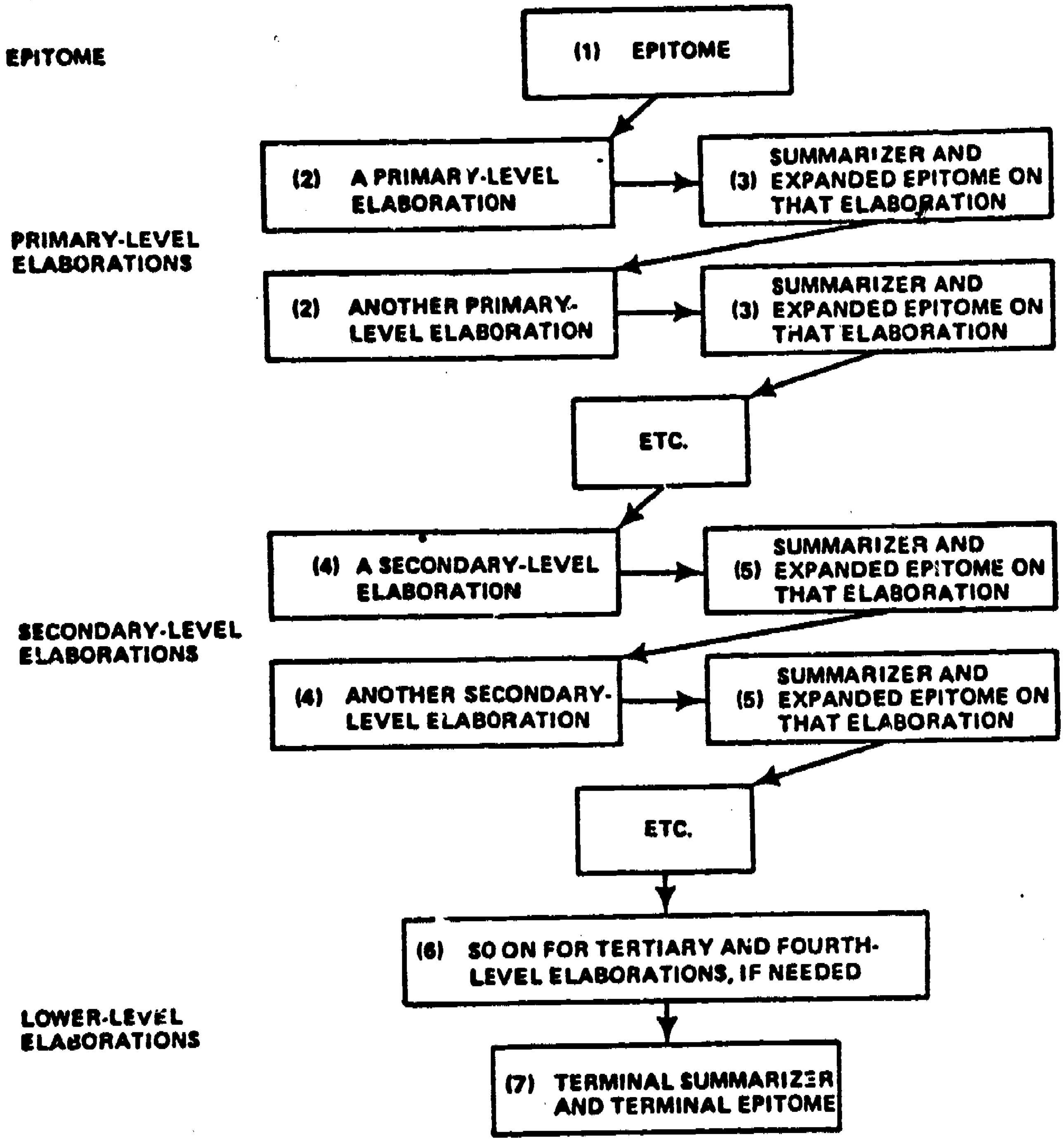


Figure 22. An epitome of the elaboration model of instruction

7) At the very end of the instruction, a terminal epitome is presented to synthesize the entire domain of the subject matter.

VARIATIONS OF THE MODEL

There are many possible variations of this model. In reference to the zoom lens analogy, the instruction could zoom in on just one primary-level elaboration before zooming in on its secondary-level elaborations, rather than zooming in on all primary-level elaborations before zooming in on any secondary-level elaborations. Or the learner could be given control over the sequencing of elaborations. However, we hypothesize that the most cost-effective variation is the one that was just described in some detail and was illustrated in Figure 22.

Assuming that the most cost-effective variation were known, it is likely that the above-described aspects of the model would not vary from course to course--that is, the instructional components described would always all be present and in the same order. However, there are two ways in which this model may systematically vary from one kind of course to another.

First, the nature of the major strategy components described varies with the type of orientation goal. Although their presence and their order would probably not change, the epitome, the elaborations, and the synthesizers all vary considerably depending upon whether the orientation goals are conceptual, procedural, or theoretical. Below is a description of those variations and when each should be used.

The second way in which this model may vary from one course to another is that the epitomes, elaborations, and synthesizers are usually based on a <u>number of interrelated structures</u> (i.e., a multi-structure) rather than on a single orientation structure. These variations are also briefly described below.

<u>Epitome</u>

The nature of the epitome and the procedures for creating it are different for each type of orientation goal: conceptual, procedural, or theoretical. The procedure for creating the epitome will be described in some detail in the next section of this report. The following is a description of the nature of the epitome for each type of orientation goal.

<u>Conceptual</u>. Like all epitomes, a conceptual epitome has two major parts: a synthesizer and the instruction necessary to understand that synthesizer. The <u>synthesizer</u> in this case is a conceptual structure (either a taxonomy or a matrix), but this synthesizer must be a very simple or general version of the conceptual orientation structure, and it must subsume the majority of the subject matter that is to be taught. It should contain the maximum amount of material that a student can learn comfortably in one lesson (e.g., in a one-hour

sitting). Such a conceptual synthesizer is shown in Figure 23.

Insert Figure 23 about here

The instruction necessary for the student to understand the epitome's synthesizer will include generalities, instances, and practice on each concept and a clear description of the relations portrayed in the synthesizer. The instances and practice do not have to be abstract; in fact, they should be concrete, real-life cases. But they should be chosen or generated so as to be simple enough for the student to learn at the initial stages of the instruction. In order to teach each concept in the synthesizer, it may be necessary to identify its learning prerequisites, and to include them in the instruction if they cannot be assumed as entering knowledge of the students.

Procedural. A procedural epitome is also comprised of ✓ a synthesizer and the instruction necessary to understand that synthesizer. The major difference is that in this case ✓ the synthesizer is a procedural structure (either procedural-prerequisite or procedural-decision). Again it must be a very simple or general version of the complete procedural structure which represents the majority of the

TYPES OF
ELECTRIC CIRCUITS

		I	E	R
DC	Series			
	Parallel			
	Combination			
AC	Series			
	Parallel			
	Combination			

ELEMENTS OF
ELECTRIC CIRCUITS

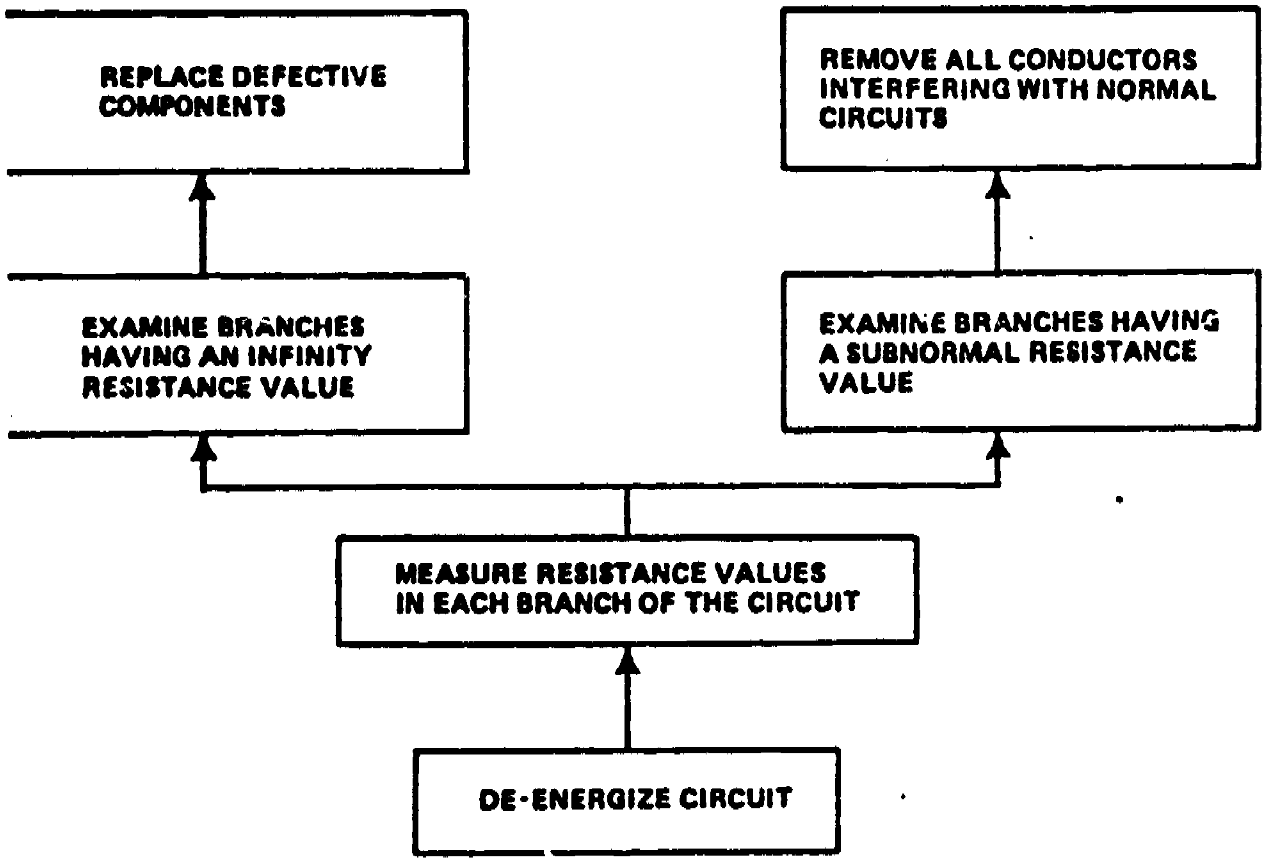
Figure 23. A simple version of a conceptual structure that could be used as the synthesizer in a conceptual epitome for an electronics course

subject matter that is to be taught. Such a simplified procedural synthesizer is shown in Figure 24.

Insert Figure 24 about here

The instruction necessary for understanding the epitome's synthesizer will include generality-instance-practice instruction on each step (construct) and a clear description of the relation portrayed in the synthesizer. The instances and practice should be real-life cases that are chosen or generated so as to be possible for the student to learn at the initial stages of the instruction. For example, in reference to Figure 24, the circuit may be an extremely simple one having only one branch and no infinity resistance value (just a subnormal resistance value). If any steps involve concept classification, those concepts may need to be taught; and their learning prerequisites may also need to be identified and included in the instruction (if they cannot be assumed as entering knowledge of the students).

Theoretical. A theoretical epitome is also comprised of a synthesizer and of the instruction necessary to understand it. In this case the synthesizer is a theoretical structure (either empirical or logical). Again it must be a very simple or general version of the complete theoretical structure which represents the majority of the



KEY: The arrow between two boxes on different levels means that the lower box must be performed before the higher box can be performed. Boxes on the same level can be performed in any order.

Figure 24. A simple version of a procedural structure that could be used as the synthesizer in procedural epitome for a course on electronics troubleshooting

subject matter to be taught. Such a simplified theoretical synthesizer is shown in Figure 25.

Insert Figure 25 about here

The instruction necessary for understanding the epitome's synthesizer will include generalities, instances, and practice on each construct and a clear description of the theoretical relations in that synthesizer. Again, the instances and practice should be real-life cases that are on a simplified level. (For example, in reference to Figure 25, the student should be shown actual instances of the effects on E and I of a given change in R.) The theoretical structure is comprised primarily of concepts, and therefore their learning prerequisites may also need to be identified and included in the instruction.

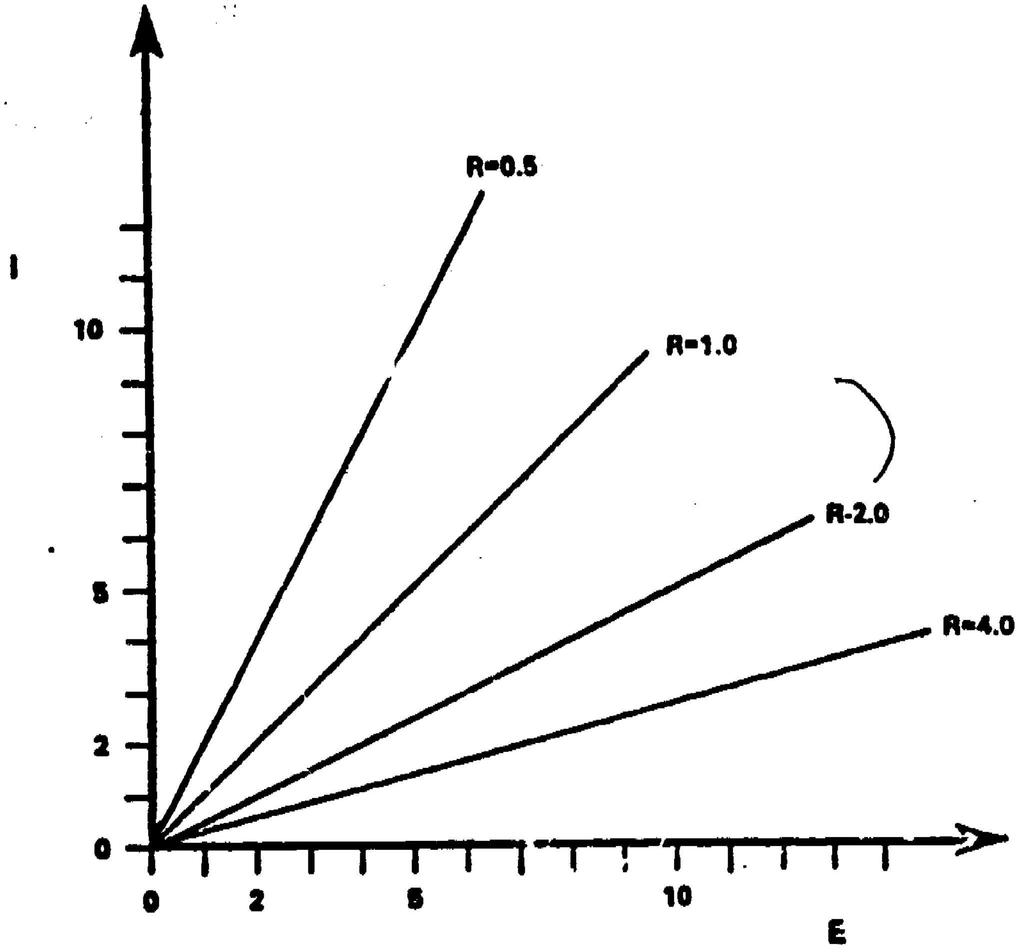
Expanded epitomes. The expanded epitomes are basically the same as the epitome, except that their synthesizers are correspondingly extended to include more complexity or detail, and those synthesizers will often be nested multistructures. This applies for each type of orientation goal (conceptual, procedural, and theoretical).

Elaborations

The nature of the elaborations and of the procedures for creating them are also different for each type of orientation goal: conceptual, procedural, and theoretical.

$$R = \frac{E}{I}$$

KEY: THE MATHEMATICAL SYMBOLS SHOW THE LOGICAL-THEORETICAL RELATIONS BETWEEN RESISTANCE (R), ELECTROMOTIVE FORCE (E) AND CURRENT (I) IN A SIMPLE SERIES DC CIRCUIT. EMPIRICALLY DETERMINED VALUES MAY VARY SLIGHTLY FROM THE LOGICAL.



KEY: THE LINES ON THE GRAPH SHOW THE RELATIONSHIP BETWEEN CHANGES IN E AND I FOR GIVEN VALUES OF R.

Figure 25. Two representations of a simple version of a theoretical structure that could be used as the synthesizer in a theoretical epitome for a course in electronics

The procedure for creating the elaborations will be described in some detail in the next part of this section. The following is a description of the nature of the elaborations for each type of orientation goal.

Conceptual. Like all elaborations, the conceptual elaborations gradually lead the student from a very general understanding of the subject matter to be taught (i.e., the epitome or the wide-angle view) to a level of complexity or detail specified by the objectives. In this case, each elaboration teaches concepts which are subordinate to a general concept that has already been taught, either in the epitome (for first-level elaborations) or in an elaboration (for lower-level elaborations). In other words, the topics of an elaboration are the parts or kinds (depending upon the type of conceptual structure) of a general concept or concepts.

Regardless of the type of elaboration (conceptual, procedural, or theoretical), the amount of material within each elaboration must be gauged to the ability level of the learners. If there is too much material, it will be too difficult for the student to synthesize (due to an excessive memory and assimilation load), and the student will be less motivated (due to a greater difficulty in keeping the whole "picture" in mind). In an introductory course for graduate students, much more material should be included in each elaboration than in an introductory course for junior high school students. The amount of material in an elaboration may be adjusted either by changing the breadth of the elaboration or by changing the depth of the elaboration. For fairly simple material, a single elaboration could include an entire row of a taxonomy or of a matrix, or it could entail going three levels deep on a single box in the epitome. Specific recommendations are included in the next section of this report.

Procedural. Each procedural elaboration provides its detail or complexity on a single step of the procedural epitome. Therefore, the amount of material within an elaboration should be adjusted only by changing the depth of the elaboration (with the exception that two steps of the epitome could be included in an elaboration if they both have little depth). These are the two most important differences from the conceptual elaboration.

Theoretical. Each theoretical elaboration provides its complexity by teaching more local, detailed, and complex principles that relate to a single aspect of the elementary model in the epitome. As with the procedural elaboration, the amount of material within a theoretical elaboration should be adjusted only by changing the depth of the elaboration (but again, two aspects of the elementary model could be included in an elaboration if they both have little depth). Many textbooks which follow the course of the historical development of a theory or model come fairly close to this paradigm of instructional organization.

Synthesizers

The nature of the synthesizer which follows each elaboration is very similar to that of the synthesizer which is part of the epitome. The major difference is its scope: the synthesizer that follows each elaboration synthesizes only the constructs that were taught in that elaboration. In addition this synthesizer shows the context of the part elaborated within the whole, but it is not intended to teach relations among the parts of different parts--that is a task reserved for the expanded epitome.

Conceptual. A conceptual synthesizer is a conceptual structure that shows super/co/subordinate relations among its concepts. It may show either parts-ordinate relations, or kinds-ordinate relations. Usually the synthesizer is just a part of the total conceptual structure.

Procedural. A procedural synthesizer is a procedural structure that shows the order relations among its event concepts (steps). It may show either procedural-prerequisite relations or procedural-decision relations. Again the synthesizer is just a part of the total procedural structure.

Theoretical. A theoretical synthesizer is a theoretical structure that shows the theoretical relations (usually causal) among its constructs. It may show either logical or empirical theoretical relations. And this synthesizer is also just a part of the total theoretical structure.

Multi-Structures

We mentioned above that the epitomes, elaborations, and synthesizers comprising a course are usually based on a number of interrelated structures rather than on a single structure. We refer to such a set of interrelated structures as a multi-structure. In the section on epitomes, it was indicated that learning structures may be needed in the design of the instruction on the epitome synthesizer, in order to teach the learning prerequisites for each concept comprising the epitome synthesizer. But learning structures are not the only kind of structures that can be nested in an epitome or in an elaboration.

The most important structure for a course is referred to as the orientation structure. It is selected on the basis of the orientation goals for the course (e.g., for conceptual orientation goals, a conceptual orientation structure is used, etc.). That orientation structure should subsume all the important subject matter that is to be taught. If the goals of a course are fairly diverse, it may be necessary to treat it as several independent courses lumped into one, with each of those several courses having its own orientation structure.

Given, say, a theoretical orientation structure, the nature of the goals of the course may call for teaching certain efficient procedures associated with different parts of the theory or model. In such a case, procedural structures would be nested within the theoretical orientation structure, and some of the elaborations would elaborate on procedures rather than on parts of the theory or model. Similarly, some synthesizers would be procedural and some expanded epitomes would be multi-structural.

SUMMARY FOR THIS PART

In this part of Section 2 we have described an instructional model for sequencing and synthesizing instruction, based on the concepts described in the first part of this section.

First, we distinguished two kinds of models and expressed the need for a model which describes ways to achieve some end in instruction. Since general goals (ends)--such as effectiveness, efficiency, and appeal--do not vary much from course to course, the elaboration model of instruction is fairly consistent in related aspects. But since particular goals (ends)--such as conceptual, procedural, or theoretical orientations--do vary from course to course, the elaboration model varies from course to course with respect to related aspects.

Second, we presented some hypothesized principles of instruction upon which the elaboration model is based. These included: (1) the initial synthesis principle, (2) the gradual elaboration principle, (3) the "most important first" principle, (4) the optimal size principle, (5) the periodic synthesis principle, (6) the type of synthesizer principle, and (7) the periodic summary principle.

Third, we presented the zoom-lens analogy to facilitate an understanding of the nature of the elaboration model of instruction. A student starts with a wide-angle view of the subject matter and proceeds to zoom in for more detail on each part of that wide-angle view, occassionally zooming back out for context and synthesis. In some cases it may be best for a learner to pan across the entire subject matter on one level of the zoom before zooming in for more detail on any part, whereas in other contexts it may be best for the learner to continue to zoom in all the way on one area before zooming in at all on any of the other areas. In still other contexts, it may be best to let the student follow his interests, as long as it is a zoom-in pattern rather than a zoom-out pattern.

Fourth, the basic *unvarying components of the elaboration model* of instruction were described: an epitome, the first-level elaborations, the summarizer and synthesizer following each first-level elaboration, the summarizer and expanded epitome following all the first-level elaborations, the second-level elaborations, the summarizer and synthesizer following each second-level elaboration, the summarizer and expanded epitome following each set of second-level elaborations, and the terminal epitome summarizing the entire course--both its constructs and its relations.

Fifth, we described the *variations of the elaboration model* for different courses. The different patterns of sequencing, including learner control, were briefly mentioned. Then the nature of the epitomes, the elaborations, and the synthesizers were described for each kind of orientation: conceptual, procedural, and theoretical. And finally, we discussed the use of diverse multi-structures as a basis from which to design and organize the epitomes, the elaborations, and the synthesizers.

SECTION 2, PART 3

A PROCEDURE FOR DESIGNING INSTRUCTION: THE ELABORATION MODEL

This part of Section 2 describes a procedure for designing instruction according to the elaboration model. The elaboration model of instruction was itself described in some detail in the previous parts of Section 2.

CONTEXT

We would like to reemphasize an important distinction presented in the first part of this section: that there are two important kinds of organizational strategies--presentation strategies[2], which are methods for organizing instruction on a single construct, and structural strategies, which are methods for organizing aspects of instruction that relate to more than one construct. Instructional design must produce specifications, or blueprints, for both of these kinds of strategies, and also for delivery and management strategies. The Instructional Quality Inventory (Merrill, Richards, Schmidt, & Wood, 1977) describes when and how to use different presentation strategies, and this report is an important advance in describing when and how to use different structural strategies.

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[2] In a previous contract from the NPRDC we developed an instrument called the Instructional Quality Inventory to describe instructional design considerations related to presentation strategies.

Therefore, the procedure for designing instruction that is presented in this part of Section 2 is only one of the procedures that a designer needs. It is a procedure for planning the basic structure or framework of the instruction--that is, for planning what specific constructs will be taught (selection), what order they will be taught in (sequencing), what relations among them will be taught (synthesizing), and what ways those constructs and relations will be previewed and reviewed (summarizing). In effect, the design procedure described here replaces traditional task analysis and content analysis procedures. However, it should be kept in mind that the procedure described herein is in need of extensive field testing and improvement in order to be developed and refined to an extent that will make it a reliable guide for instructional designers.

In this report, we will describe a six-step design procedure for structuring the instruction. This will include a description of variations in the procedure for each kind of orientation goal: conceptual, procedural, or theoretical. Then, we will illustrate this procedure with Navy electronics subject matter, culminating in a "blueprint" for the Basic Electricity and Electronics course developed from the use of this procedure. Finally, we will outline the organization of the Navy's current Basic Electricity and Electronics (BE and E) course to facilitate the comparison of a hierarchical course design with our elaboration model design.

THE DESIGN PROCEDURE

The following is a tentative six-step design procedure for structuring the instruction in any course entailing cognitive subject matter (see Figure 26). This six-step procedure is illustrated in the next section of this report.

Insert Figure 26 about here

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1. Choose the Type of Orientation Structure

On the basis of the general goals of instruction, select one of the three types of orientation structures: conceptual, procedural, or theoretical. This will be the "structural emphasis" of the course, but it does not exclude teaching some of the relations included in the other two types of orientation structures.

If the emphasis of the course is on learning a large set of related concepts, then a conceptual orientation structure is most appropriate. If its emphasis is on learning a routine performance--one that occurs only with slight variation--then a procedural orientation structure is most appropriate. And if its emphasis is on learning a set of underlying processes--ones that enable the learner to deal with or to understand a wide variety of situations (e.g., problem solving)--then a theoretical orientation structure is most appropriate.

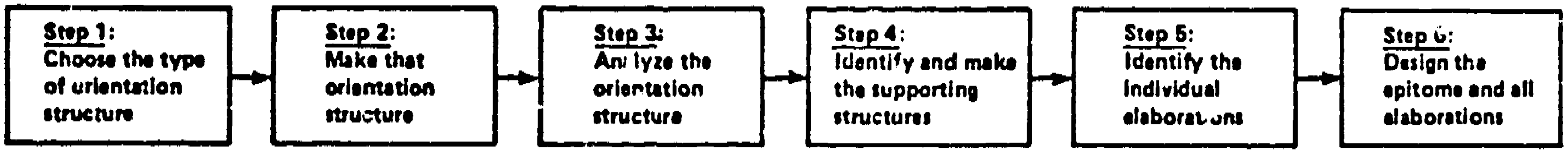


Figure 26. The six-step design procedure for structuring the instruction in any course entailing cognitive subject matter.

2. Make that Orientation Structure

Once one of the three kinds of orientation structures has been selected, the instructional designer should make the most detailed or complex version of that structure for the subject matter to be taught. The amount of detail or complexity included in that structure depends upon the objectives of the course. A subject-matter expert (SME) will be needed to help derive the orientation structure, but it is likely that the (SME) may not be explicitly aware of the existence of the structure to be derived, because structures are seldom taught. It is also likely that the SME (subject-matter expert) will not be familiar with what a subject-matter structure is. Therefore, specific procedures are needed for the instructional designer to use in order to "tease out" of the subject-matter expert the necessary knowledge to make the orientation structure. These specific procedures are different for each of the three kinds of orientation structures, and they are as follows.

2a. Conceptual orientation structures. The following are the steps that an instructional designer should follow in order to help a SME to construct a conceptual orientation structure. First, make sure the SME understands the notion of super/co/subordinate relations among concepts and the notions of parts-ordinate and kinds-ordinate varieties of those relations.

Second, have the SME identify the most general concept in the subject-matter area to be taught. This will usually be represented by the name of the subject-matter area, such as "electronics" or "computers". Write that concept at the top of two separate pieces of paper.

Third, have the SME divide that concept into its most general parts, and put them on one level just below the top concept on one piece of paper. Also have the SME divide it into its most general kinds, and put them on one level just below the top concept on the other piece of paper.

Fourth, continue to derive a parts taxonomy on one piece of paper and a kinds taxonomy on the other by successively dividing each part into its most general parts and by successively dividing each kind into its most general kinds, until you have reached the level of detail specified by the objectives. You will find that there are often several dimensions along which a concept may be divided into kinds. For instance, trees may be divided into kinds according to their age (e.g., seedling, sapling), their type of leaf (e.g., deciduous, pine), their root structure (e.g., tap root system), their ecological environment (e.g., jungle), etc. It will be helpful to identify all important dimensions.

Fifth, on the basis of the objectives of the course, have the SME identify which taxonomies are most important and which ones are most usefully combined to form a matrix.

importance may be influenced to a large extent by its utility in a matrix. Select the most important taxonomy or matrix as the orientation structure. The most important taxonomy may not fit into a useful matrix, but it is likely that it will. If it does, the conceptual orientation structure will be either a parts-by-kinds matrix or a kinds-by-kinds matrix. The taxonomies that are not selected as the orientation structure should be saved, because they will probably be used later as nested conceptual structures within the orientation structure.

Sixth, have the SME check to make sure that every concept that needs to be taught either is a part of the orientation structure or can be subsumed by the orientation structure as a part of a nested conceptual structure.

2b. Procedural orientation structures. The following are the steps that an instructional designer should follow in order to help a SME to construct a procedural orientation structure. First, make sure the SME understands the notions of procedural prerequisite relation and procedural decision relation.

Second, have the SME identify all of the steps that the learner needs to be able to do in order to perform the procedure under the variety of conditions specified by the objectives. To do this, it may be helpful to have the SME identify a very general procedure that subsumes all of the steps to be taught. Then have him systematically break down each step of that general procedure into its major parts and alternatives, and each of them into its major parts and alternatives, and so on until (1) you reach the level of detail necessary to accommodate student entering knowledge and (2) you reach the level of complexity (i.e., the number of alternative branches) specified by the objectives. If there are several procedures for doing the same thing under the same conditions, then include only the most efficient one.

Third, have the SME check to make sure that all steps and all branches that need to be taught are included in the procedural orientation structure.

2c. Theoretical orientation structure. The following are the steps that the instructional designer should follow in order to help a SME to construct a theoretical orientation structure. First, make sure the SME understands the notions of empirical and logical theoretical relations.

Second, have the SME identify all the principles (theoretical relations) that the learner must know in order to be able to perform as required by the objectives. To do this, it may be helpful to have the SME identify an elementary set of theoretical relations (model) that represents a foundation upon which the other theoretical relations elaborate. Then have him systematically identify the major theoretical relations (principles and models) which provide more detail or complexity on the elementary model, until you reach the level of detail and complexity specified by the objectives.

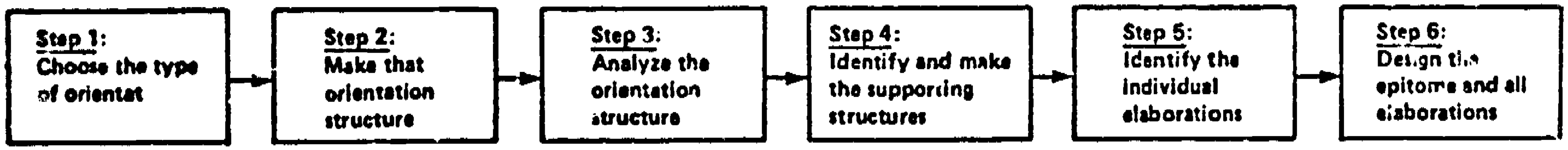
Third, have the SME check to make sure that all of the important principles have been included in the theoretical orientation structure.

3. Analyze the Orientation Structure

The next step (see Figure 27) is for the instructional designer and the SME to analyze the orientation structure just created in order to identify which parts of it should be included in the epitome and which should be added at each level of elaboration. Each level of elaboration is comprised of individual elaborations that are highly different from each other with respect to content because they elaborate on distinct parts of the subject matter. But each level of elaboration as a whole tends to be quite similar to the previous level because it provides more detail on the same content that was provided in the previous level.

Insert Figure 27 about here

Deriving the epitome requires extracting from the orientation structure a set of constructs and relations that epitomize the whole orientation structure. And deriving the levels of elaboration requires deciding upon "dimensions of complexity" which represent the basis upon which the dif-



Conceptual
Procedural
Theoretical

2a. Conceptual
Develop all useful parts and kinds taxonomies, select the most important one(s), and combine into a matrix (if possible).

2b. Procedural
Identify all useful steps and alternative paths to be learned, and combine them into a procedural structure.

2c. Theoretical
Identify all important principles to be learned, and combine them into a theoretical structure.

Figure 27. The six-step design procedure for structuring the instruction in any course entailing cognitive subject matter.

ferent levels elaborate on the epitome or on each other. Also, those dimensions of complexity must be analyzed to determine the order in which the different kinds of detail or complexity will be presented in the instruction.

The result of this third step is an outline of the subject-matter content to be included in the epitome and in each level of elaboration. The specific procedures for doing this analysis of the orientation structure are also somewhat different for each of the three kinds of orientation structures, and they are as follows.

<u>3a. Conceptual.</u> The conceptual orientation structure is the easiest one from which to derive an <u>epitome</u>. In the case of a <u>taxonomy</u>, you start "pruning" from the bottom up until you reach a small enough number of constructs for the student to be able to learn and systhesize in one lesson. In the case of a <u>matrix</u>, (1) you split it into two (or in some cases three) composite taxonomies, (2) you "prune" each taxonomy from the bottom up until you reach half the number of constructs that the student can learn and synthesize in one lesson, and (3) you put the taxonomies back together to form a matrix between their lowest remaining levels. The resulting portion of the conceptual structure is presented as the epitome.

The conceptual orientation structure is also the easiest for deriving the <u>levels of elaboration</u>, because the different dimensions of complexity are merely the levels on the taxonomy(ies). In the case of a taxonomy, the content for the primary level of elaboration is the highest level of the orientation structure that is missing from the epitome. If that level is fairly small, it may be advantageous to add back the two highest levels at the same time. In the case of a matrix, you add back the highest level of the most important (as determined by your SME) taxonomy comprising the matrix. This process is continued until all the parts of the orientation structure have been included. The result of this step is therefore an outline of the portions of the conceptual orientation structure that will be taught in the epitome and in each level of elaboration.

3b. Procedural. The procedural orientation structure is usually the hardest from which to derive an epitome because unlike the other two orientation structures it is not merely "pruned". The following is the procedure that the instructional designer should follow. You should simplify the procedural orientation structure by lumping steps together into more general steps and by eliminating branches for handling special conditions. This simplification should continue until the resulting "idealized" structure has a small enough number of steps for the student to be able to learn and synthesize them all in one lesson. That resulting structure must include only the most important (e.g., most typical) actions to be taken--those actions which contribute most to understanding the complete procedure.

In order to derive the levels of elaboration, you should decide what is the most important one of the actions (i.e., steps and/or branches) that were eliminated or lumped together and select that as the topic for the first-level elaboration. If it is smaller in scope than what the student can comfortably learn and synthesize in one lesson, then the two most important actions could be included in that elaboration. This process is continued until you have identified the content of all the levels of elaboration that are needed to elaborate the epitome to the level of detail and complexity of the entire procedural orientation structure. The result of this step is therefore an outline of the aspects of the procedural orientation structure that will be taught in the epitome and in each level of elaboration.

3c. Theoretical. The epitome can be derived from the theoretical orientation structure by the following procedure. You should "prune" the theoretical orientation structure by eliminating all but the most fundamental theoretical relations. Generally those are similar to the relations that were discovered first, historically. For example, Ohm's Law (E=IR) expresses mathematically the most fundamental theoretical relations in electronics, and the law of supply and demand embodies the most fundamental theoretical relations in economics. The theoretical orientation structure is therefore simplified until the remaining theoretical relations (1) are all of a fundamental or elemental nature (and thereby subsume the remainder of the theoretical subject matter) and (2) are of a number or size that the student is able to learn and synthesize in one lesson.

Deriving the levels of elaboration is more difficult. There are two techniques which help to identify the dimensions of complexity that form the basis for distinguishing the different levels of elaboration. First, you should list all the remaining principles (theoretical relations) in decreasing order of importance. Importance is estimated by the SME on the basis of such factors as contribution to understanding the whole theoretical structure, frequency of use, extensiveness of application, and utility for more advanced training. Principles that are of about the same importance should merely be grouped on a single level of importance--i.e., it is not necessary to try to put them in decreasing order in relation to each other. Then the SME should decide how many of the principles at the top of the list are fundamental enough to warrant inclusion in the primary level of elaboration, and how many of the remaining principles (after removing those for the primary level) should be included in the secondary level of elaboration, and so on. Keep in mind that level of importance is the most important criterion for inclusion according to this technique.

The second technique to help in identifying the different levels of elaboration involves the development of a parallel conceptual structure, whose concepts are different conditions which require different levels of complexity of the principles (e.g., perfect competition in economics, and simple DC circuits in electronics). This parallel conceptual structure helps provide a basis for deciding which principles on the above-mentioned list should be introduced at each level of elaboration, and it also helps to indicate ways in which individual principles can be simplified for their initial presentation to the student. The SME should try to identify conditions which simplify the application of principles and/or reduce the number of principles which apply, and he should try to arrange those conditions into a conceptual structure. Both of these techniques are illustrated below. The result of this step is an outline of the parts of the theoretical orientation structure that will be taught in the epitome and in each level of elaboration, and it may indicate parts of a parallel conceptual structure that will also be taught in the epitome and in each level of elaboration.

4. Identify and Make the Supporting Structures

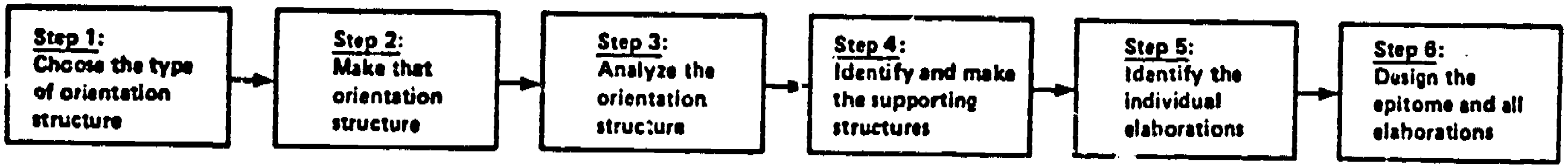
The next step (see Figure 28) is to identify and make all the important supporting structures for the subject-matter content in the epitome and in each level of elaboration. Except for conceptual structures, an orientation structure will usually not have the same kind of supporting structure.

The procedure for performing this step varies little from one kind of orientation structure to another. It is as follows.

Insert Figure 28 about here

First, for each level of detail identify any of the following three kinds of supporting goals which are important (but not yet attained by the students) for the subject-matter content that is introduced at that level: contextual, which specify useful super/co/subordinate relations within the content; procedural, which specify useful procedures that relate to the content; and explanatory, which specify underlying processes or useful change relations entailing the content. Conceptual orientations are often supported by additional contextual goals; procedural orientations are often supported by contextual goals (concept-classification is an important part of most procedures--hence the usefulness of showing coordinate relations and sometimes even super/-subordinate relations); and theoretical orientations are often supported both by procedural goals (to teach an efficient way to implement a principle) and by contextual goals.

Second, for each level of detail make the supporting structure that corresponds to each supporting goal. Some of these supporting structures may be so small as to be in reality "supporting constructs", but they should be included



Conceptual
Procedural
Theoretical

2a. Conceptual
Develop all useful parts and kinds taxonomies, select the most important one(s), and combine into a matrix (if possible).

2b. Procedural
Identify all useful steps and alternative paths to be learned, and combine them into a procedural structure.

2c. Theoretical
Identify all important principles to be learned, and combine them into a theoretical structure.

Decide on the aspects of the orientation structure that should comprise the epitome and each level of elaboration.

3a. Conceptual
Prune the orientation structure to form the epitome. Add back levels to form each level of elaboration.

3b. Procedural
Lump steps and branches together to form the epitome. Break apart each general step to form each level of elaboration.

3c. Theoretical
Prune the orientation structure to form the epitome. Use rank-order of importance and/or a parallel conceptual structure to identify principles for each level of elaboration.

Figure 28. The six-step design procedure for structuring the instruction in any course entailing cognitive subject matter.

just the same. There should be a conceptual supporting structure for each contextual supporting goal, a procedural supporting structure for each procedural supporting goal, and a theoretical supporting structure for each explanatory supporting goal. The result is a more detailed outline of the subject-matter content to be included in the epitome and in each level of elaboration.

Third, for every construct (including those in supporting structures) at every level of detail, identify whether or not an enabling supporting goal is necessary, given the entering knowledge of the students; and for each necessary enabling goal make a learning prerequisite structure that extends down to the level of entering knowledge of the students. Many of these supporting structures may also be so small as to be constructs but should nevertheless be included. In fact, a major purpose of the elaboration approach to sequencing is to make it unnecessary to have learning structures with more than about two levels at any given level of detail.

The result of these three sub-steps is a complete outline of all the subject-matter content that should be included in the epitome and in each level of elaboration.

Alternative for exploration. We have identified an alternative to nesting the supporting structures (with the exception of learning structures) within each level of elaboration, but we need more time to explore its advisability. The alternative is to hold off on presenting the supporting structures (with the exception of learning structure) until a later level of elaboration, and then to present all the supporting structures of a given kind (e.g., procedural supporting structures) on one level of elaboration. The advantage of this alternative is that it may be more consistent with the "most important first" principle in that the secondary (supporting) types of content are presented after the most important (orientation) type of content. But a possible disadvantage is that the instruction may be disjointed--for instance, a procedure that is closely related to a principle is presented separately from the principle rather than right with it. For now we will stay with the nested presentation of supporting structures within each level of elaboration, but we will explore the advantages and disadvantages of presenting them later in a separate level of elaboration.

5. Identify the Individual Elaborations

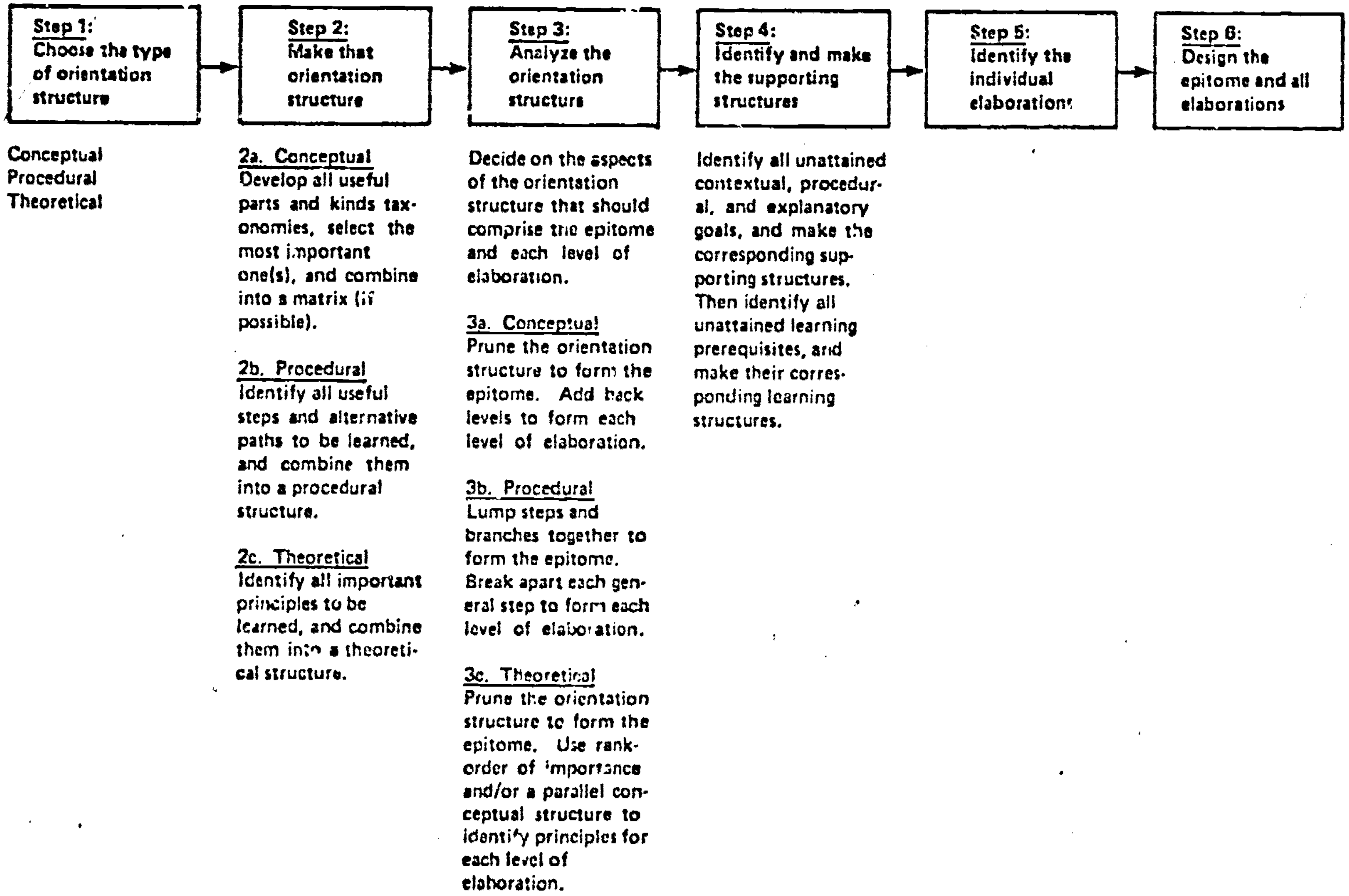
The next step (see Figure 29) is to use both the orientation structure and the supporting structures to analyze each level of elaboration as to its component elaborations. (The epitome is not comprised of any elaborations and is therefore excluded from this step.) This step is fairly constant for all three types of orientation structures, and it is as follows.

Insert Figure 29 about here

We mentioned above that each level of elaboration tends to discuss the same parts of the subject-matter content that were presented in the previous level only at a greater level of detail, whereas the individual elaborations comprising each level tend to contain parts of the subject-matter content that are highly different from each other.

In the primary level of elaboration, each individual elaboration should be comprised of content that (1) provides more detail on one of the parts of the epitome plus its supporting structures, or that (2) provides more detail on the whole epitome. The length of each elaboration can be controlled to some extent by varying the amount of detail (especially with respect to the number of supporting structures) that is presented in the elaboration.

The secondary level of elaboration should reach a more complex, realistic, and/or detailed representation of the orientation structure, but otherwise it should be quite similar to the primary level. In the secondary level each individual elaboration contains more detailed content on one part of the content that was presented in one of the



Conceptual
Procedural
Theoretical

2a. Conceptual
Develop all useful parts and kinds taxonomies, select the most important one(s), and combine into a matrix (if possible).

2b. Procedural
Identify all useful steps and alternative paths to be learned, and combine them into a procedural structure.

2c. Theoretical
Identify all important principles to be learned, and combine them into a theoretical structure.

Decide on the aspects of the orientation structure that should comprise the epitome and each level of elaboration.

3a. Conceptual
Prune the orientation structure to form the epitome. Add back levels to form each level of elaboration.

3b. Procedural
Lump steps and branches together to form the epitome. Break apart each general step to form each level of elaboration.

3c. Theoretical
Prune the orientation structure to form the epitome. Use rank-order of importance and/or a parallel conceptual structure to identify principles for each level of elaboration.

Identify all unattained contextual, procedural, and explanatory goals, and make the corresponding supporting structures. Then identify all unattained learning prerequisites, and make their corresponding learning structures.

Figure 29. The six-step design procedure for structuring the instruction in any course entailing cognitive subject matter.

primary-level elaborations. Secondary-level elaborations should be grouped on the basis of the natural parts of the orientation structure and each such group should be internally synthesized (i.e., relations among its component constructs should be taught). If additional levels of elaboration are necessary, their content is identified in a similar manner.

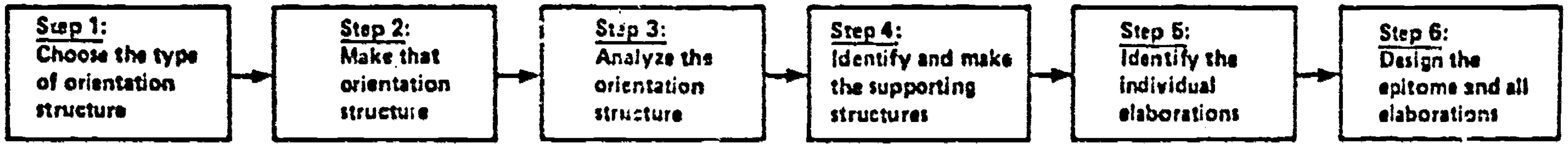
Alternative for exploration. Rather than having more detailed content on one part of the epitome (including that part's supporting structures) in each elaboration in the primary level, it may be advantageous to include more detailed content on all parts of the epitome (without supporting structures, except obviously for learning structures) in one elaboration, and to include all of one kind of their respective supporting structures (e.g., all procedural supporting structures), plus the learning prerequisites for those structures, in another elaboration, etc. Or if this would make each elaboration too long, then the more detailed content on the parts of the epitome (and their learning prerequisites) could be divided into two or three elaborations (even up to one elaboration per part). Then their respective supporting structures (and their learning prerequisites) could be divided correspondingly. This alternative needs further evaluation.

6. Design the Epitome and All Elaborations

The last step of the structural design procedure (see Figure 30) is to make a "blueprint" of the structural strategy components and subject-matter content that are included in each of those components. This step is fairly constant for all three types of orientation structures.

Insert Figure 30 about here

First, design the epitome. Plan out the sequence in which to present the constructs (including those in the supporting structures), and plan out the synthesizers and summarizer. A very general synthesizer (i.e., a very simple or general version of the orientation structure) should be presented first to show a pervasive relation among constructs, even though the constructs themselves are not understood yet. Then each construct should be presented individually according to presentation strategy design specifications (see Merrill, Reigeluth, & Faust, in press; Merrill, Richards, Schmidt, & Wood, 1977; Merrill & Tennyson, 1977). Then those constructs should be summarized--i.e., listed along with a concise generality for each. And finally a more complex synthesizer should be presented to show the pervasive relation once more (and in somewhat greater detail), now that the constructs comprising that simple or general version of the orientation structure are understood.



Conceptual
Procedural
Theoretical

2a. Conceptual
Develop all useful parts and kinds taxonomies, select the most important one(s), and combine into a matrix (if possible).

2b. Procedural
Identify all useful steps and alternative paths to be learned, and combine them into a procedural structure.

2c. Theoretical
Identify all important principles to be learned, and combine them into a theoretical structure.

Decide on the aspects of the orientation structure that should comprise the epitome and each level of elaboration.

3a. Conceptual
Prune the orientation structure to form the epitome. Add back levels to form each level of elaboration.

3b. Procedural
Lump steps and branches together to form the epitome. Break apart each general step to form each level of elaboration.

3c. Theoretical
Prune the orientation structure to form the epitome. Use rank-order of importance and/or a parallel conceptual structure to identify principles for each level of elaboration.

Identify all unattained contextual, procedural, and explanatory goals, and make the corresponding supporting structures. Then identify all unattained learning prerequisites, and make their corresponding learning structures.

Divide each level of elaboration into its individual elaborations, according to the part of the epitome, or of an elaboration, that is being elaborated.

Figure 20. The six-step design procedure for structuring the instruction in any course entailing cognitive subject matter.

Keep in mind that this design document is a "blueprint", not the finished instructional product.

Second, design each elaboration in the primary level of elaboration. Basically the same pattern is followed as for the epitome. Plan out the sequencing of constructs, the synthesizers, and the summarizer. A very general synthesizer should be presented first (it may be a supporting structure instead of a part of the orientation structure). Then each construct should be presented individually with full use of appropriate presentation strategies. Then those constructs should be summarized. And finally, an expanded epitome should be presented to internally and externally synthesize the constructs that were taught in this elaboration. In the case of a supporting structure having just been taught, the expanded epitome would be a nested multi-structure that would both internally synthesize the constructs (i.e., show interrelations among each other) and externally synthesize them (i.e., show interrelations with other types of constructs). This pattern is continued for each elaboration in the primary-level until all primary-level elaborations have been designed.

Third, design each elaboration in each of the remaining levels of elaboration. Here, the procedure is almost identical to that for the primary level. The major difference is that often there is a separate elaboration/expanded epitome for each part of each primary-level elaboration. In such a case, each secondary-level elaboration/expanded epitome relates to a single primary-level elaboration in the same way that each primary level elaboration relates to the whole epitome: each secondary-level elaboration elaborates on a part of a single primary-level elaboration. However, it is also possible to design just one secondary-level elaboration to elaborate on an entire primary-level elaboration.

Fourth, the instruction ends with a terminal epitome that is identical to the entire orientation structure, except that some supporting structures may also be illustrated, making it a nested multi-structure. Figure 31 summarizes the six-step structural design procedure.

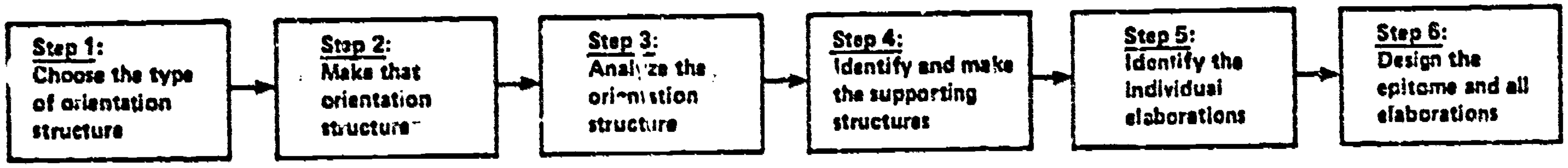
Insert Figure 31 about here

ILLUSTRATION OF THE DESIGN PROCEDURE

The following is an illustration of the above-described six-step design procedure for structuring the instruction in any course entailing cognitive subject matter. The course material selected for the illustration is that which is presented in the Navy's Basic Electricity and Electronics (BE and E) course.

1. Choose the Type of Orientation Structure

The BE and E course's major purpose is to provide trainees with a basic understanding of electronics and



Conceptual
Procedural
Theoretical

2a. Conceptual
Develop all useful parts and kinds taxonomies, select the most important one(s), and combine into a matrix (if possible).

2b. Procedural
Identify all useful steps and alternative paths to be learned, and combine them into a procedural structure.

2c. Theoretical
Identify all important principles to be learned, and combine them into a theoretical structure.

Decide on the aspects of the orientation structure that should comprise the epitome and each level of elaboration.

3a. Conceptual
Prune the orientation structure to form the epitome. Add back levels to form each level of elaboration.

3b. Procedural
Lump steps and branches together to form the epitome. Break apart each general step to form each level of elaboration.

3c. Theoretical
Prune the orientation structure to form the epitome. Use rank-order of importance and/or a parallel conceptual structure to identify principles for each level of elaboration.

Identify all unattained contextual, procedural, and explanatory goals, and make the corresponding supporting structures. Then identify all unattained learning prerequisites, and make their corresponding learning structures.

Divide each level of elaboration into its individual elaborations, according to the part of the epitome, or of an elaboration, that is being elaborated.

Design the epitome.
- general synthesizer
- constructs
- summarizer
- epitome (synthesizer)

Design each elaboration in the primary level
- general synthesizer
- constructs
- summarizer
- expanded epitome

etc.

Design the terminal epitome.
- orientation structure
- important supporting structures

Figure 31. The six-step design procedure for structuring the instruction in any course entailing cognitive subject matter.

electricity. The course is not a "terminal" course that is intended to completely prepare the trainee for a specific job; rather it is an "introductory" course that is intended to prepare the trainee for more advanced courses. This preparation entails the learning of concepts, procedures, and principles; but by far the most important of these three types of content is principles. The emphasis of the course should be on teaching a set of fundamental theoretical relationships. Therefore, a theoretical orientation structure is most appropriate for the course.

2. Make that Orientation Structure

A subject-matter expert (SME) is used to help derive the most detailed or complex version of the theoretical orientation structure that is required by the objectives of the BE and E course.

First, we made sure that the SME understood what we meant by theoretical relations.

Second, we had the SME list all of the theoretical relations (principles) that the trainee should know (see Figure 32), given the objectives of the course; and we had him diagram those relations so as to form a diagramatic representation of the theoretical orientation structure (see Figure 33).

Insert Figures 32 and 33 about here

Third, we had the SME double check to make sure that no important theoretical relations were left out.

3. Analyze the Orientation Structure

First, the designer and the SME identified the most fundamental theoretical relations (principles). They are expressed by Ohm's Law, which is mathematically described as I=ER. This was selected as the topic for the epitome.

Second, the SME arranged the remaining theoretical relations (principles) in Figure 32 in decreasing order of importance (this is already done in Figure 32). Many principles were more or less at the same level of importance, so they were grouped together into levels.

Third, the SME identified a set of conditions which simplify the application of the principles and reduce the number of principles which apply. Those conditions are the type of electricity (DC or AC) and the type of electrical circuit (simple, series, parallel, or combination). Figure 34 shows the resulting parallel conceptual structure.

Insert Figure 34 about here

Fourth, on the basis of both the prioritized list and the dimensions of complexity shown in Figure 34, we identified a set of theoretical relations that are of fundamental importance to understanding electricity and electronics. They are those which relate to (1) power, which elaborates on E, and

		TYPES OF ELECTRICITY	
		DC	AC
TYPES OF CIRCUITS	Simple	DC in simple circuits	AC in simple circuits
	Series	DC in series circuits	AC in series circuits
	Parallel	DC in parallel circuits	AC in parallel circuits
	Combination	DC in combination circuits	AC in combination circuits

Figure 34. A types-by-types matrix as the parallel conceptual structure. It shows the conditions that influence the number and complexity of principles. Those conditions influence the selection of content from the orientation structure for each level of elaboration.

(2) frequency in alternating current, which elaborates on R. These were selected as the constructs for the primary level of elaboration, along with the AC-DC distinction in the parallel conceptual structure.

Fifth, on the basis of both the prioritized list and the dimensions of complexity shown in the parallel conceptual structure, we identified the remaining theoretical relations that are the most fundamental elaborations on the theoretical relations presented in the primary level of elaboration. They are those related to the simple-series-parallel-combination distinction in the parallel conceptual structure. These theoretical relations were selected as the constructs for the secondary level of elaboration, along with the simple-series-parallel-combination distinction in the parallel conceptual structure.

This process was continued until the entire orientation structure was allocated to one or another part of the instruction. Figure 35 outlines the parts of the theoretical orientation structure and of the parallel conceptual structure that were selected for the epitome and for each level of elaboration.

Insert Figure 35 about here

Structural strategy component	Part of theoretical orientation structure included	Part of parallel conceptual structure included
Epitome	Ohm's law: $I = \frac{E}{R}$	DC simple
Primary Level of Elaboration	$P = EI$ $C = \frac{Q}{E}$ Factors affecting: inductance capacitance	DC – AC simple
Secondary Level of Elaboration	$E_a = E_1 + E_2 + \ldots$ $I_T = I_1 = I_2 = \ldots$ $R_T = R_1 + R_2 + \ldots$ $L_T = L_1 + L_2 + \ldots$ $C_T = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \ldots}$ $E_a = E_1 = E_2 = \ldots$ $I_T = I_1 + I_2 + \ldots$ $R_T = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \ldots}$ $L_T = \frac{1}{\frac{1}{L_1} + \frac{1}{L_2} + \ldots}$ $C_T = C_1 + C_2 + \ldots$ $P_T = P_{R1} + P_{R2} + \ldots$	DC – AC Series Parallel
Tertiary Level of Elaboration	Left-hand rule Faraday's Law Lenz's Law $\frac{Ep}{Es} = \frac{Np}{Ns} = \frac{Is}{Ip}$ $Pp = Ps$ $X_L = 2 \pi f L$ $X_C = \frac{1}{2 \pi f C}$ $\text{Effic} = \frac{P\ \text{out}}{P\ \text{in}}$ $P_f = \frac{\text{True P}}{\text{Appar. P}}$ $T_C = RC$ Phase and power relationships	DC – AC Combination

Note: This figure is intended to be exemplary. It is beyond our intent and the scope of our funding to include all of the content that should be taught in the BE and E course.

Figure 35. The parts of the theoretical orientation structure and of the parallel conceptual structure that are allocated to the epitome and to each level of elaboration.

4. Identify and Make the Supporting Structures.

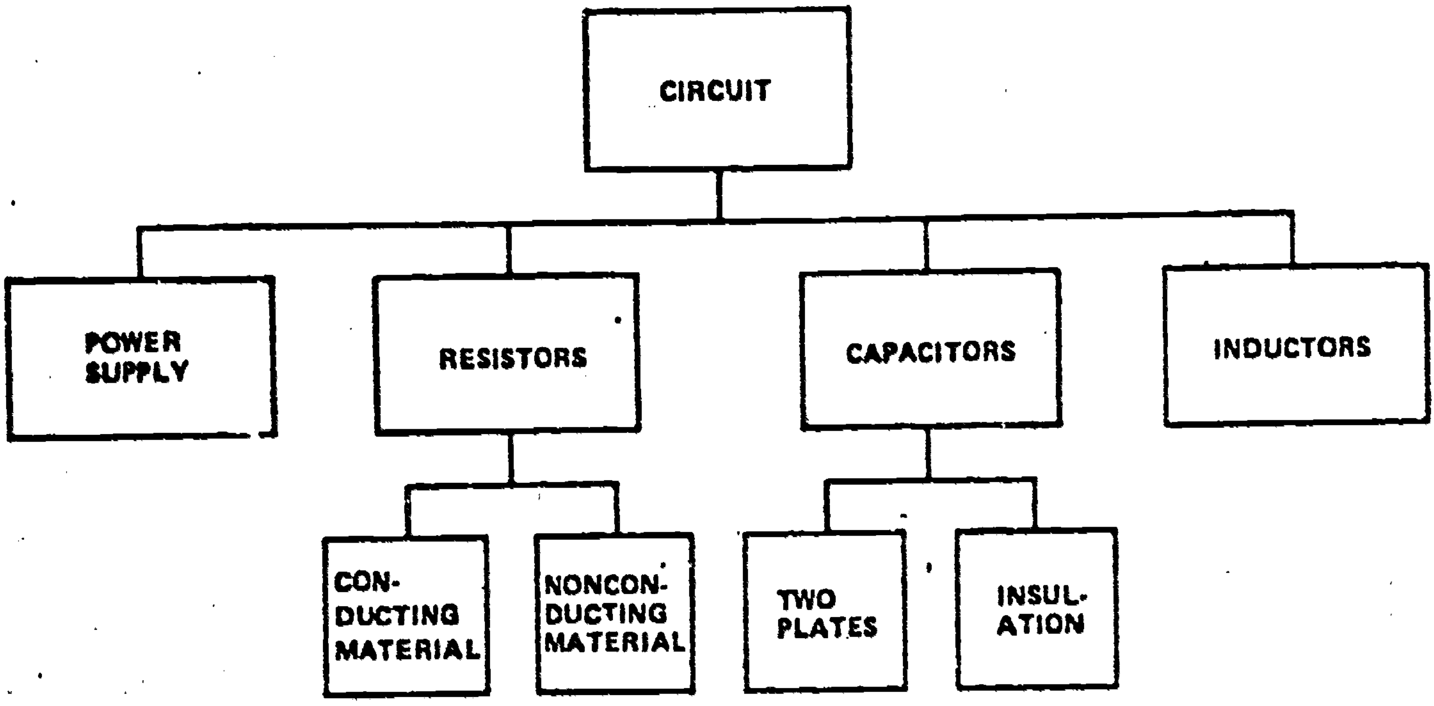
Given that we had selected a theoretical orientation goal, the supporting goals would not be explanatory; but it is highly likely that there would be both important contextual and important procedural supporting goals. Therefore, we first helped the SME identify those supporting goals for the epitome and for each level of elaboration.

Second, for each level of detail (including the epitome) we helped the SME make a conceptual supporting structure for each contextual supporting goal, and we helped him make a procedural supporting structure for each procedural supporting goal. Examples are shown in Figures 36-39.

Insert Figures 36-39 about here

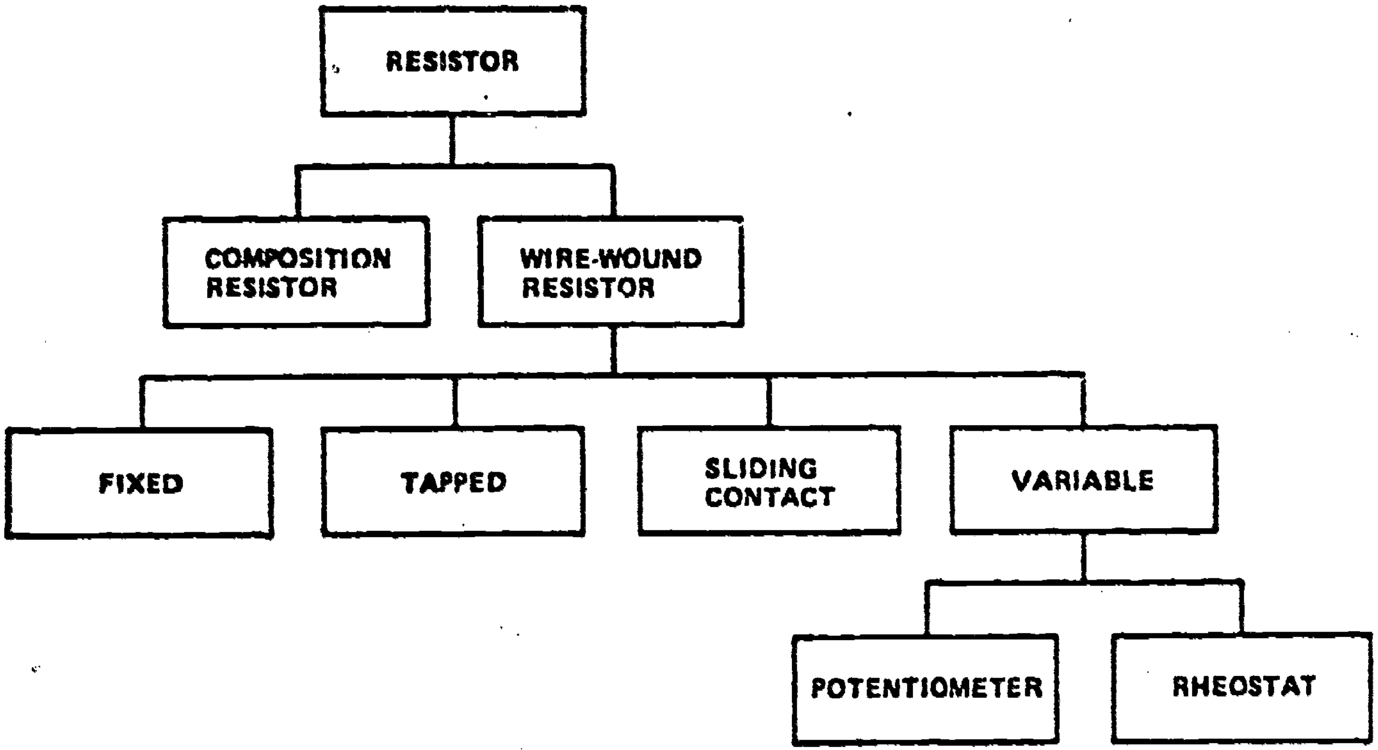
Third, for every construct (including those in supporting structures) at each level of detail, we identified whether or not an enabling supporting goal was necessary, given the entering knowledge of the trainees. And for each necessary enabling goal, we helped the SME to make a learning-prerequisite structure that extended to the level of entering knowledge. Examples are shown in Figures 40-42.

Insert Figures 40-42 about here



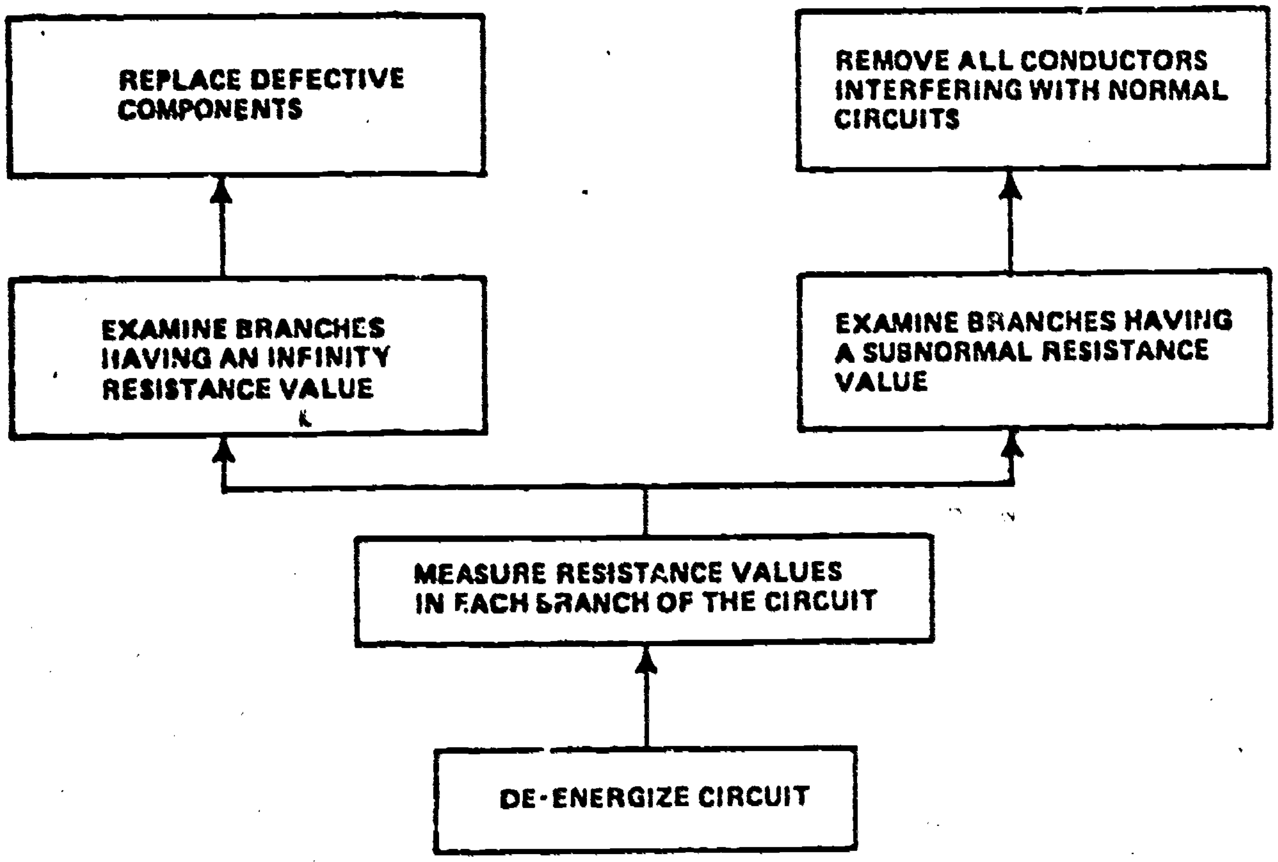
Key: The line between two boxes on different levels means that the lower box is a part of the higher box.

Figure 36. A parts taxonomy as a conceptual supporting structure.



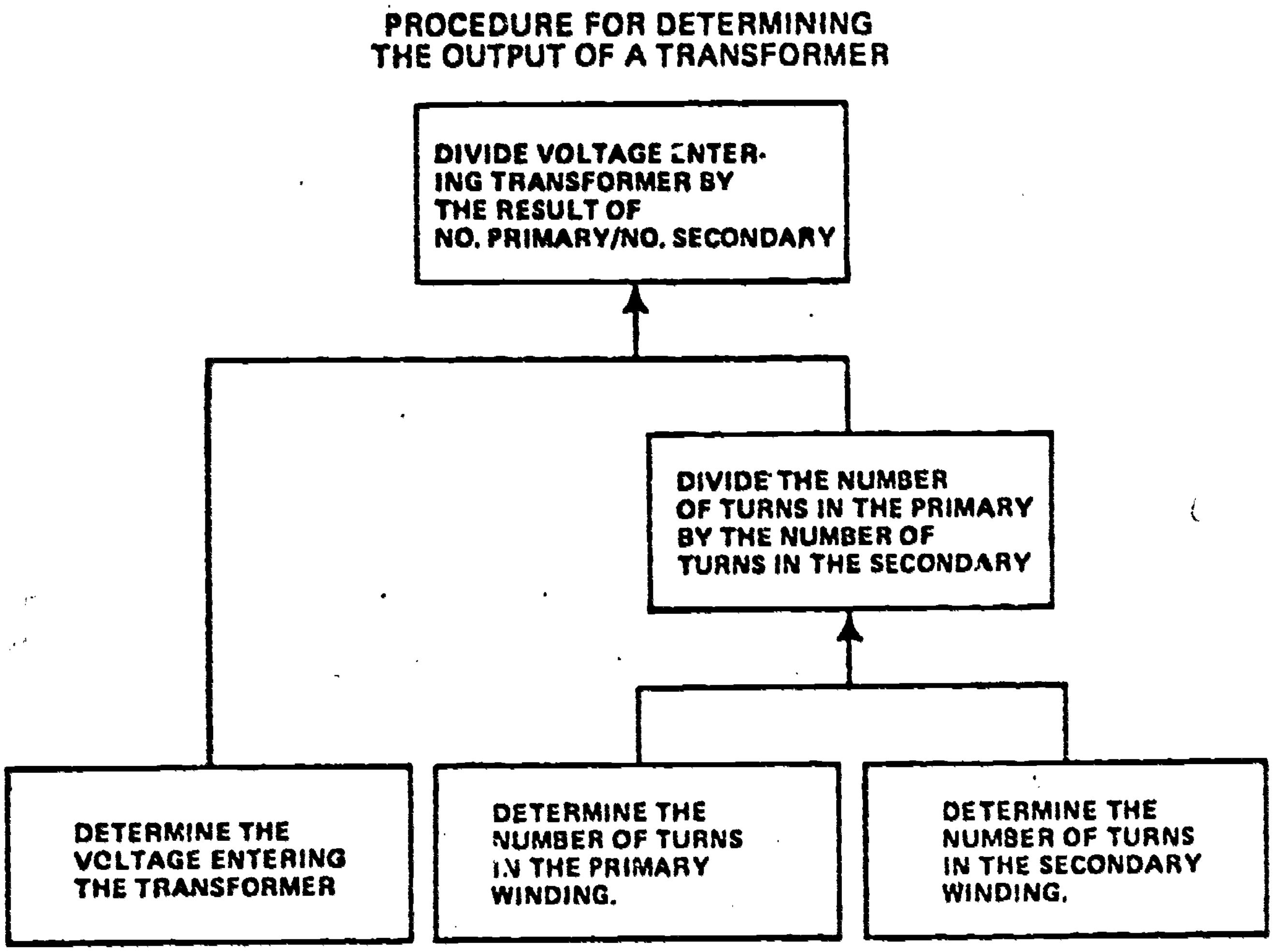
Key: The line between two boxes on different levels means that the lower box is a kind of the higher box.

Figure 37. A kinds taxonomy as a conceptual supporting structure



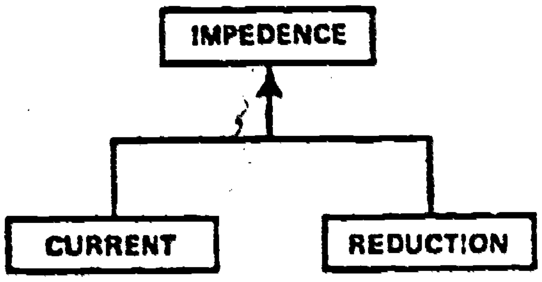
KEY: The arrow between two boxes on different levels means that the lower box must be performed before the higher box can be performed. Boxes on the same level can be performed in any order.

Figure 38. A procedural-prerequisite structure as a procedural supporting structure.



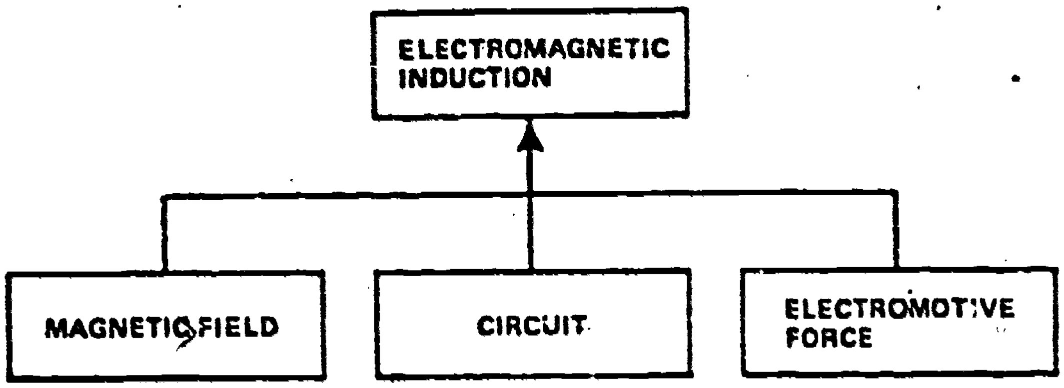
Key: The arrow between two boxes on different levels means that the lower box must be performed before the higher box can be performed. Boxes on the same level can be performed in any order.

Figure 39. A procedural-prerequisite structure as a procedural structure.



Key: The arrow between tow boxes on different levels means that the lower box must be learned before the higher box can be learned.

Figure 40. A learning-prerequisite structure (or more precisely, construct) as a supporting structure.



Key: The arrow between two boxes on different levels means that the lower box must be learned before the higher box can be learned.

Figure 42. A learning prerequisite structure (construct) as a supporting structure.

As a result of this fourth step, we prepared a complete outline of the subject-matter content that should be included in the epitome and in each level of elaboration. This outline is shown in Figure 43.

Insert Figure 43 about here

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5. Identify the Individual Elaborations

With the help of the SME, we divided up the principles in the primary level of elaboration according to the part of the epitome on which each of those principles elaborates. For instance, P (power) is an elaboration on E (electromotive force) because power is conceptually closer to E than to either I or R. Therefore, the power formula (see Figure 43) should comprise primary-level elaboration--that which elaborates on E. In a similar way we identified the primary-level content that elaborates on I and that which elaborates R.

Then, with the help of the SME we divided up the principles in the secondary level of elaboration according to the part of a primary-level elaboration on which each of those principles elaborates.

Figure 44 shows the content in each level of elaboration that was allocated to each individual elaboration within that level.

Insert Figure 44 about here

Structural strategy component	Part of theoretical orientation structure included	Part of conceptual parallel structure included	Conceptual supporting structures included	Procedural supporting structures included	Learning prerequisite structures included
Epitome	$I = \frac{E}{R}$	DC simple		Manipulating I Measuring E, I, R Calculating E, I, R Troubleshooting	E, I, R Scientific notation shorts, opens
Primary Level of	Factors affecting: inductance capacitance $C = \frac{Q}{E}$ $P = EI$	DC – AC simple	Resistor (kinds) Capacitor (kinds) Inductor (kinds) Power supply (kinds) Frequency (kinds) Electromagnetic inductor (parts)	Measuring L, C Calculating P Manipulating f Reading resistor, inductor, capacitor values	DC, AC, magnetism, electromagnetic induction, counter EMF, generator, frequency, phase, L, C, P, resistor, capacitor, inductor, induction.
Secondary Level of Elaboration	$E_a = E_{R1} + E_{R2} + \ldots$ $I_T = I_{R1} = I_{R2} = \ldots$ $R_T = R_1 + R_2 + \ldots$ $L_T = L_1 + L_2 + \ldots$ $C_T = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \ldots}$ $E_a = E_{R1} = E_{R2} = \ldots$ $I_T = I_{R1} + I_{R2} + \ldots$ $R_T = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \ldots}$	DC – AC series-parallel		Calculations Troubleshooting	Series circuits, parallel circuits, applied voltage, equivalent resistance.

Note: This figure is intended to be exemplary. It is beyond our intent and the scope of our funding to include all of the content that should be taught in the BE and E course.

Figure 43. An outline of the subject-matter content that should be included in the epitome and in each level of elaboration.

Structural strategy component	Part of theoretical orientation structure included	Part of conceptual parallel structure included	Conceptual supporting structures included	Procedural supporting structures included	Learning prerequisite structures included
Secondary Level of Elaboration (Continued)	$L_T = \frac{1}{\frac{1}{L_1} + \frac{1}{L_2} + \ldots}$ $C_T = C_1 + C_2 + \ldots$ $P_T = P_{R1} + P_{R2} + \ldots$				
Tertiary Level of Elaboration	Left-hand rule Faraday's Law Lenz's Law $Pp = Ps$ $\frac{Ep}{Es} = \frac{Np}{Ns} = \frac{Is}{Ip}$ $X_L = 2 \pi f L$ $X_C = \frac{1}{2 \pi f C}$ $\text{Effic.} = \frac{P\ out}{P\ in}$ $P_f = \frac{\text{True } P}{\text{Appar. } P}$ $Tc = RC$ Phase and power relationships	AC – DC Combination	Transformer (parts)	Measuring X_L, X_C Calculating X_L, X_C, RC time constant, appar. P, Pf. transformer efficiency Designing a voltage divider	Transformers, transformer efficiency, turns, primary, secondary, load, rectifier, combination circuits, RC time constant, X_L, X_C, vectors, appar. P, Pf.

Note: This figure is intended to be exemplary. It is beyond our intent and the scope of our funding to include all of the content that should be taught in the BE and E course.

Figure 43. (Continued) An outline of the subject-matter content that should be included in the epitome and in each level of elaboration.

Structural strategy component		Part of theoretical orientation structure included	Part of conceptual parallel structure included	Conceptual supporting structures included	Procedural supporting structures included	Learning prerequisite structures included
Epitome		$I = \frac{E}{R}$	DC simple		Manipulating I Measuring E, I, and R Calculating E, I, R Troubleshooting	E, I, R, Scientific notation shorts, opens
Primary Level of Elaboration	1.	$P = EI$	DC – AC simple	Power Supply (kinds) Electromagnetic inductor (parts)	Calculating P	DC, AC, magnetism, electromagnetic induction, counter EMF, generator, P
	2.		AC simple	Frequency (kinds)	Manipulating frequency	Frequency, phase
	3.	$C = \frac{Q}{E}$ Factors affecting: inductance capacitance	AC simple	Resistor (kinds) Capacitor (kinds) Inductor (kinds)	Measuring L, C Reading resistor, inductor, capacitor, values	L, C, resistor, capacitor, inductor, induction
Secondary Level of Elaboration	1.1	$E_a = E_{R1} + E_{R2} \cdots$ $P_T = P_{R1} + P_{R2} + \ldots$	DC – AC series		Calculations	Series circuits, applied voltage
	2.1	$I_T = I_{R1} = I_{R2} = \ldots$	DC – AC series		Calculations	
	3.1	$R_T = R_1 + R_2 + \ldots$ $L_T = L_1 + L_2 + \ldots$ $C_T = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \ldots}$	DC – AC series		Calculations Troubleshooting	

Note: This figure is intended to be exemplary. It is beyond our intent and the scope of our funding to include all of the content that should be taught in the BE and E course.

Figure 44. An outline of the subject-matter content that should be allocated to the epitome and to each individual elaboration within each level of elaboration.

Structural strategy compons.		Part of theoretical orientation structure included	Part of conceptual parallel structure included	Conceptual supporting structures included	Procedural supporting structures included	Learning prerequisite structures included
Secondary Level of Elaboration (Continued)	1.2	$E_a = E_{R1} = E_{R2} = \ldots$ $P_T = P_{R1} + P_{R2} + \ldots$	DC – AC parallel		Calculations	Parallel circuits
	2.2	$I_T = I_{R1} + I_{R2} + \ldots$	DC – AC parallel			
	3.2	$R_T = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \ldots}$ $L_T = \frac{1}{\frac{1}{L_1} + \frac{1}{L_2} + \ldots}$ $C_T = C_1 + C_2 + \ldots$	DC – AC parallel			Equivalent resistance
Tertiary Level of Elaboration	1.1.1 (2.2.1)	$Pp = Ps$ $\frac{Ep}{Es} = \frac{Np}{Ns}$ $\text{Effic.} = \frac{P\ out}{P\ in}$	DC – AC Combination	Transformer (parts)	Calculations	Transformers, transformer efficiency, turns, primary, secondary, load, rectifier, combination circuits
	2.1.1 (2.2.1)	$\frac{Np}{Ns} = \frac{Is}{Ip}$	DC – AC Combination		Calculations	
	3.1.1 (3.2.1)	$Tc = RC$ $X_L = 2\pi f L$ $X_C = \frac{1}{2\pi f C}$	DC – AC Combination		Calculations Measuring X_L, X_C	X_L, X_C, RC time constant

Note: This figure is intended to be exemplary. It is beyond our intent and the scope of our funding to include all of the content that should be taught in the BE and E course.

Figure 44. (Continued) An outline of the subject-matter content that should be allocated to the epitome and to each individual elaboration within each level of elaboration.

Structural strategy component	Part of theoretical orientation structure included	Part of conceptual parallel structure included	Conceptual supporting structures included	Procedural supporting structures included	Learning prerequisite structures included
Tertiary Level of Elaboration (Continued) 1.1.2 (1.2.2)	$P_f = \frac{\text{True P}}{\text{Appar. P}}$ Phase & power relationships	DC – AC Combination		Calculations	Appar. P, P_f, vectors
1.1.3 (1.2.3)	Left-hand rule Faraday's Law Lenz's Law	DC – AC Combination			

Note: This figure is intended to be exemplary. It is beyond our intent and the scope of our funding to include all of the content that should be taught in the BE and E course.

Figure 44. (Continued) An outline of the subject-matter content that should be allocated to the epitome and to each individual elaboration within each level of elaboration.

6. Design the Epitome and All Elaborations

This last step of the structural design procedure results in a "blueprint" of the structural strategy components and of the subject-matter content that is included in each of those components.

First, we designed the epitome by planning out the sequence in which to present the constructs (including those in the supporting structures), and by planning out the synthesizers and the summarizers. The resulting "blueprint" of the epitome is shown in Figure 45.

Insert Figure 45 about here

Second, we designed each elaboration in the primary level of elaboration, again by planning out the sequence in which to present the constructs, and by planning out the synthesizers and summarizers. The resulting blueprints are shown in Figures 46-48.

Insert Figures 46-48 about here

Third, we designed each elaboration in the secondary level of elaboration, again by planning out the sequence in which to present the constructs, by planning out the synthesizers and summarizers, and also by planning out the order in which to present each secondary-level elaboration.

EPITOME

Initial synthesizer: $I = \frac{E}{R}$ Parallel con. structure

Instruction on E, I, and R, DC (concepts)
- generality-instance-practice format

Instruction on $I = \frac{E}{R}$ (Principle)
- generality-instance-practice format

Initial synthesizer scientific notation

Instruction on scientific notation
- generality-instance-practice format

Summarizer/synthesizer on scientific notation

Initial synthesizer on measuring E, I, R

Instruction on measuring E, I, R
- generality-instance-practice format

Summarizer/synthesizer for measuring E, I, R

Initial synthesizer on calculating E, I, R

Instruction on basic algebra
- generality-instance-practice format

Summarizer/synthesizer for basic algebra

Instruction on calculating E, I, R.
- generality-instance-practice format

Summarizer/synthesizer on calculating E, I, R

Summarizer and expanded epitome synthesizer
($I = \frac{E}{R}$ and its supporting structures)

Figure 45. A "blueprint" of the epitome.

PRIMARY LEVEL OF ELABORATION
First Individual Elaboration

Initial synthesizer: P = EI.

Instruction on P (concept)

- generality-instance-practice format

Instruction on P = EI (principle)

- generality-instance-practice format

Initial synthesizer on parallel conceptual structure

Instruction on kinds of power supply (AC - DC)

- generality-instance-practice format

Summarizer/synthesizer on kinds of power supply

Initial synthesizer Instruction Summarizer/synthesizer	on magnetism, electromagnetic induction, counter EMF, and generators (concepts).

Initial synthesizer on parts of electromagnetic inductors

Instruction on parts of electromagnetic inductors (G-I-P format)

Summarizer/synthesizer on parts of electromagnetic inductors

Initial synthesizer on calculating P

Instruction on calculating P (G-I-P format)

Summarizer/synthesizer on calculating P

Summarizer and expanded epitome.

Figure 46. A "blueprint" of the first primary-level elaboration.

PRIMARY LEVEL OF ELABORATION
Second Individual Elaboration

Initial synthesizer on kinds of frequency

Instruction on kinds of frequency

- generality-instance-practice format

Summarizer/synthesizer on kinds of frequency

Initial synthesizer Instruction Summarizer/synthesizer	on phase
Initial synthesizer Instruction Summarizer/synthesizer	on manipulating frequency

Expanded epitome showing the context of frequency within the orientation structure

Figure 47. A "blueprint" of the second primary-level elaboration

PRIMARY LEVEL OF ELABORATION
Third Individual Elaboration

Initial synthesizer: $C = \frac{Q}{E}$

Instruction on induction, L, C, Q, E (concepts)

- G-I-P format

Instruction on $C = \frac{Q}{E}$ (principle)

- G-I-P format

Initial synthesizer Instruction Summarizer/synthesizer	on measuring $\left\{\begin{matrix} L \\ C \end{matrix}\right.$
Initial synthesizer Instruction Summarizer/synthesizer	on calculating C
Initial synthesizer Instruction Summarizer/synthesizer	on kinds of elect. components (resistors, capacitors, inductors) and on kinds of those kinds
Initial synthesizer Instruction Summarizer/synthesizer	on factors affecting inductance and capacitance

Summarizer and expanded epitome

Figure 48. A "blueprint" of the third primary-level elaboration.

For the purposes of this report, we feel it is unnecessary to present further illustrations of the resulting "blueprints".

The way in which these individual "blueprints" fit together is shown in Figure 49.

Insert Figure 49 about here

COMPARISON WITH HIERARCHICAL DESIGN

To facilitate the comparison of our elaboration approach with a hierarchical approach to instructional design, we have outlined the organization of the Navy's current Basic Electricity and Electronics (BE and E) course (see Figure 50). The hierarchical design tends to start with the trivial and is characterized by a notable lack of integration or synthesis of the content.

Insert Figure 50 about here

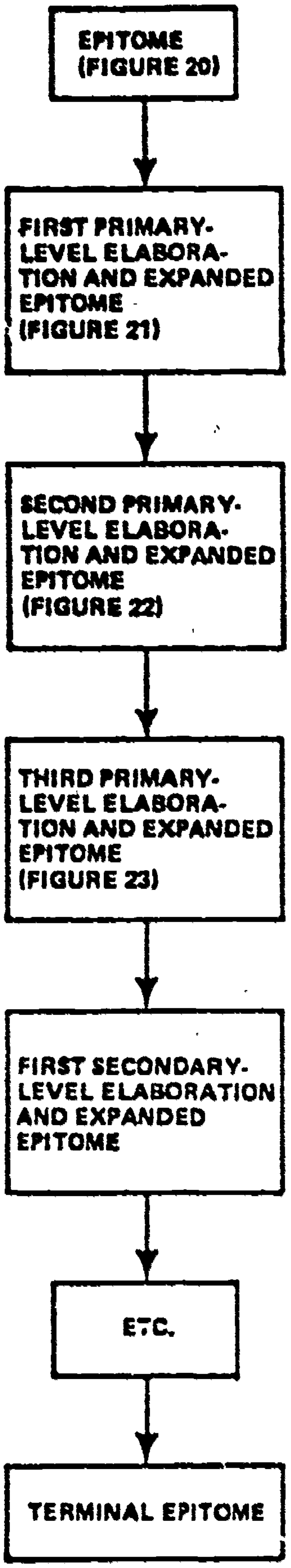

Figure 49. A "blueprint" of the way in which the blueprints" fit together.

BEand E Module Number	Part of theoretical orientation structure included	Part of conceptual parallel structure included	Conceptual supporting structures included	Procedural supporting structures included	Learning prerequisite structures included
1		Simple circuit		Measuring I	I, simple circuit, basic algebra, scientific notation
2	Left-hand rule	DC, AC, (series)		Measuring E	E, magnetism, electromagnetic induction, generator
3		Simple DC	Resistor (kinds)	Measuring R, reading resistor values	R, resistor
4	$I_1 = I_2 = \ldots$ $E_a = E_{R1} + E_{R2} + \ldots$	Series, (parallel) DC		Measuring I, E Calculating E_a	Series circuit, (parallel circuit), applied voltage
5	$I = \frac{E}{R}$ $P = EI$	Series, DC		Calculating E, I, R, P Manipulating I Troubleshooting	P, short circuits, open circuits
6	$E_a = E_{R1} = E_{R2} = \ldots$ $I_T = I_{R1} + I_{R2} + \ldots$ $R_T = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \ldots}$ $R_T = R_1 + R_2 + \ldots$ $P_T = P_{R1} + P_{R2} + \ldots$	Parallel		Calculations Troubleshooting	Parallel circuit, equivalent resistance

Note: This figure does not contain all of the content in the BE and E course. It is intended to give an indication of the nature of the organization of this version of the course.

Figure 50. An outline of the organization of the Navy's Basic Electricity and Electronics course.

BE and E Module Number	Part of theoretical orientation structure included	Part of conceptual parallel structure included	Conceptual supporting structures included	Procedural supporting structures included	Learning prerequisite structures included'
7 (Continued)		Combination		Calculations Designing a voltage divider	Combination circuits, voltage dividers
8	Left-hand rule Faraday's Law Lenz's Law Factors affecting inductance	AC	Inductor (kinds) Electromagnetic inductor (parts)	Calculating L	L, induction, inductor, counter EMF
9*	$L_T = L_1 + L_2 + \ldots$ $L_T = \frac{1}{\frac{1}{L_1} + \frac{1}{L_2} + \ldots}$ $X_L = 2 \pi f C$	All		Calculations Reading inductor values	T_C, X_L
10	$\frac{Ep}{Es} = \frac{Np}{Ns} = \frac{Is}{Ip}$ $Pp = Ps$ Effic. $= \frac{P\ out}{P\ in}$	AC	Transformer (parts)	Calculations	Transformer, turns, primary, secondary, load, transformer efficiency, rectifier
11	$C = \frac{Q}{E}$ Factors affecting capacitance $C_T = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \ldots}$ $C_T = C_1 + C_2 + \ldots$	All	Capacitor (kinds)	Calculations Reading capacitor values	C, capacitance, capacitor, X_C, phase, RC time constant, appar. P, P_t

Note: This figure does not contain all of the content in the BE and E course. It is intended to give an indication of the nature of the organization of this version of the course.

Figure 50. (Continued) An outline of the organization of the Navy's Basic Electricity and Electronics course.

BE and E Module Number	Part of theoretical orientation structure included	Part of conceptual parallel structure included	Conceptual supporting structures included	Procedural supporting structures included	Learning prerequisite structures included
11 (Continued)	$X_C = \frac{1}{2 \pi f C}$ $P_f = \frac{\text{True P}}{\text{Appar. P}}$ Phase and power relationships				

Note: This figure does not contain all of the content in the BE and E course. It is intended to give an indication of the nature of the organization of this version of the course.

Figure 50. (Continued) An outline of the organization of the Navy's Basic Electricity and Electronics course.

SECTION 3

APPLICABILITY TO NAVY TRAINING

The applicability of the instructional model and instructional design procedures to Navy training is excellent and highly important. The elaboration model of instruction applies equally as well to <u>training</u> (i.e., the teaching of performance skills and procedures) as to more purely cognitive (academic) types of instruction. Most training types of instruction have a procedural orientation and can very profitably utilize a procedural epitome and subsequent levels of elaboration according to the model. There are two infrequent situations in which the model would not apply. If the course is very <u>short</u>, the notion of epitome/elaboration would make little difference because the content is small enough that sequencing and synthesizing will not make much difference (as long as learning prerequisites are considered). And if there is no <u>structural interrelatedness</u> among the constructs being taught, such as a course that entails memorizing morse code or signal flags, then the notion of epitome/elaboration does not apply.

In addition to having broad applicability to Navy training, the elaboration model is very <u>important</u> for Navy training. There are two reasons for this importance (they are really different sides of the same coin): (1) the inadequacy of current hierarchical methods for structuring a course and (2) the particular strengths of the elaboration model for structuring a course.

The major reason for the inadequacy of current hierarchical methods for structuring a course is that learning hierarchies are only one aspect of the structure of subject matter content. Therefore, at best it represents a very incomplete basis upon which to make decisions about sequencing that subject matter content. Also, of all the aspects of the structure of subject matter content, learning hierarchies are the only one that is totally useless for synthesizing the content.

There are at least three particular strengths of the elaboration model for structuring a course: (1) its emphasis is on the analysis of the organization or structure of the subject matter; (2) the model was developed on the basis of prescriptive principles of instruction that place top priority on increased effectiveness, efficiency, and appeal of the instruction, and those principles are highly consistent with recent theories of cognitive psychology; and (3) the increased efficiency and effectiveness of this method for structuring a course should reduce training costs in a criterion-referenced setting.

The elaboration model emphasizes the analysis of the organization or structure of the subject matter. This is an important improvement in the theory of instructional design because it provides a clarity in the understanding of relationships (within the subject matter) that provide an important basis for making decisions about good sequencing and synthesizing strategies. Being able to make consistently good decisions about sequencing and synthesizing strategies makes possible a level of instructional effectiveness, efficiency, and appeal that was previously unattainable.

Second, the elaboration model is based on prescriptive principles of instruction that place top priority on increased instructional effectivenss, efficiency, and appeal. The emphasis is on what ought to happen and how to make it happen, rather than on what tends to be in the majority of cases. It is the difference between improving the way people learn and merely describing the way people learn. This difference is what distinguishes the science of instruction from the science of learning. Yet, clearly, the science of instruction is based to some extent in the science of learning; improving the way people learn is dependent to some extent on understanding the way people learn. For these reasons, we would like to emphasize that the elaboration model is highly consistent with current theories of cognitive psychology. It is highly consistent with Ausubel's theory of subsumption (Ausubel, 1963, 1968) and with the newer schemata theory (Anderson, 1978). On the basis of these theories and on the basis of our empirical experience, the elaboration model should result in greater effectiveness, long-term retention, and transfer/generalization to new situations because of greater meaningfulness and cohesiveness of the instructional content.

The third reason why the elaboration model is very important for Navy training is that it should reduce training time in a criterion-referenced setting and thereby reduce training costs. This savings is a benefit of the model's higher instructional effectiveness and efficiency.

Finally, we would like to point out that the elaboration model extends and complements the Instructional Quality Inventory. Whereas the IQI focused on considerations for instructional design on a single construct, the elaboration model focuses on design considerations related to relationships among constructs. The two instruments form a comprehensive approach to instructional design.

SECTION 4

FURTHER INVESTIGATIONS

There are two major kinds of further investigations which we feel need to be done: (1) those which improve the products that we have already developed in this project and (2) those which extend what we have done to new applications. These two kinds of investigations are discussed in greater detail below.

Improving What We Have

We recommend two separate activities for improving the products that we have developed in this project: (1) empirical research to test and improve the instructional model and (2) a large-scale development project to extensively and rigorously field-test the design procedures.

We propose that the type of empirical research needed is not of the prevalent "controlled experiemnt" variety. Rather we advocate the type of empirical research that studies whole models of instruction and determines what components are needed to comprise the best possible model for given instructional conditions (see Reigeluth, 1977). Therefore, this type of research must be performed under realistic conditions.

Toward this end, we recommend the performance of two types of experiments: a correlational study and an experimental study. The purpose of the correlational study is to determine the relative value (i.e., relative contribution to instructional effectiveness, efficiency, and appeal) of each part of an extremely "rich" model (i.e., a model that includes an unusually large number of strategy components). This study results in a rank-ordering of the strategy components that comprise the model.

Then, on the basis of this rank-ordering the experimental study can be designed. Its purpose is to test that rank-ordering under an "alternative models" paradigm. This paradigm requires that each strategy component be tested in combination with only those strategy components which are more valuable than itself, rather than being tested in combination with all other strategy components. To accomplish this, the first treatment is formed by implementing the most valuable strategy component (or the two most valuable components, etc.) as determined by the correlational study. The second treatment is formed by adding to it (them) the next most valuable strategy component, and so on until about ten treatments are formed. The least valuable strategy components in the correlational study will probably be left out of this experiment. This experiment will either confirm the rank-ordering of strategy components, or it will lead to a new rank-ordering, which in turn may need to be confirmed by another similar experimental study.

The result of these two types of studies will be an improved model of instruction. Some strategy components will probably be eliminated from the model for lack of contribution to effectiveness, efficiency, and appeal; and other components may be added.

We also propose that a large-scale development project is needed to improve the instructional design procedures. Our field test on electronics helped greatly to improve the design procedures developed in this project, but it was only a partial field test because it was beyond the scope of our funding to develop more than a "blueprint" of the most important constructs in electronics. An entire large-scale development project would undoubtedly lead to considerable improvement in the instructional design procedures that we have developed in this project. Although the development project would cost more than the standard development currently done by Courseware, Incorporated, that extra cost would in reality be a relatively inexpensive research project; and we are confident that the instruction resulting from the project would be superior to that currently produced by Courseware, Incorporated, in spite of the experimental nature of the development project.

Extending What We Have

We recommend extending what we have developed in this project to new applications (i.e., applications other than design). The most valuable extension for the Navy would probably be the development of a diagnostic/evaluative instrument (similar to the Instructional Quality Inventory) for analyzing and improving existing Navy instruction. Such an instrument would complement rather than replace the Instructional Quality Inventory because it would extend the analysis of instructional quality to structural strategies, which are currently totally ignored by the IQI. It is likely that the structural aspects of instructional quality will have at least as great an impact on improving the effectiveness and efficiency of instruction as have the IQI's presentation aspects of instructional quality.

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