

# Classes of Instructional Variables

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In this article, we describe the classes of variables which we believe must be considered when one is designing instructional materials, doing research on instructional variables, or developing better methods of instruction. Familiarity with these classes of variables can help instructional designers by indicating what sorts of method variables should be included in their designs and what sorts of conditions may influence how and when those method variables should be used. It can also help instructional scientists, such as researchers and theory builders, by indicating important relationships for investigation or theory building and by providing a common terminology for discussing such relationships.

There is a growing interest in the *design science of instruction* (Glaser, 1976; Reigeluth, Bunderson, and Merrill, 1978). The major products of this design science are prescriptive principles of instruction, which provide an increasingly powerful *knowledge base* for the professions of instructional design and evaluation (Reigeluth and Merrill, 1978). When a sufficient number of these principles is discovered, they should allow instructional designers to prescribe instructional methods that are more likely to be optimal for given sets of conditions, and they should help instructional evaluators identify (without expensive empirical trials) methods that are not optimal for given sets of conditions.

In essence, prescriptive principles of instruction describe *cause-and-effect relationships* among instructional variables. Before principles and theories (which are interrelated sets of principles) of instruction can be developed, the instructional variables that they include must be clearly described and unambiguously labeled. In recognition of this need, Reigeluth, Bunderson, and Merrill (1978) advocated the use of "top-down," deductive theory-construction procedure (see Snelbecker, 1974).

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This theory-construction procedure entails four stages: (1) what Snow (1973) refers to as "D-Theory" (descriptive theory and taxonomy) construction, which is the identification, description, and classification of instructional *variables*, both on the "cause" side (i.e., the independent variables), and on the "effect" side (i.e., the dependent variables); (2) the formulation of some basic postulates (i.e., hypothesized *principles*) which relate those independent and dependent variables to each other through the specification of certain methods or strategies under certain conditions; (3) the use of those postulates to derive testable deductions, predictions, or hypotheses and to test the validity of each postulate by systematic *experimental testing* of the hypotheses; and (4) the creation and testing of optimal *models* of instruction, which are combinations of method variables (see Reigeluth, 1978, for a discussion of model creation and testing).

Instructional scientists are interested in prescribing *methods* of instruction that are highly effective under given *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 spite of concerted efforts by many instructional scientists, the lack of a comprehensive set of clearly defined variables and the lack of a common terminology are among the greatest impediments to progress in instructional science. This article is not intended to present a comprehensive taxonomy of instructional variables, although the authors are currently working toward that goal. Rather it takes a preliminary step in that direction by presenting (1) a scheme for classifying instructional variables, and (2) a model which hypothesizes the most important interrelationships among those classes.

### Categories of Variables

The authors propose that it is helpful to classify all the variables that are of interest to instructional scientists as belonging to three categories: conditions, methods, and outcomes. Because of our "prescriptive science" orientation (i.e., providing prescriptions that are useful to instructional designers and evaluators), the only *conditions* that interest us are those which both (a) interact with methods, and (b) cannot be manipulated by the instructional designer or educator. Conditions which do interact with methods but can be manipulated become, in effect, methods for improving instructional outcomes; and conditions that do not interact with methods have no value for deciding when to use which methods.

The second category, instructional *methods*, includes all the different ways to achieve different outcomes under different conditions. By definition, all methods can be manipulated by the instructional designer or educator. If a "method" cannot be manipulated in a given situation, then it has become a condition. Therefore, conditions and methods are not fixed categories—they may vary from one setting to another. For instance, in school A it may be possible to use a variety of parameters of a method variable, whereas in school B, it may be possible to use only one of those parameters. In such a case, that which is a method variable in school A is a condition in school B (assuming that it interacts with method variables in school B).

The third category, instructional *outcomes*, includes all the various effects that provide a measure of the value of alternative methods of instruction

under different conditions. Therefore, outcomes include effects on such people as teachers, maintenance personnel, and parents, as well as effects on the students.

There are two sets of important interrelationships among the conditions, the methods, and the outcomes of instruction (see Figure 1). For *descriptive scientists* (i.e., learning theorists and researchers), the conditions and the methods are independent variables; and their parameters conditionally interact to produce a set of outcomes, which are the dependent variables. On the other hand, *prescriptive scientists* (i.e., instructional theorists and researchers, instructional designers, and evaluators) use the descriptive scientists' knowledge about the relationships among variables to prescribe methods of instruction. The conditions and the outcomes are the independent variables; and their parameters (in interaction) are used to prescribe the parameters of the method variables, which are the dependent variables.

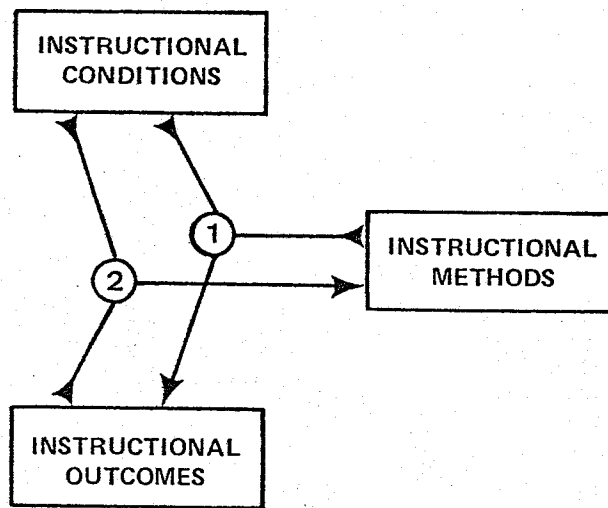
In the remainder of this article, we break down each of these three categories into *classes of variables*; we describe each class, and we indicate the major interrelationships among those classes. Since the method variables are of central importance to both descriptive and prescriptive scientists, we discuss them first.

### METHODS

Keeping in mind the two sets of relationships shown in Figure 1, it will now be helpful to simplify this representation for further elaboration. Figure 2 shows the three categories of instructional variables, and it shows that conditions have the major (but by no means only) effect on the selection of methods and that methods have the major (but by no means only) effect on outcomes.

Like trees (see above), instructional methods can be classified in a variety of different ways. As opposed to classifying them along such lines as methods for teaching mathematics, reading, etc., or special education, adult education, etc., we propose that the following classification will have high prescriptive utility. *Instructional method variables* can be conceptualized as being of three kinds: components of strategies for organizing instruction, components of strategies for delivering the instruction to the learner, and components of strategies for managing the interaction of the learner with the instruction (see Figure 2).

- *Organizational Strategy Variables*: Components of methods for organizing the subject-matter content that has been selected for instruction. "Organize" refers to such things as choice of words, diagrams, for-



- 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 1. Three categories of instructional variables, and two sets of interrelationships among those categories.

mat, and student response possibilities. (See below for more detail.)

- *Delivery Strategy Variables*: Components of methods for conveying the instruction to the learner and/or for receiving and responding to input from the learner. (See below for more detail.)
- *Management Strategy Variables*: Components of methods for arranging the interaction between the learner and the other method variables—the organizational and delivery strategy variables. See details below.

#### Organizational Strategy Variables

Organizational strategy variables can be divided into two important kinds: presentation strategy variables, and structural strategy variables.

- *Presentation Strategy Variables*: Components of methods for organizing the instruction on a *single* construct (i.e., a single concept, procedure, principle, etc.).
- *Structural Strategy Variables*: Components of methods for organizing those aspects of

instruction which relate to more than one construct.

*Presentation Strategy Variables*. The most generic presentation strategy variables have been labeled by Merrill (Merrill, Reigeluth, and Faust, in press; Merrill, Richards, Schmidt, and Wood, 1977; Merrill and Wood, 1974) as “primary presentation forms,” and they include the following: (1) *generalities*, such as definitions of concepts and statements of procedures and principles; (2) *instances*, such as examples of a concept, applications of a procedure, and explanations of a principle; (3) *generality practice*, which is student recall or recognition of a generality; and (4) *instance practice*, which requires the student either (a) to remember an instance or (b) to work an instance, such as classifying an instance as to whether or not it is an example of a concept, performing an instance of a procedure, or explaining an instance of a principle.

Each of these four types of variables can in turn be analyzed as to its characteristics, such as formatting and construction (Faust, O’Neal, and

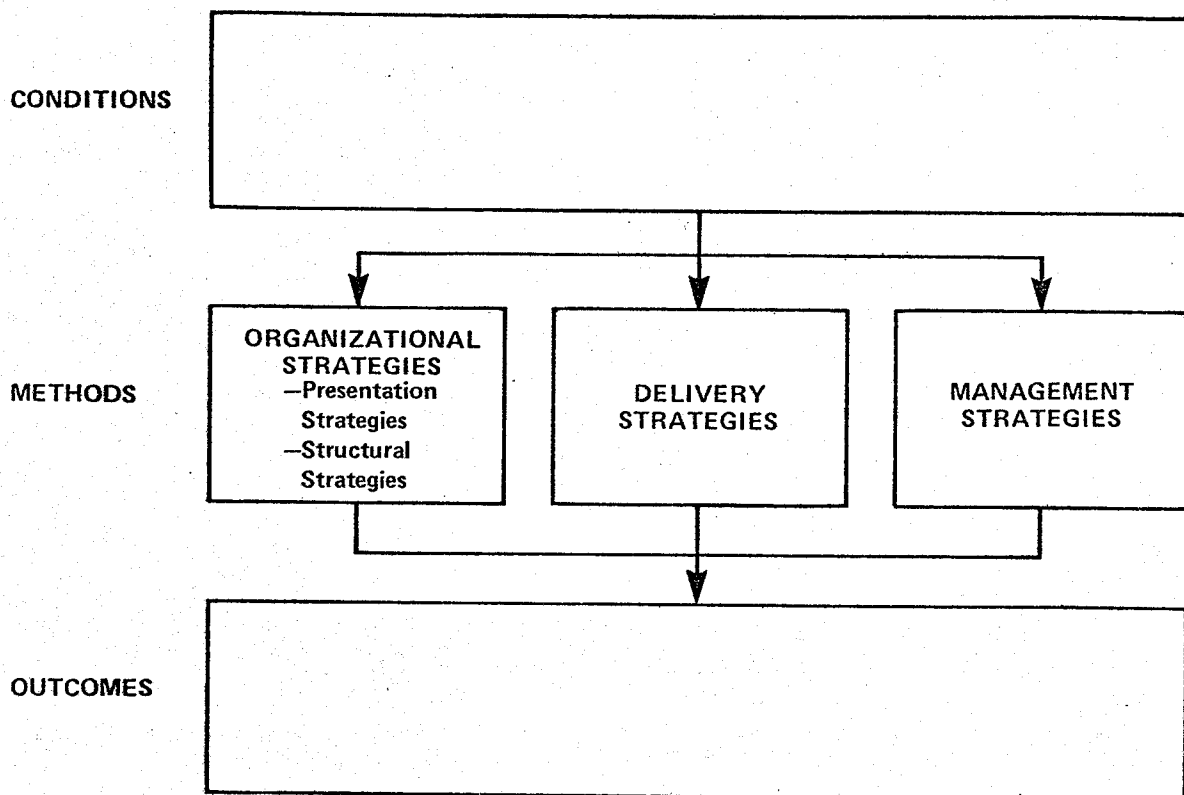


Figure 2. A model showing the major categories of instructional variables and a simplification of the relationships among those shown in Figure 1. Method variables are broken into three major classes.

O'Neal, in press). Each can also be analyzed as to its strategy components, such as the presence of *feedback* after practice, an adequate *sampling* of instances with respect to number, divergence, and difficulty level of instances, and the use of mathemagenic information (i.e., instructional "helps"), which includes attribute isolation and such "secondary presentation forms" as mnemonics, algorithms, or heuristics, and alternative representations (Merrill, Reigeluth, and Faust, in press). These strategy variables all deal with how to internally organize the instruction on each construct.

**Structural Strategy Variables.** Structural strategy variables deal with how to select, sequence, synthesize, and summarize a number of related constructs (i.e., concepts, procedures, etc.). *Selection* at this level (i.e., given certain goals) refers to decisions as to which constructs and relations among those constructs are needed to accomplish the goals. *Sequencing* refers to decisions as to the order(s) in which those constructs and relations should be presented in the instruction. *Synthesizing* refers to

decisions as to how to show the important relations among those constructs. And *summarizing* refers to decisions as to how to preview or review the constructs and relations taught. These are all "multi-construct" strategy questions. (For an in-depth treatment of structural strategies, see Reigeluth, Merrill, and Bunderson, 1978; and Reigeluth *et al.*, 1978).

#### Delivery Strategy Variables

Delivery strategy variables are components of methods for carrying out the instructional process. There are at least two important functions of delivery strategies (see Merrill and Goodman, 1972): (1) conveying information to the student, and (2) providing for student performances (i.e., practice and tests). Although there are some important differences in delivery strategy needs for these two functions, the strategy variables are mostly the same for both.

There are at least five ways that media may be usefully classified for prescribing delivery strategies: (1) their degree of fidelity of representation,

(2) the degree to which they are interactive (i.e., they provide immediate, individualized responses to student behavior, (3) the degree to which they have useful special capabilities, (4) the degree to which they are motivational, and (5) their costs.

The degree of *fidelity of representation* of a delivery strategy variable usually falls on a continuum, such as the following: objects, sound films, silent films, still pictures, diagrams, audio media, and written symbols. However, this continuum is subject to variation. For instance, instruction on a concert will have a very different continuum of media based on fidelity of representation.

The degree of *interactiveness* of a delivery strategy variable also falls on a continuum, but points on this continuum are indicated by slightly different delivery strategy variables: computers, tutors, workbooks, textbooks/recordings, and broadcasts. Many of these variables can present a variety of the variables discussed in the previous paragraph. For instance, tutors can present all of those variables, and workbooks can present still pictures, diagrams, and written symbols. It is also possible to use a combination of variables, such as (1) a workbook with a film or with objects (e.g., a chemistry lab book), (2) a workbook with a textbook or a broadcast, and (3) written symbols with a film or with objects.

The degree to which a medium provides other *special capabilities* which result in more effective and/or efficient instruction is a third important aspect for prescribing delivery strategies. Those other special capabilities might include simulation (such as a flight simulator that allows a pilot to "land" an airplane ten times in an hour without having to take off again each time to get into position for the next landing), time-lapse features, and other capabilities which give an advantage to a medium that is at a lower level of fidelity of representation.

The degree of the *motivational effect* of a medium is a fourth important aspect for prescribing delivery strategies, but here the variance within categories can often vary as much as, or more than, that between categories. For instance, a tutor can highly motivate a student or he/she can completely turn the student off to the subject matter. These differences are the result of the kinds of management variables and organizational variables used by the medium. This is not to deny that different media have different motivational effects, if all else is held constant. It is also likely that media interact with types of subject matter in their motivational effects.

Finally, the *cost* of a medium is also important for prescribing delivery strategies. Costs for preparing, delivering, and updating instruction can be

estimated for each type of medium; and potential costs related to accidents, such as injuries, deaths, and loss of equipment, must also be considered.

### Management Strategy Variables

Management strategy variables (Tosti and Harmon, 1973) are components of methods for arranging the interaction of the student with the other instructional method variables—the organizational and delivery variables. From our perspective, it appears that there are at least three important classes of management strategy variables: scheduling, recordkeeping, and motivation variables.

With respect to *scheduling variables*, both delivery strategy components and organizational strategy components may be scheduled. The *scheduling of delivery strategy components* (media) usually involves decisions as to when and for how long a student will use each of a variety of media, such as when the language lab will be most helpful in relation to studying a certain lesson in the Spanish textbook, or when actually flying the airplane will be most helpful in relation to "flying" a simulator, and when the simulator will be most helpful in relation to using a workbook.

The *scheduling of organizational strategy components* usually entails questions as to when and for how long a student should see each organizational strategy component. These questions include decisions as to the optimal order of presentation forms (e.g., is instance-generalty-practice better than generality-instance-practice?), the optimal number of instances or practice items, how often past learning should be reviewed, when the test should be given, and even whether or not to study a given strategy component, to cite just a few. Such aspects of the instruction may be *fixed* (i.e., standardized) or *variable* (i.e., individualized) for each student. And if they are variable, they may be *system-controlled*, such as Atkinson's optimal control theory (Atkinson, 1972), or they may be *learner-controlled*, such as on the TICCIT\* system (Bunderson, 1974; Merrill, 1975; Merrill, Fletcher, and Schneider, in press). Research indicates that learner control may be incompatible with an educational system based on external accountability (Axtell and Merrill, 1978). This kind of management strategy may specify skipping certain organizational or delivery strategy components.

*Recordkeeping variables* can have an effect on instructional outcomes to the extent that they

\*The TICCIT system is a computer-assisted instruction system developed by Mitre Corporation and Brigham Young University.

provide a basis for *other management decisions*. Both system-controlled scheduling and learner-controlled scheduling require information for the system or the learner to make good decisions, and the need for more motivational strategy components is also indicated by records on a student's performance. A second major application is that *system improvement* depends on information about student performance on different objectives. Such information is important for identifying and correcting weaknesses in organizational, delivery, and management strategies.

*Motivation variables* are also a very important part of managing the interaction of the student with the instruction. These variables could be classified as two types: those which are *extrinsic* to the learning task (i.e., contingency management), and those which are *intrinsic* (e.g., enjoyment of learning or the importance and usefulness of what was learned). The contingency management technique of positive reinforcement has been shown to have a very beneficial effect on certain kinds of instructional outcomes (Harrison, 1975); but like all extrinsic motivators it ceases when the instruction ceases.

Most subject matter is intrinsically motivational, but most instruction fails to convey its intrinsic appeal. There are components of instruction—motivational variables—that can be used to increase intrinsic motivation to learn a subject matter. Using *good organizational and delivery strategies* so that the instruction is as effective and efficient as possible has an important influence on a student's motivation. In particular, the elaboration model for sequencing and synthesizing instruction (Reigeluth *et al.*, 1978) shows special promise for increasing intrinsic motivation because it places all learning in meaningful contexts, and it emphasizes important interrelationships. But motivational strategies can include much more. McConnell (1978) has indicated how analogies, anecdotes, and hypothetical situations can be used to create more emotional involvement and to show the importance and usefulness of what is being learned by indicating some of its applications.

### CONDITIONS

Having just elaborated on instructional method variables (see Figure 3), it is logical to attempt to describe and classify the condition variables which influence the use of those method variables. To be of interest to us for prescribing instructional methods, the condition variables must both (a) interact with methods and (b) be beyond the control of the instructional designer or educator. Our purpose is to identify those condition variables that have important influences on each of the three

classes of method variables, and therefore we need to divide the condition variables into three groups.

We hypothesize that goals and subject-matter characteristics have the majority of the influence on the selection (and outcomes) of organizational strategies, that constraints and subject-matter variables have the majority of the influence on delivery strategies, and that student characteristics have the majority of the influence on the selection (and outcomes) of management strategies. However, it is likely that other kinds of condition variables influence each class of variables to some extent (e.g., student characteristics may influence the selection and outcomes of organizational and delivery strategies to some extent).

- *Instructional Goals*: Statements about what the results of the instruction should be. They may be very general, very detailed, or anywhere in between.
- *Subject-Matter Characteristics*: Aspects of a subject-matter area which provide a useful basis for prescribing instructional strategies.
- *Constraints*: Limitations of resources, such as time, equipment, personnel, and money.
- *Student Characteristics*: Qualities or aspects of an individual student, such as student aptitudes, motivation, and prior achievement.

### Goals and Subject-Matter Characteristics

Since the classification of subject-matter characteristics will facilitate our discussion of goals, we shall discuss subject-matter characteristics first. But before we proceed with a top-down classification of subject-matter variables, it will be helpful to introduce some fundamental concepts about subject matter.

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 and Wood, 1974, 1975; Reigeluth, Merrill, and Bunderson, 1978; Scandura, 1968, 1970). A *DOMAIN* is comprised of one or more referents of one or more concepts, which are referred to as "domain concepts." A *RANGE* is also comprised of one or

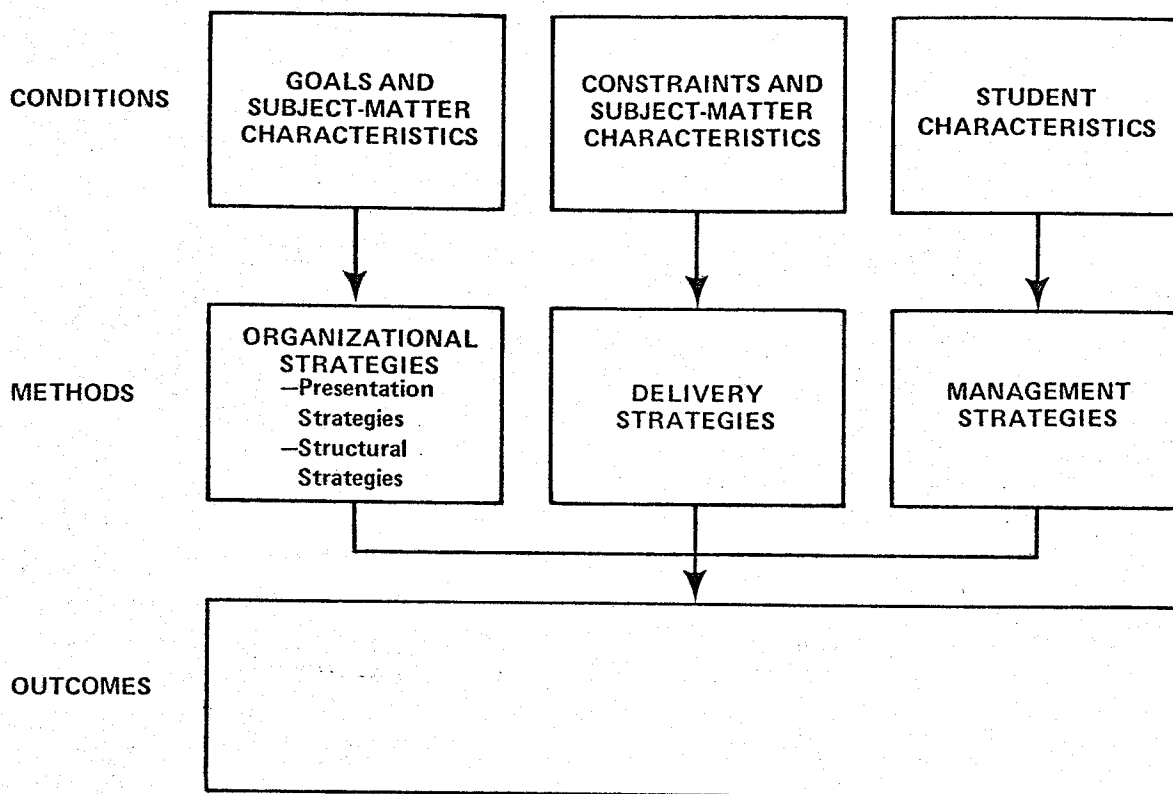


Figure 3. A model showing classes of instructional variables and the major relationships among them. Condition variables are broken into three classes according to their major influences on the classes of instructional method variables.

more referents of one or more concepts, which are 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, each of which has its own domain, operation, and range.

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, and Bunderston, 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. An

example of a structure is provided below.

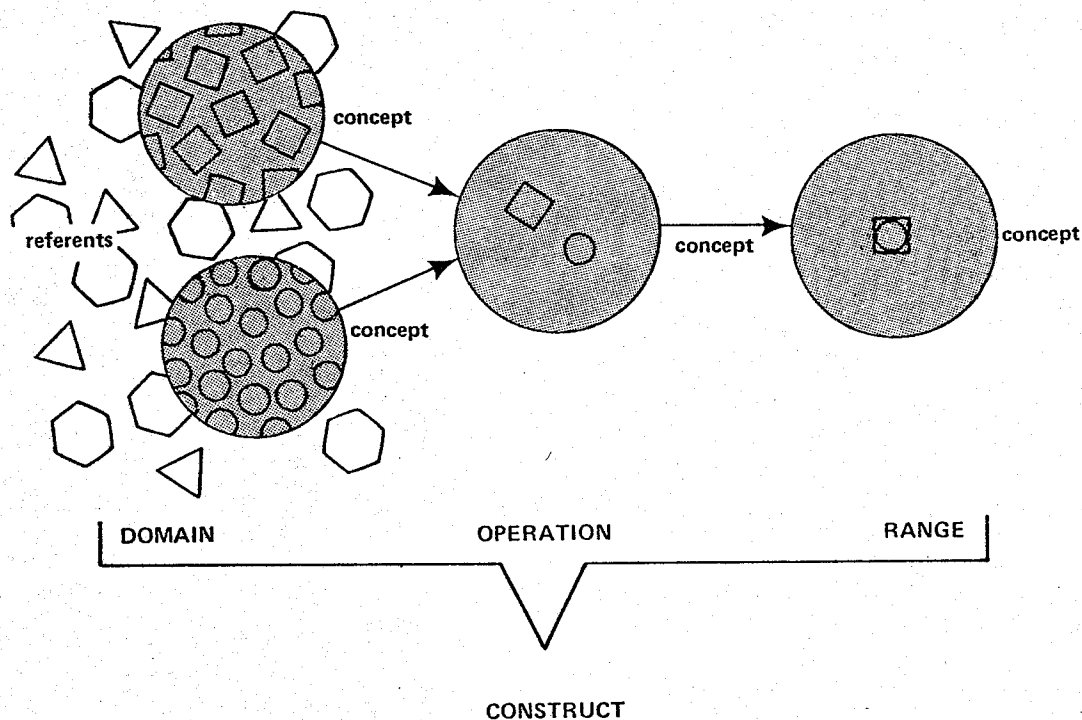
Returning to our classification of subject-matter variables, the above-described conceptualization of subject matter leads to its classification as referents, constructs, structures, and multi-structures, each of which is a "set" of members of the previous class (i.e., a construct is a set of referents, a structure is a set of constructs, etc.).

- *Referent*: An object, event, or symbol which exists in our real or imagined environment.
- *Construct*: A single domain, operation, and range taken as a unit. It is a set of referents.
- *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 *relation*.
- *Multi-Structure*: A "multiple-structure" in which the relations among two or more structures are shown.

*Referents*. Instruction never takes place at the level of an individual referent; the closest it gets is



## 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.

at the "fact" level of a construct (see next paragraph). Therefore, this classification of subject matter is of no interest to us.

**Constructs.** The major kinds of constructs which seem to have the most utility for prescribing organizational strategies are: facts, concepts, subsets, principles, and steps of procedures. (See Reigeluth, Merrill, and 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 *identity*, 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



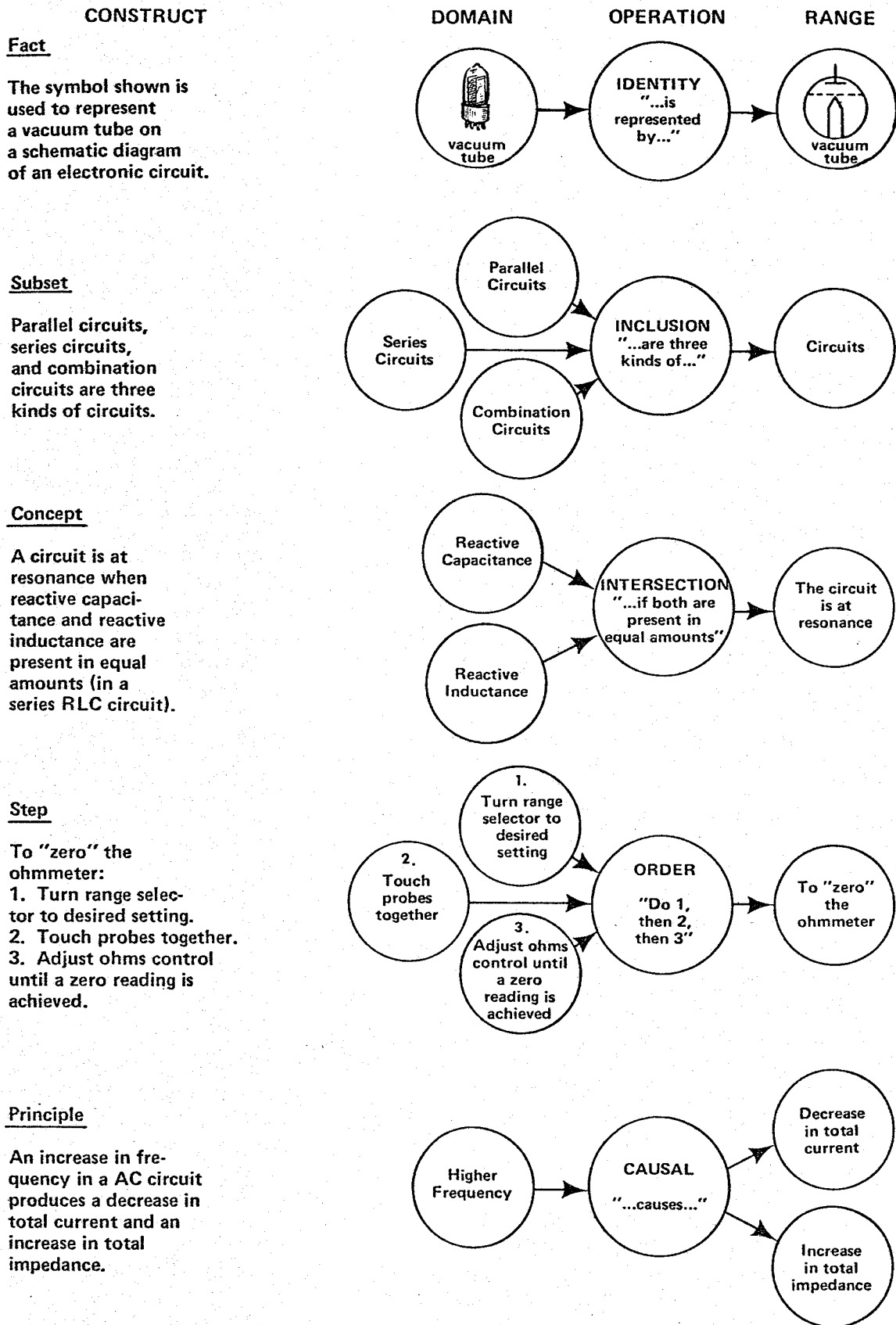


Figure 5. An example of each of the five kinds of constructs.

