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THE STRUCTURE OF SUBJECT MATTER CONTENT AND ITS INSTRUCTIONAL DESIGN IMPLICATIONS

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ABSTRACT

This paper discusses the analysis of subject matter structure for purposes of designing instruction. The underlying assumption is that subject matter structures provide an important basis for deciding how to sequence and synthesize the "modules" of a subject matter area. Four types of fundamental structures are briefly described and illustrated: the learning hierarchy, the procedural hierarchy, the taxonomy, and the model. Then a theoretical framework is presented for classifying types of subject matter content – both "modules" and structures. Finally, some implications of these content classifications are discussed. The classification of "modules" is hypothesized to be valuable for prescribing strategies for the presentation of single "modules", and the classification of structures is hypothesized to be valuable for prescribing strategies for selecting, sequencing, synthesizing, and summarizing related "modules". The need to take into account more than one kind of structure in the process of instructional design is emphasized.

Subject matter structure refers to the interrelationships among the components [1] of a subject matter. The structure of subject matter can be, and has been, analyzed for a variety of purposes. This paper discusses the analysis of subject matter structure for the purpose of *designing instruction* – textbooks, courses, workbooks, etc. The underlying motivation for this analysis is our belief that subject matter structures have important implications for the best ways to sequence (i.e., order) and to synthesize (i.e., show the interrelationships among) related components of a subject matter.

Our work in instructional strategies has led us to the conclusion that "structural" strategies such as synthesizers (i.e., explicit descriptions of types of pervasive relations among subject matter components) can have a far greater impact on instructional outcomes than the vast majority of instructional strategy variables that have been investigated to date. The purpose of this paper is to identify and describe some of those aspects of subject matter structure which may have the most prescriptive power for the development of, and the selection of, optimal structural strategies (e.g., the selection, sequencing, synthesizing, and summarizing of related components of a subject matter).

Instructional scientists and designers have long recognized the importance of analyzing subject matter structure for purposes of designing instruction. For several years, instructional designers have been using (or have claimed to be using) content and task analysis procedures based on Gagné's (1968, 1977) cumulative learning theory and *learning hierarchies*. However, there has been a growing recognition that such hierarchical analyses, although valid and useful, are insufficient for prescribing or developing optimal sequences for a range of entire subject matter areas (see Gibbons, 1977) and that they are irrelevant for prescribing or developing optimal synthesizers.

As a result, much attention has been paid recently to the use of *relational networks* and/or digraph theory (Harary et al., 1965) for the analysis of subject matter content (Crothers, 1972; Pask, 1975; Shavelson, 1974). Yet this emphasis has gone to the opposite extreme: rather than assuming that only one type of content relation (the learning prerequisite) is sufficient for an analysis of subject matter content for instructional design purposes, most of these relational network analysts (many of whom, in all fairness, are not instructional-design-oriented) seem to assume that content should be analyzed as to an awkwardly large number of different types of relations, and that all these diverse relations should be represented together in one large network.

There are two major problems that instructional designers encounter in attempting to use such network approaches for their content and task analyses. (1) These networks include many kinds of relations that are not of value to them for the purposes of selecting, sequencing, or synthesizing the subject matter components. Usually the relations are too detailed. (2) These networks often do not clearly identify the nature of each relation (i.e., the meaning of each line between "modules"), and often the relations of most importance to designers are not adequately identified or clearly portrayed.

We propose that, for purposes of instructional design, a small number of types of *pervasive content relations* is all that is necessary, and that each type should be represented in a different diagram as a different kind of "structure". However, these types of pervasive content relations must be selected such that they have prescriptive value for instructional designers' use of sequencing and synthesizing strategies. The following are some types of content relations which we hypothesize to have these properties.

Types of Pervasive Content Relations and Structures

A content *structure*, as referred to in this paper, is a diagram which shows just one kind of pervasive relation within a unified (i.e., interrelated) subject matter area. A *pervasive relation* is one which exists both "below" and "above" at least one concept, principle, etc. These two terms will be

clarified by example below. Also, the term "structure" should not be confused with the *representation* of that structure. For instance, one kind of representation, such as the tree representation, can be used to portray different kinds of structures (i.e., different kinds of pervasive relations). In practice, it might be better to assign a different kind of representation to each kind of structure; but in the figures that follow we use the same kind of representation for different kinds of structures whenever possible, just to emphasize the difference between a structure (as herein defined) and its representation.

LEARNING STRUCTURES

The most widely-investigated kind of content structure is the learning structure, or learning hierarchy, which shows the *learning-prerequisite relations* among the components of a subject matter (see Gagné, 1977). The learning structure describes what must be *known* (what the learner must be *able* to do) before something else can be learned. Figure 1 shows that the concepts of time and velocity must both be understood before the concept of acceleration can be learned. (Of course a student can learn to *calculate*

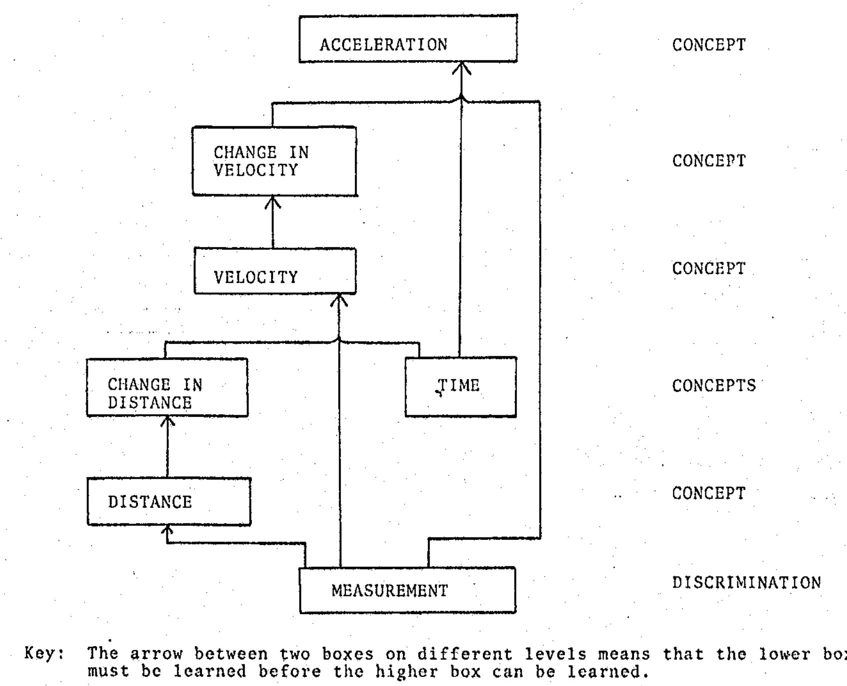


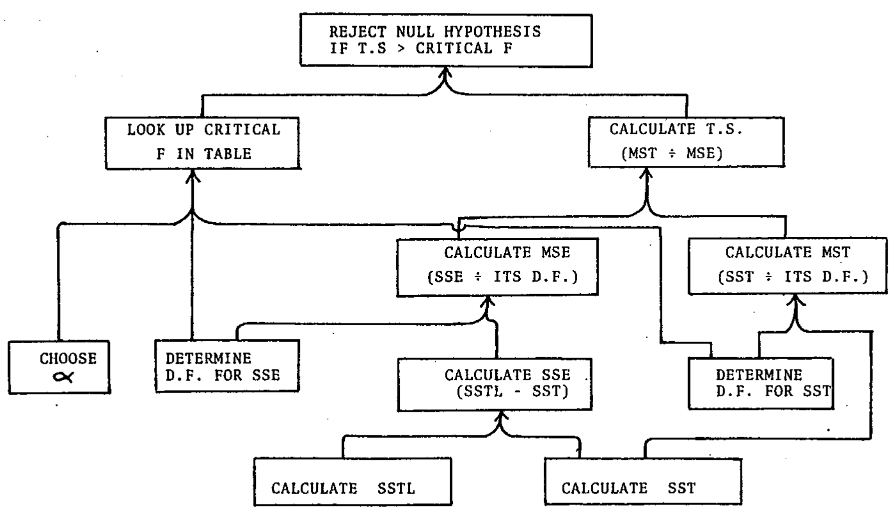
Fig. 1. Part of a learning structure showing learning-prerequisite relations among constructs of a subject matter.

acceleration – see below – without knowing the concept of velocity and/or the concept of time.) The learning-prerequisite relation is identified by the following sentence: "A learner must know (be *able* to do) 'X' in order to learn (be able to do) 'Y'." In task analyses, instructional designers often confuse learning prerequisite relations with procedural-prerequisite relations (discussed next).

PROCEDURAL STRUCTURES

Perhaps the second most common kind of content structure is the procedural structure, or procedural hierarchy, which shows procedural relations among subject matter components (see Gropper, 1974; P. Merrill, 1971). We propose that there are two types of procedural relations.

(1) Procedural-prerequisite relations are the relations among the steps of a single procedure (specifically the order(s) for performing those steps), and they can be shown in a procedural hierarchy such as the one in Fig. 2. The procedural-prerequisite relation is identified by the following sentence: "The performer must *do* (often confused with 'be *able* to do') 'X' before he can do 'Y'."



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

Fig. 2. Part of a procedural structure showing procedural-prerequisite relations among constructs of a subject matter.

SELECTION CRITERIA					METHODS
Two numerical variables	Linear association	Scores used on X or Y or both			1 PEARSON r $r = \frac{N\Sigma XY - \Sigma X\Sigma Y}{\sqrt{[N\Sigma X^2-(\Sigma X)^2][N\Sigma Y^2-(\Sigma Y)^2]}}$
		Ranks Used on both X and Y	Most common measure for ranks (r_s)	No ties on X or on Y: Easiest formula for hand calculation	2 SPEARMAN r_s $r_s = 1 - \frac{\Sigma d^2}{1/6(N^3-N)}$ d = difference between ranks
				Easiest formula for machine calculation	2a r_s FOR MACHINE X and Y are ranks $r_s = \frac{3}{N-1}\left[\frac{4\Sigma XY}{N(N+1)} - (N+1)\right]$
				Ties on X or Y	2b r_s WITH TIES See Method Outline
			Measures which are very similar to r_s	Ties on X or on Y: None	3 KENDALL TAU (r_τ) See Method Outline
				Few	3a r_τ WITH TIES See Method Outline
				Many	r_γ (gamma) See Goodman & Kruskal (1963) for directions on computing r_γ and establishing a confidence band around it.
	Nonlinear association	Simple method			Draw scatterplot
		More exact method			See Method 6
A numerical variable (scores or ranks) correlated with a categorical variable	Two Categories	Scores	Have within-category means and standard deviations been computed?	No	4 POINT BISERIAL r $N = n_1+n_2$ $r_{pb} = \frac{M_2-M_1}{S} \times \sqrt{\frac{n_1 n_2}{N(N-1)}}$
				Yes	4a $S = \sqrt{\frac{(n_1-1)S_1^2+(n_2-1)S_2^2+\frac{n_1 n_2}{N}(M_1-M_2)^2}{N-1}}$ Enter this value of S into method 4.
		Ranks	OD curve not drawn		5 GLASS RANK-BISERIAL CORRELATION M_1, M_2 are within-group mean ranks $r_g = \frac{2}{N}(M_2-M_1)$
			OD curve drawn		5a r_g = 1 - 2 (proportion of area under OD curve)
	Three or more categories				6 CORRELATION RATION (η^2) See Method Outline
Two categorical variables	X and Y both dichotomous			Formula using frequencies	7 PHI $r_\phi = \frac{AD-BC}{\sqrt{(A+B)(C+D)(A+C)(B+D)}}$
	Should the correlation measure the degree to which X and Y measure the same dimension--	--at the same level?		Formula using marginal proportions	7a PHI USING MARGINAL PROPORTIONS $r_\phi = \frac{Pxy-PxPy}{\sqrt{PxqxPyqy}}$
		--or at different levels?			8 YULE $r_q = \frac{AD-BC}{AD+BC}$

Adapted from Darlington, R.B., Radicals and squares: Statistical methods for the behavioral sciences. Ithaca, New York: Logan Hill Press, 1975.

Fig. 3. Part of a procedural structure showing procedural-decision relations among alternate procedures.

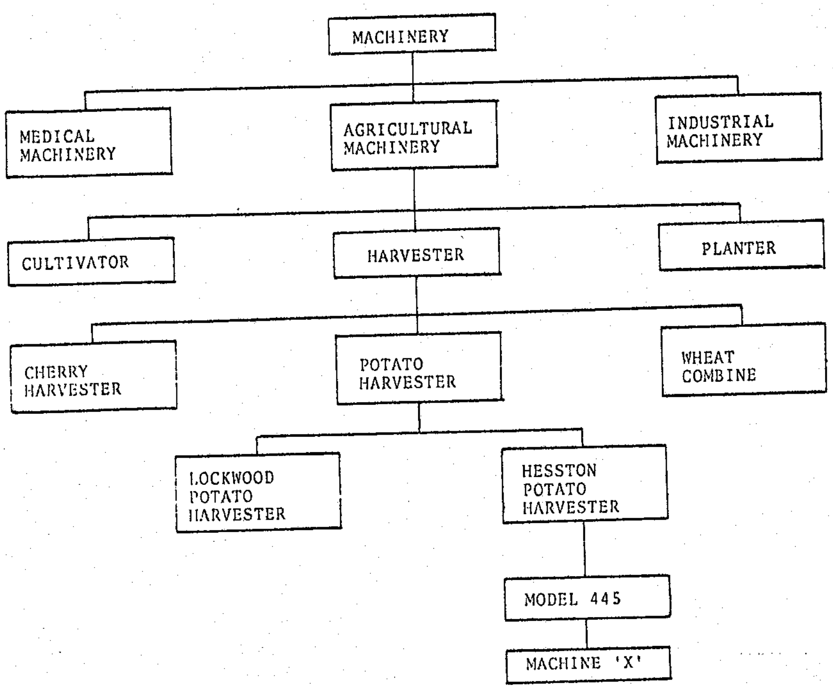
(2) Procedural-decision relations, on the other hand, are the relations between alternate procedures (rather than those within a single procedure); and they describe (e.g., in a decision box) the factors necessary for deciding which procedure, or sub-procedure, to use in a given situation. This kind of relation essentially portrays the differences among the conditions under which alternate procedures (or sub-procedures) are used, and it may even portray differences among the procedures themselves. The familiar flow diagram is one way to represent a decision structure, and Fig. 3 illustrates another often less cumbersome way. The procedural-decision relation is identified by the following sentence: "Given condition 'A', the performer must do 'X' rather than 'Y' or 'Z'."

TAXONOMIC STRUCTURES

Perhaps the most common kind of content structure is the taxonomic structure, or taxonomy, which shows the *superordinate/coordinate/subordinate relations* among the concepts of a subject matter. In Fig. 4 the concept "harvester" is superordinate to the concept "wheat combine", it is coordinate to the concept "cultivator", and it is subordinate to the concept "agricultural machinery".

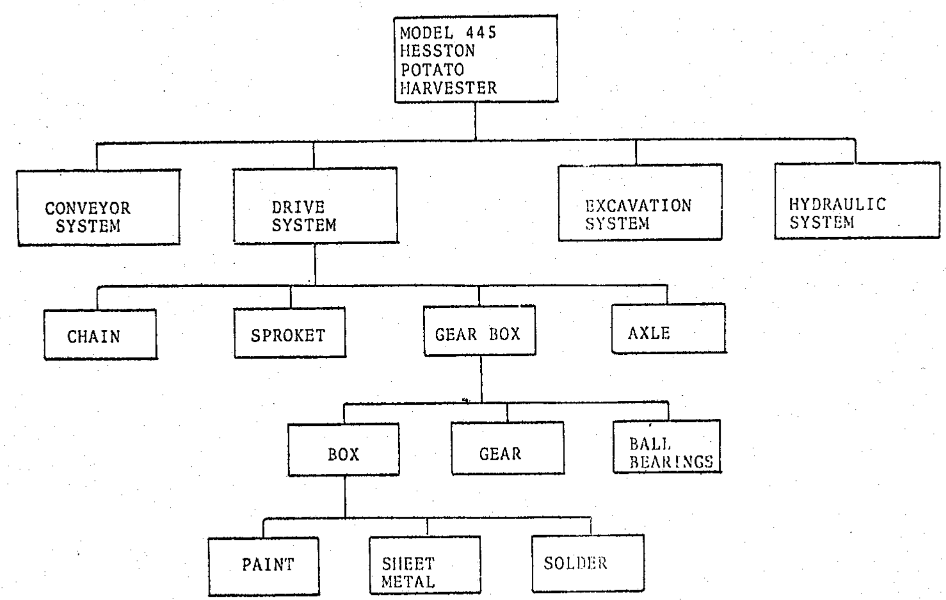
There are at least two types of taxonomic structures. Figure 4 shows a "kinds" taxonomy in which any given concept (represented by a box in the figure) is a variety of its superordinate concept. This type of taxonomic relation is identified by the following sentence: "An 'X' is a kind of 'Y'." Another type of taxonomic structure, called a "parts" taxonomy, is one in which the subordinate concepts are components of the concept to which they are subordinate. In Fig. 5 the concept "gear box" is superordinate to the concept "ball bearing", coordinate to the concept "chain", and subordinate to the concept "drive system". This type of taxonomic relation is perhaps the one most commonly used by instructional designers in their task analyses. It is identified by the following sentence: "An 'X' is a part of a 'Y'."

These two types of relations are similar to what Rumelhart et al., (1972) have referred to as "ISA" and "HAS". It is also interesting to note the similarity between these two kinds of "ordinate" (i.e., super/co/subordinate) relations and the fact that most concepts can be subdivided into smaller concept classes (kinds) and all concepts have critical attributes



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

Fig. 4. Part of a kinds taxonomic structure showing kinds-ordinate relations among constructs of a subject matter.



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

Fig. 5. Part of a parts taxonomic structure showing parts-ordinate relations among constructs of a subject matter.

(parts). We mentioned above that concepts are the only type of subject matter component that can comprise a taxonomic structure; however a procedural structure, such as that shown in Fig. 2, is often a parts taxonomy for steps, sub-steps, etc., of a procedure [2].

An interesting extension of taxonomic structures is the fact that two or more such structures may intersect to form a matrix structure. This type of structure shows *commonality relations* among related subject matter components. There are at least two types of matrix structures: a kinds-by-kinds matrix and a kinds-by-parts matrix. Figure 6 is a kinds-by-kinds matrix structure, and it demonstrates that crocodiles, lions, hawks, sharks, and lady bugs all have something in common: they are carnivorous animals (a kind of animal). It also shows something they do not have in common: the class of animal that each is (a different dimension of kind). Although Fig. 6 is a two-dimensional matrix, higher-dimensional matrices are possible. In essence, Fig. 6 is the intersection of pieces of two kinds taxonomies (shown in Fig. 7): the same concepts are subordinate in each taxonomy.

THEORETICAL STRUCTURES

Theoretical structures, or models, show chains of *causal relations* among concepts (i.e., chains of principles – principles show single causal relations among concepts). Theoretical structures are usually represented very differently from the other types of structures we have illustrated. In many cases, mathematical representations are used, but diagrams with arrows are also common. Theoretical structures, like procedural structures, are productive; but their main function is to provide a meaningful understanding of the causes rather than to teach a rote method (a method that *can* be learned by

	Reptiles	Mammals	Birds	Fish	Insects
Herbivores	Turtles	Cows	Chickadees	Minnows	Ants
Carnivores	Snakes	Lions	Vultures	Sharks	Lady Bugs
Omnivores	Leopard Lizards	Dogs	Robins	Carp	Black Stink Bugs

Key: In this matrix structure, each box is an instance of both its row heading and its column heading.

Fig. 6. Part of a two-dimensional kinds-by-kinds matrix structure showing the commonality relations among some constructs of a subject matter.

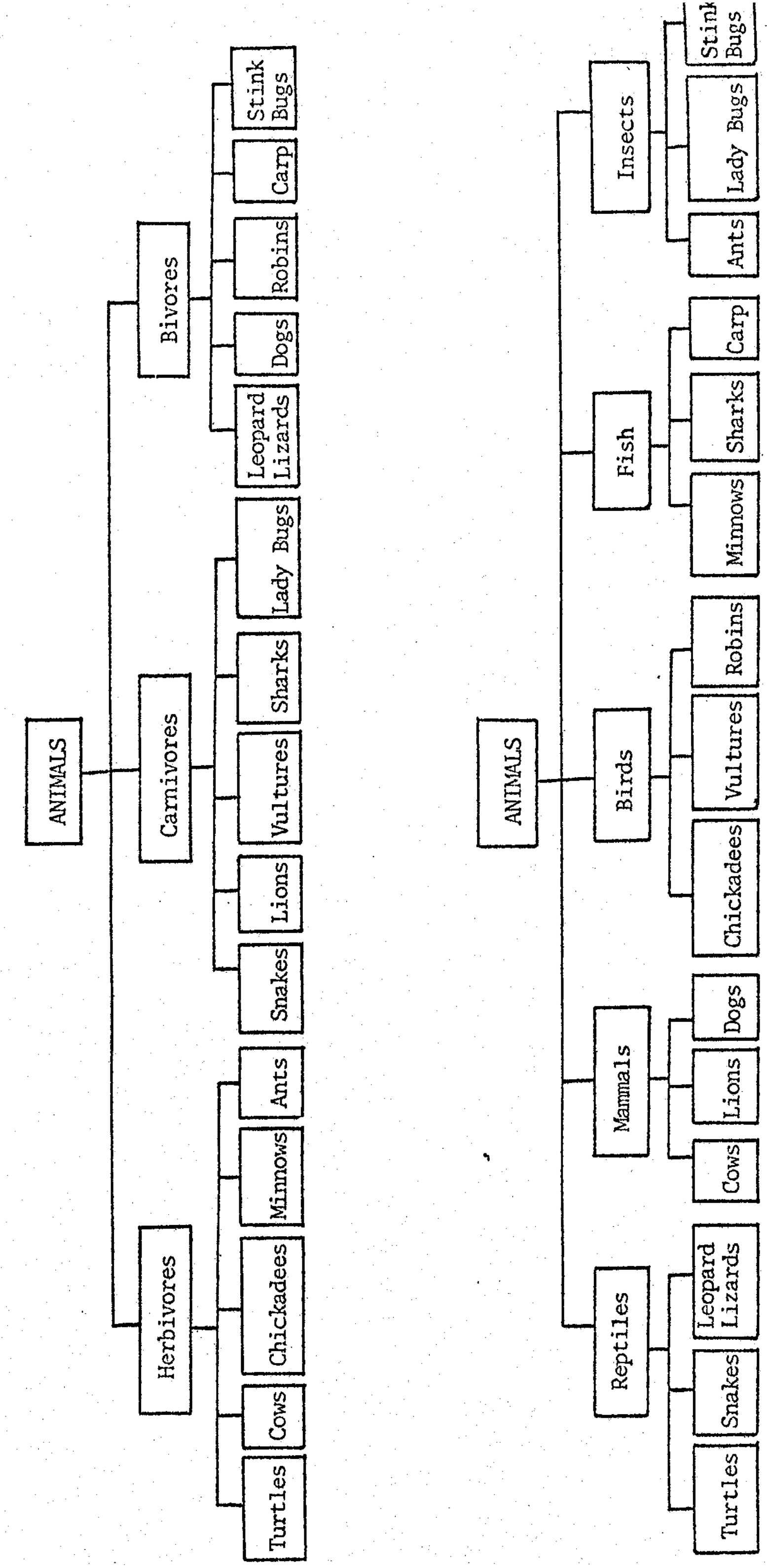


Fig. 7. The two partial taxonomic structures from which the matrix structure in Fig. 6 was formed.

rote memorization) for effecting some well-defined result under specified conditions.

Figure 8 shows a theoretical structure for macro-economics. It is a fairly crude theoretical structure because it is not quantified, but it does show a chain of causal relations. A more precise theoretical structure showing the same causal relations could include interrelated curves for liquidity preference, marginal efficiency of investment, and savings-investment schedule (see Samuelson, 1967, p. 317). This chain of causal relations could also be shown mathematically, although considerable interpretation is usually necessary for a meaningful understanding of a mathematical representation. (Note: a mathematical formula may also be used to represent a procedure, such as $PV = nRT$, but a student may learn the formula on the procedure level without ever learning it on the principle level. A principle explains *what* will be the result of a given action and *why* – how it works; whereas a procedure merely explains *how to do* something.)

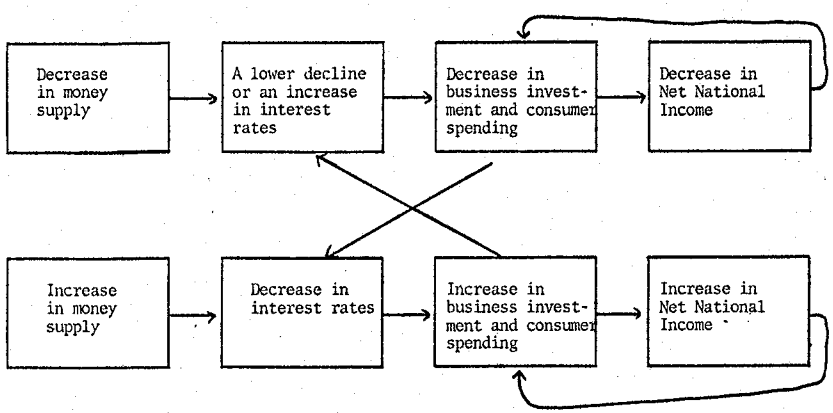


Fig. 8. Part of a theoretical structure (or model) showing chains of causal relations among constructs of a subject matter.

LISTS

Lists show no relations among their composite components, according to our definition of "relation," and therefore they are not true "structures". However, a list can show a "relationship" between *attributes* of its composite components. For instance, rocks can be listed in order of hardness, countries can be listed in order of size, and historical events can be listed in chronological order. But relationships among attributes of the components of a list are very different from relations among the components of a structure. Given a set of components for a list (e.g., countries), there are *many possible orders* in which they could be arranged, depending upon the attribute selected (e.g., size, median income, population, agricultural production).

A structure, on the other hand, is based on a *single kind* of relation (which exists among its composite components rather than among attributes of those components). Given a set of constructs which are all interrelated by this single kind of relation, there is only one basic way that those constructs can be arranged in the structure. Therefore, according to the definitions given in this paper, a list is not a structure, and the relationships among the many possible attributes of the components comprising the list are not relations.

SUMMARY

We have briefly described four types of pervasive relations and their related structures: the learning-prerequisite relation, the procedural relation (both procedural-prerequisite and procedural–decision), the ordinate relation (kinds, parts, and commonality), and the causal relation. We have also discussed lists, which are comprised of no relation (as we have defined that term) and therefore are not structures (by our definition).

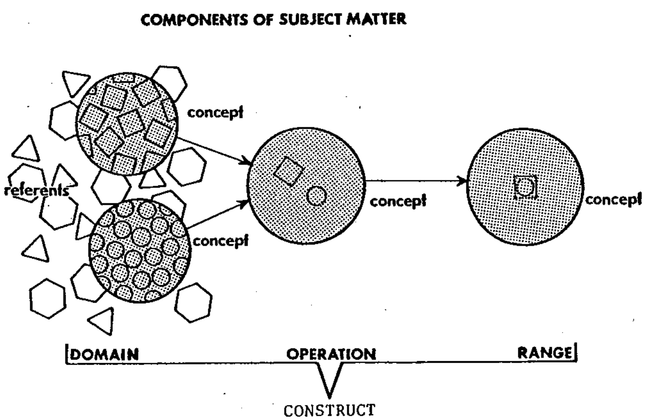
It is important to note that each type of structure is homogeneous in two ways. First, a structure is comprised of only one kind of construct at a time (except for the learning structure, which can have both concepts and principles): a procedural structure contains only steps [3] and a taxonomic structure contains only concepts. Second, a structure contains only one kind of relation. One may identify the kinds-ordinate relations, the parts-ordinate relations, or the learning-prerequisite relations for a given concept, but each type of relation should be portrayed in a different structure.

Finally, there may well be other types of pervasive relations that we have not yet been exposed to or thought of. And each of these types of pervasive relations could be, or has been, broken down into a variety of sub-types, sub-sub-types, etc. However, on the basis of some extensive work on developing optimal selection, sequencing, synthesizing, and summarizing strategies for each kind of structure, we feel that such break-downs may not be valuable to instructional designers – that their benefits may not be worth their costs.

Types of Subject Matter Content

Having thus identified what we believe are the major types of pervasive relations, or structures, which are of high utility to instructional designers, it is interesting to study the characteristics of each in order to try to classify them according to fundamental common characteristics. This effort is dependent upon an analysis of subject matter content into its most basic building blocks.

All subject matter components can be conceptualized as having a construction which is independent of the subject matter (Merrill, 1973). This basic construction is characteristic of all cognitive subject matter components and it contains three parts (see Fig. 9): (1) a *domain,* which is comprised of one or more instances (referents) of one or more concepts (referent sets), hereafter referred to as "domain concepts," (2) a *range,* which is also comprised of one or more instances of one or more concepts, hereafter referred to as "range concepts," and (3) an *operation,* which describes a particular mapping between a domain and a range (Merrill, 1973; Merrill and Wood, 1975a, 1975b; Scandura, 1968, 1970). An operation, when applied to instances of the domain concept(s), results in the selection of corresponding



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 construction consisting of a domain, an operation, and a range.

Fig. 9. The composition of a content construct.

instances of the range concept(s). The overall construction (i.e., the domain, operation, and range taken together) is hereafter referred to as a content *construct* rather than as a subject matter component [4].

This conceptualization of subject matter content is important for two reasons. First, it supports the contention of Macdonald-Ross (1974) and others that the relational network analysts' distinction between "modules" (nodes) and "relations" (lines) is an arbitrary one by indicating that, in effect, all "modules" (i.e., constructs) are "relations" (i.e., operations) and any "relation" can be represented as a "module." Second, this conceptualization of subject matter content is important because it allows a classification of content constructs on the basis of the type of operation involved in each construct.

TYPES OF CONSTRUCTS

Merrill and Wood (1974, 1975a) defined three primary types of operations: (1) *the identity operation,* which is an arbitrary one-to-one mapping between an instance of a domain concept and an instance of a range concept, (2) *the descriptive operation,* by which instances of the range concept(s) are selected through logical combinations of instances of two or more domain concepts, and (3) *the productive operation,* by which instances of the range concept(s) are produced by composition, decomposition, or some other change operation, such that the instances of two or more domain concepts are qualitatively changed as they are used to produce an instance (or instances) of the range concept(s).

In effect, an identity operation is an arbitrary one-to-one association, such as a symbol for an object or a date for an event: it has no examples, and (unlike descriptive and productive operations) the notion of transfer learning is inapplicable. A descriptive operation specifies a simple union or intersection of attributes – such as in a concept – or of concepts – such as in a subset – (see Bruner et al. 1956). And a productive operation entails some kind of change, such as in a principle or a procedure. (For a more in-depth description of the types of constructs, see Merrill and Wood, 1975a).

However, this classification of types of constructs fails to distinguish between some importantly different (for instructional design purposes) types of constructs, such as principles and procedures. The solution to this problem seems to lie in a distinction drawn by several cognitive and instructional psychologists. Greeno (1973) and Mayer (1975) have distinguished between "meaningful" and "calculational" knowledge, and Scandura (1974) made a distinction between "propositional" and "algorithmic" knowledge. These are both basically the same distinction, and we shall use the terms *meaningful* and *rote.*

It should be noted that this distinction is not the same as Ausubel's

(1963, 1968) distinction between meaningful and rote learning for two important reasons. First, we are talking about kinds of content, not kinds of learning. But Ausubel also talks about meaningful and rote content; for meaningful learning to occur, Ausubel specifies two conditions which must be met: (1) the content to be learned must be potentially meaningful, and (2) the learner must employ a meaningful learning set (thus, even potentially meaningful material can be learned at a rote level). Merrill (Merrill and Boutwell, 1973; Merrill and Wood, 1975a) has made a similar distinction between the type of content and the level of student behavior at which that content is learned. For instance, a student may *remember* the definition of a concept – which is rote learning – or she/he may learn to *use* the definition to classify unencountered instances and noninstances of the concept – which is meaningful learning. Meaningful learning is demonstrated (and is usually required) only at the use level of student behavior.

However, Ausubel's distinction between meaningful and rote content is still different from our distinction. Ausubel's is one of not meaningful vs. potentially meaningful, which is in effect one of identities vs. all other types of constructs. On the other hand, our distinction is one of constructs that *can* be learned rotely at the use level vs. constructs that *cannot,* which is in effect one of subsets and steps vs. concepts and principles. A student can learn to use a step (of a procedure) without any meaningful understanding of that step – that is, without any knowledge of the principle upon which the step is based (for example, such is usually the case when students take an introductory course in statistics). A student can also learn to use a subset (to classify concept sets as members or nonmembers of a given concept set) without any meaningful understanding of the concept classes involved. But one cannot learn to use a concept (for concept classification) or to use a principle (for explaining a phenomenon) without a meaningful understanding of the concept or principle involved.

	Identity	Descriptive	Productive
Meaningful		"Union/ intersection" (Concept)	"Causal" (Principle)
Rote	"Identity" (Fact)	"Inclusion" (Subset)	"Order" (Step)

Fig. 10. Five elemental operations and the common names of their respective constructs.

When we apply this rote-meaningful distinction to the identity-descriptive-productive classification of operations, the result is the identification and description of five elemental operations (see Fig. 10): (1) *identity* operations which are rote-identity, (2) *inclusion* operations, which are rote-descriptive, (3) *union/intersection* operations, which are meaningful-descriptive, (4) *order* operations, which are rote-productive, and (5) *causal* operations, which are meaningful-productive. Figure 11 shows some examples of these five elemental operations.

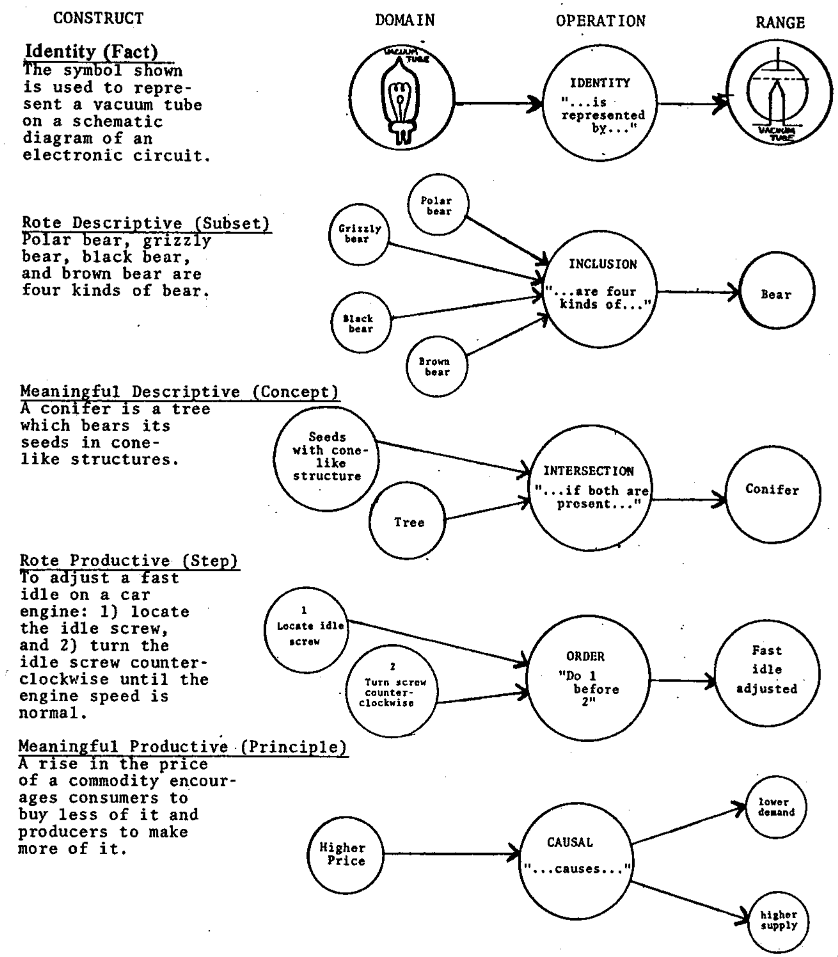


Fig. 11. Examples of five types of operations and their respective constructs.

Turning to the objective of classifying content constructs on the basis of the type of operation involved in each construct, we will hereafter refer to the respective constructs with the following familiar labels: (1) *facts,* (2) *subsets,* (3) *concepts,* (4) *steps,* and (5) *principles* (see Fig. 10).

TYPES OF STRUCTURES

Now, how is this classification of constructs important to an analysis of subject matter structures? Partly because the above-mentioned structures are homogeneous, both in terms of the type of their component constructs and in terms of the type of relation interrelating those constructs, we propose that those structures can be usefully classified in the same ways as constructs. In fact, all five types of elemental operations for constructs described above can be used to describe elemental relations for structures: (1) *no* relation, which is rote-identity, (2) the *ordinate* relation, which is rote-descriptive, (3) the *learning-prerequisite* relation, which is meaningful-descriptive, (4) the *procedural-prerequisite* relation, which is rote-productive, and (5) and *causal* relation, which is meaningful-productive (see Fig. 12).

	Identity	Descriptive	Productive
Meaningful	//////	"Learning-prerequisite" (Learning hierarchies)	"Causal" (Theories or models)
Rote	None (Lists)	"(Super/co/sub-) ordinate" (Taxonomies)	"Procedural-prerequisite" (Procedural hierarchies)

Fig. 12. Five elemental relations and the common names of their respective structures.

Turning to the objective of classifying content structures on the basis of the type of relation involved in each structure, we will hereafter refer to the respective structures with the following familiar labels: (1) *lists*, (2) *taxonomies*, (3) *learning hierarchies*, (4) *procedural hierarchies*, and (5) *theories* or *models* (depending on the degree of evidence for their validity).

CONSTRUCTS VERSUS STRUCTURES

Having just established the great difference between constructs and structures, we must now qualify it with a discussion of how the "push-down" principle can move the boundary between structures and constructs. Merrill (1971) described the push-down principle as follows:

> a behavior acquired at one level will be pushed down to a lower level as soon as conditions have changed sufficiently so that the learner is able to respond to the stimulus situation using lower level behavior (p. 181).

Each relation, as described above, is almost identical to its corresponding operation. For example, the order operation exists in essentially the same form at both the construct level and the structure level, partly because practically every "step" that is taught can be broken down into substeps. With experience, what was once a procedure (set of steps) becomes for practical purposes a single step for the performer. In a similar manner, what is a learning hierarchy for a naive learner may become a concept for an expert. And what was a theory for a naive learner may become for practical purposes a principle for an expert. This does not in any way reduce the value of distinguishing constructs from structures, but it does point out the importance of describing the learners and their entry behaviors before commencing instructional design.

SUMMARY

Figure 13 summarizes the concepts and their labels discussed in this section. We have described two kinds of relationships among the "modules" of content (i.e., content constructs): (1) *operations*, which are components of content constructs, and (2) *relations*, which are components of content structures. Five kinds of operations and their respective constructs were described: identity (fact), rote-descriptive (subset), meaningful-descriptive (concept), rote-productive (step), and meaningful-productive (principle). Then five kinds of relations and their respective structures were described: none (list), rote-descriptive (taxonomy), meaningful-descriptive (learning hierarchy), rote-productive (procedural hierarchy), and meaningful-productive (theory or model).

		CONSTRUCT		STRUCTURE	
		Operation	Construct	Relation	Structure
Identity	Rote	Identity	Fact	(Arbitrary)	List
Descriptive	Rote	Inclusion	Subset	(super/co/ sub-)ordinate	Taxonomy
	Meaningful	Union/ Intersection	Concept	Learning Prerequisite	Learning Hierarchy
Productive	Rote	Order	Step	Procedural Prerequisite	Procedural Hierarchy
	Meaningful	Causal	Principle	Causal	Theory/ Model

Fig. 13. A summary of construct/structure concepts and their labels.

Instructional Design Implications

These two schemes for classifying subject matter content (i.e., classifying constructs and classifying pervasive relations among constructs) were developed primarily as a basis for prescribing the use of different instructional strategies. The underlying assumption is that different strategies will be optimal for teaching different types of constructs and different types of structures. The value of these classification schemes will be measured in terms of their utility for prescribing effective instructional strategies.

We believe that the classification of constructs (along with a classification of levels of behavior desired for each construct) will be useful for prescribing what we refer to as presentation strategies (which are strategies for the teaching of a single construct), such as the use of attribute isolation, mnemonics, divergent examples, and different representation forms (see Merrill et al., 1977, for such an application of this classification of constructs).

We also believe that the classification of structures will be useful for prescribing what we refer to as structural strategies (which are strategies for selecting, sequencing, synthesizing, and summarizing related constructs), such as overviews and advance organizers. We have not yet finished any publications describing such prescriptive relationships, so we will briefly outline some important considerations and orientations.

First, all subject matter areas appear to be comprised of all of the above-mentioned kinds of structures (we have encountered no exceptions to date). But not all of them are necessarily relevant to the particular instructional goals and objectives of a given course of instruction. An instructional designer must select those structures which are relevant to the course's particular goals and objectives.

Second, the instructional designer will usually find that more than one kind of content structure is relevant. In current practice, a content or task analysis does not recognize the independence (nor even the existence) of these different structures. However, distinguishing these kinds of content structures has important ramifications for both sequencing and synthesizing instruction. For instance, it becomes apparent that a different learning structure can be derived for each and every box in a procedural structure and for each and every box in a taxonomic structure. This means that three-dimensional combinations of structures are often necessary for performing a task analysis: one could visualize the procedural (or taxonomic) structure in a horizontal plane, with a learning structure dangling down from each of its boxes.

In relation to *sequencing instruction,* more options are now available, because learning structures are the only ones which require a certain learning sequence. When teaching a procedure, rather than being obligated to teach the whole procedure from beginning to end in its most complex form, one could decide what are the most important and meaningful parts of the procedure, and further simplify each of them if necessary (e.g., eliminating alternate procedures from the procedural decision structure) so that the essence of the procedure can be presented at the very beginning of the instruction. The remaining instruction would then be an *elaboration* on that simplified procedure until it reaches its most complete and complex form, including alternate subprocedures (Merrill, 1977; Reigeluth and Merrill, 1977).

In relation to *synthesizing instruction,* schematic representations such as hierarchies have had very little effect because the student has not been able to interpret them. The lines among the boxes can represent any of the major kinds of relations. If such a schematic representation of relations contained only one kind of relation which was explicitly explained to the student, then this could be a very valuable way to synthesize certain types of content.

It is beyond the scope of this paper to perform a more in-depth analysis of the implications of these structures for sequencing and synthesizing instruction. It is our hope that this analysis, which is but one part of our theory-construction effort in the area of structural strategies, will stimulate further empirical and theoretical work in this important area of instructional science.

Notes

1 A subject matter component, as referred to in this paper, is a single concept, principle, fact, etc.
2 Also, if a parts taxonomy for concepts contains only critical parts (attributes) of its concepts, it is the same as a learning hierarchy.
3 Steps of a procedure are really *event concepts.*
4 We appreciate the ideas and perspectives of Edward Schneider, who contributed much to the final version of this paragraph and to the wording in Fig. 9.

References

Ausubel, D. P., (1963). *The Psychology of Meaningful Verbal Learning.* New York: Grune & Stratton.

Ausubel, D. P., (1968). *Educational Psychology: A Cognitive View.* New York: Holt, Rinehart and Winston.

Bruner, J. S., Goodnow, J. J. and Austin, G. A., (1956). *A Study of Thinking.* New York: Wiley and Sons.

Crothers, E. J., (1972). "Memory Structure and the Recall of Discourse," in J. B. Carroll and R. O. Freedle (eds.), *Language comprehension and the acquisition of knowledge.* New York: John Wiley & Sons.

Gagné, R. M., (1968). "Learning hierarchies," *Educational Psychologist,* 6: 1–9.

Gagné, R. M., (1977). *The Conditions of Learning.* (3rd ed.). New York: Holt, Rinehart & Winston.

Gibbons, A. S., (1977). "A review of content and task analysis methodology." *Technical Report Series, No. 2.* San Diego: Courseware, Inc.

Greeno, J. G., (1973). "The Structure of Memory and the Process of Solving Problems," in R. L. Solso (ed.), *Contemporary Issues in Cognitive Psychology.* Washington, D.C.: Winston.

Gropper, G. L., (1974). *Instructional Strategies.* Englewood Cliffs: Educational Technology Publications.

Harary, F., Norman, R. Z. and Cartwright, D., (1965). *Structural Models: An Introduction to the Theory of Directed Graphs.* New York: Wiley.

Mayer, R. E., (1975). "Information processing variables in learning to solve problems," *Review of Educational Research,* 45: 525–541.

Macdonald-Ross, M., (1974). *Glass Beads and Geometric Monsters.* Paper presented at the meeting of the Association for Educational Communications and Technology, Atlantic City, New Jersey.

Merrill, M. D., (1971). "Necessary psychological conditions for defining instructional outcomes," *Educational Technology,* August 1971, 34–39. Also in M. D. Merrill (ed.) *Instructional Design: Readings.* Englewood Cliffs, N.J.: Prentice-Hall.

Merrill, M. D., (1973). "Content and instructional analysis for cognitive transfer tasks," *Audio Visual Communications Review,* 21: 109–125.

Merrill, M. D., (1977). "Content Analysis via Concept Elaboration Theory," *Journal of Instructional Development,* 1: 10–13.

Merrill, M. D. and Boutwell, R. C., (1973). "Instructional Development Methodology and Research," in F. N. Kerlinger (ed.), *Review of Research in Education.* Itasca, Ill.: Peacock Publishers.

Merrill, M. D. and Wood, N. D., (1974). *Instructional Strategies: A Preliminary Taxonomy.* Columbus, Ohio: Ohio State University. (ERIC Document Reproduction Service No. SE018–771).

Merrill, M. D. and Wood, N. D., (1975a). *Instructional strategies: A preliminary taxonomy,* Technical Report Series, No. 1R. Orem, Utah: Courseware, Inc.

Merrill, M. D. and Wood, N. D., (1975b). *Rules for Effective Instructional Strategies.* Instructional Design Series. Orem, Utah: Courseware, Inc.

Merrill, M. D., Richards, R. E., Schmidt, R. V. and Wood, N. D., (1977). *The Instructional Strategy Diagnostic Profile Training Manual.* San Diego: Courseware, Inc.

Merrill, P. F., (1971). "Task analysis – an information processing approach." *Technical Memo No. 27.* Tallahassee, Florida: CAI Center, Florida State University.

Pask, G., (1975). *Conversation, Cognition and Learning.* Amsterdam: Elsevier.

Reigeluth, C. M. and Merrill, M. D., (1977). "Planning instruction – Concept elaboration theory," *Audiovisual Instruction,* 22 (7).

Rumelhart, D. E., Lindsay, P. H. and Norman, D. A., (1972). "A Process Model for Long-term Memory," in E. Tulving and W. Donaldson (eds.), *Organization of Memory.* New York: Academic Press.

Samuelson, P. A., (1967). *Economics* (seventh Ed.), New York: McGraw-Hill.

Scandura, J. M., (1968). "New directions for theory and research on rule learning: I. A set-function language," *Acta Psychologica,* 28: 301–302.

Scandura, J. M., (1970). "Role of rules in behavior: Toward an operational definition of what (rule) is learned," *Psychological Review,* 77: 516–533.

Scandura, J. M., (1974). "The Structure of Memory: Fixed or Flexible?" in F. Klix (ed.), *Organismische informationsverarbeitung.* Berlin: Akademie-Verlag.

Shavelson, R. J., (1974). "Methods for examining representations of a science subject-matter structure in a student's memory," *Journal of Research in Science Teaching,* 11: 231–249.