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MEANINGFULNESS AND INSTRUCTION: RELATING WHAT IS BEING LEARNED TO WHAT A STUDENT KNOWS

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ABSTRACT

Any comprehensive theory of instruction must include ways to optimize the acquisition, organization, and retrieval of new knowledge. An important concern in this regard is making new knowledge meaningful by relating it to prior knowledge. Although meaningfulness is usually thought of in terms of relating new knowledge to prior *superordinate* knowledge (as with the advance organizer), there are at least six other kinds of prior knowledge that can facilitate the acquisition, organization, and retrieval of new knowledge. Seven kinds of prior knowledge are described below, followed by a section on instructional strategies that an instructional designer or teacher can use to help optimize the learner's use of the seven kinds of prior knowledge for acquiring, organizing, and retrieving new knowledge.

Any comprehensive theory of instruction must be concerned with how to optimize the acquisition, organization, and retrieval of new knowledge. Ausubel recognized as early as 1960 that making new knowledge meaningful to the learner is important for optimizing acquisition, organization, and retrieval; and it has become widely accepted that (as Ausubel, 1968, maintained) this is accomplished primarily by relating new knowledge to what a student already knows. Based on Ausubel's earlier work, many people have erroneously come to associate "making new knowledge meaningful" solely with relating it to *superordinate* knowledge (that the learner already possesses) *within* the content area of immediate interest. But – as Ausubel (1968) pointed out when he expanded his fairly restricted "subsumption theory" into his "assimilation theory" (which was

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expanded to include several other types of prior knowledge) – this is only one way of making learning meaningful.

Occasionally, Ausubel's advance organizers make learning meaningful by relating new knowledge to *parallel* knowledge (that the learner already possesses) *outside* of the content area of immediate interest. A third way (often overlooked in the literature) to make new knowledge meaningful is by relating it to specific *sensory events or actions* stored in the "experiential" data base. These sensory events and actions are what instructional theorists refer to as "instances," and the experiential data base is similar to what Lindsay and Norman (1977) refer to as the "sensori-motor data base." Relating new knowledge to the experiential data base is probably the major way that new knowledge is made meaningful during the early years of human cognitive development.

Different researchers have worked on different ways to make new knowledge meaningful by relating it to different kinds of prior knowledge (Bruner, 1960; Levin, 1973; Ortony et al., 1978; Ritchey and Beal, 1980; Pressley et al., 1981). The purposes of this article are to describe more comprehensively (1) the *kinds of prior knowledge* that can be used to facilitate the acquisition, organization, and retrieval of new knowledge, and (2) a variety of *instructional strategies* that can be used to help optimize the learner's use of those kinds of prior knowledge.

Kinds of Prior Knowledge

The following are seven kinds of prior knowledge that can be used to facilitate the acquisition, organization, and retrieval of new knowledge (see Fig. 1): (1) *arbitrarily meaningful* knowledge, to which rote (non-meaningful) knowledge can be related in order to facilitate retention, (2) a *superordinate* idea, which serves as "ideational scaffolding" for the new knowledge, (3) a *coordinate* idea, which serves an associative, comparative, or contrastive function, (4) a *subordinate* idea and (5) *experiental knowledge*, both of which serve to instantiate or concretize the new knowledge by relating it to the learner's experiential data base, (6) an *analogic* idea, which relates new (potentially meaningful) knowledge to highly similar knowledge that is external to the content of interest, and (7) a *cognitive strategy*, which provides appropriate cognitive processing during acquisition of the new knowledge. These seven kinds of prior knowledge can be categorized as those which deal with (a) content-specific knowledge *within* the content area of interest, (b) content-specific knowledge *outside* the content area of interest, and (c) knowledge of generic skills, which apply across several content areas. The first category, knowledge *within* the content area of interest, includes superordinate, coordinate, subordinate, and experiential kinds of knowledge. The second, knowledge *outside* the content area of interest, is

composed of analogic and arbitrarily meaningful knowledge. The third category, knowledge of generic skills, includes only cognitive strategies.

Perhaps there are other kinds of prior knowledge which can also be used to facilitate the acquisition, organization, and retrieval of new knowledge, but these seven kinds are the only ones of which we are aware at present. Each of these kinds of knowledge is described below, followed by a section on instructional strategies for using each of them.

Before we describe these seven kinds of prior knowledge, it will be helpful to

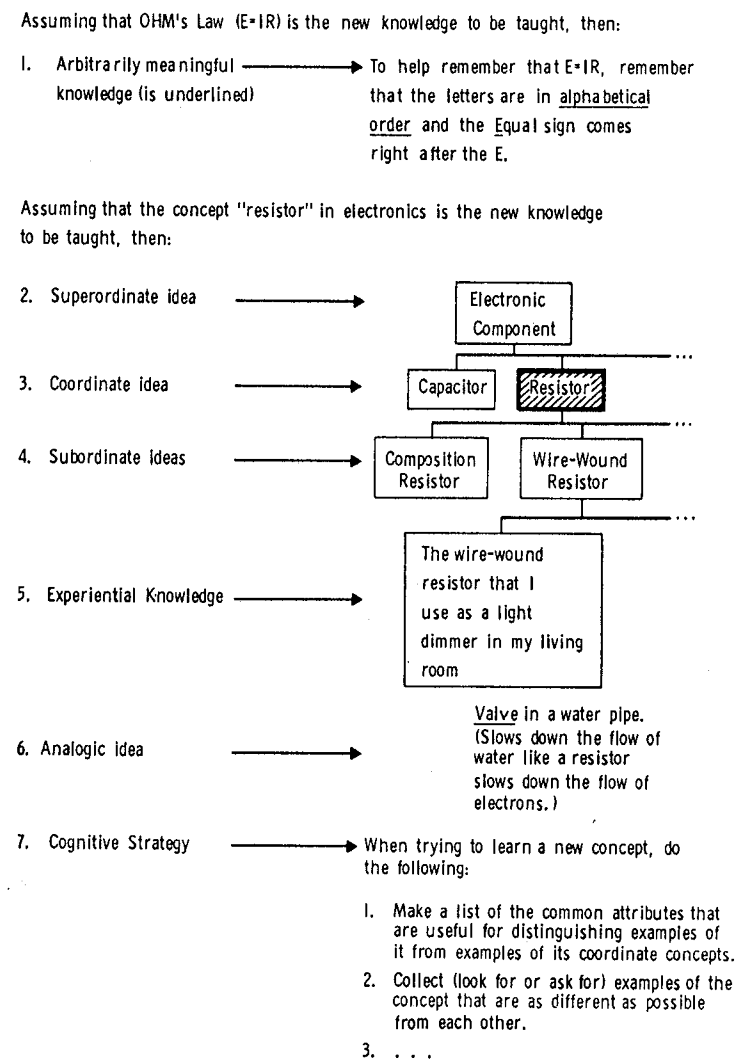


Fig. 1. Seven types of prior knowledge that can be used to facilitate the acquisition, organization, and retrieval of prior knowledge.

›riefly review the notion that knowledge can be acquired at different *levels of* ›*ehavior* (Merrill and Boutwell, 1973; Merrill and Wood, 1975), which corre-pond to different levels of cognitive processing. Although Merrill (Merrill et al., 977) has distinguished at least six different levels (see Fig. 2), the most impor-ınt distinction for this article is between the remember level and the application :vel.

The *remember* level includes knowledge for such behaviors as recognition nd recall, and they may be verbatim or paraphrased. Examples of knowledge at ıe remember level include the following: knowing the year that Columbus iscovered America (a fact), knowing (being able to state) the definition of ıegative reinforcement" (a concept), knowing (being able to state) the law of ıpply and demand (a principle), and knowing (being able to state) the steps for ›lving a quadratic equation (a rule).

On the other hand, the *application* level involves applying a generality to a ›ecific case (or instance). It includes knowledge for such behaviors as identify-g or producing the proper application of a generality to a specific case, cluding such behaviors as classification, explanation, and prediction. Exam-:s of knowledge at the application level include the following (please compare the remember level examples above): knowing the concept "negative rein-rcement" (being able to classify new examples and non-examples of it), owing the law of supply and demand (being able to use it to predict the effects

Levels of knowledge
- levels of cognitive processing during acquisition and retrieval.
- levels of behavior that result during subsequent use.

Assume that the following has been taught
"To find the current (I), divide the voltage (E) by the resistance (R).
If E = 120 Volts and R = 3 Ohms, then I = 120/3 = 40 Amps."
— Then the following is an example of a test item (or adjunct question) that is at each level of knowledge:

Remember	Recognize	Verbatim	1	If E = 120 Volts and R = 3 Ohms, then I = 120/3 = 40 Amps. True or False?
		Paraphrase	2	If you have 120 volts in an electric line and you install a 3 Ohm resistor, then your current will be 120/3, or 40 Amps. True or False?
	Recall	Verbatim	3	Complete the following exactly as you learned it: If E = 120 Volts and R = 3 Ohms, then I = ________.
		Paraphrase	4	If you have 120 Volts passing through a 3 Ohm resistor, then the current will be ________.
Apply	Identify new instances		5	If E = 220 Volts and R = 11, then I = 22 Amps. True or False?
	Produce new instances		6	Fill in the blank: If E = 120 Volts and R = 8, then I = ________.

ig. 2. Six levels at which any generalizable knowledge can exist, and an example of each.

of a new economic change), and knowing the steps for solving a quadratic equation (being able to solve a new quadratic equation).

The distinction between the remember level and the application level of knowledge will be useful for the discussion of several of the kinds of prior knowledge below.

1. ARBITRARILY MEANINGFUL KNOWLEDGE

Arbitrarily meaningful knowledge is knowledge which has no inherent relationship to the new knowledge (i.e., any relationship that may exist is not inherent in the semantic structure of the knowledge). This kind of prior knowl-edge can be useful in aiding memorization of non-meaningful, or rote, knowl-edge (i.e., for acquiring knowledge at the remember level), wherein various kinds of meaningful prior knowledge can be used for mnemonic purposes: peg words (e.g., one-bun, two-shoe, etc.), familiar places, and associations. (See Lindsay and Norman, 1977, pp. 359–364; Dansereau, 1978, pp. 5–6; and Levin, 1981, for examples.)

Lindsay and Norman (1977) observe that "the problem in learning new information is not in getting the information into the memory; it is in making sure that it will be found later on, when it is needed" (p. 337) [1]. The above-des-cribed kinds of "arbitrary" prior knowledge can be used to create links which, although arbitrary, can greatly facilitate finding the new knowledge later on when it is needed (Lindsay and Norman, 1977; Dansereau, 1978; Levin, 1981).

2. SUPERORDINATE KNOWLEDGE

The term "superordinate" is used in at least two very different ways in the instructional psychology literature. In the Gagnéan sense (see e.g., Gagné, 1968), it relates to "learning prerequisite" relationships among skills. If one skill is a learning prerequisite for a second (i.e., it must be learned before the second can be learned), then the second is often referred to as being superordinate to the first. Such a superordinate skill is more *inclusive* and more *complex* than the skill that is to be learned. In contrast, in the Ausubellian sense (see e.g., Ausubel, 1964), the term "superordinate" relates to "subsumptive" relationships among ideas. Such a superordinate idea is one which is more *inclusive* and/or *simpler* than the idea that is to be learned and which also *subsumes* the idea. In Fig. 3, if "variable resistor" is the concept that is to be learned, then "wirewound resistor" is a superordinate idea. In this paper, the Ausubellian sense of the term "super-ordinate" is used.

If the knowledge to be learned is a *concept* [2], then the superordinate concept is more inclusive (i.e., it has more specific instances and more kinds of instances), and it is simpler (i.e., it has fewer common characteristics

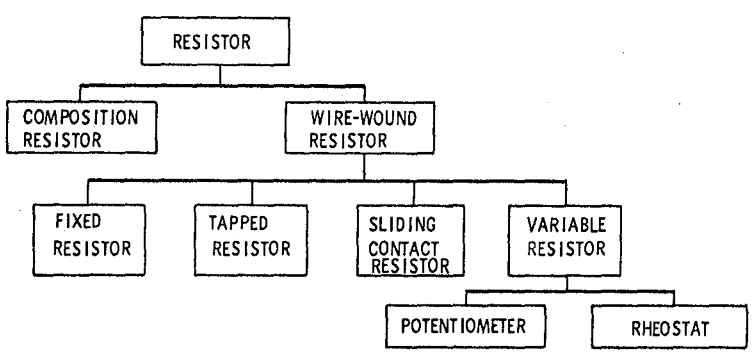
istics that are common across all of its instances). For example, "dog" is superordinate to "collie" – there are more dogs than there are collies, and dogs of all kinds have fewer things in common than do collies.

If the knowledge to be learned is a *principle* [3], then the superordinate principle is more inclusive (i.e., it has greater breadth of applicability – more specific instances, or applications), and it is simpler (i.e., it involves fewer variables and its variables tend to be more general concepts – more inclusive and simpler ones). For example, the law of supply and demand is superordinate to the principle of profit maximization – it has greater breadth of applicability, and its concepts are simpler. (See Fig. 4 for an additional example.)

If the knowledge to be learned is a *rule* [4], then the recently developed "path analysis" technique (P. Merrill, 1971, 1980; Scandura, 1973) can be used to identify what rule is superordinate (in the subsumptive sense) to the rule that is to be learned (Reigeluth and Rodgers, 1980). A superordinate rule is less inclusive (i.e., it has less breadth of applicability – fewer specific instances, or applications), and is simpler (i.e., entails fewer steps or operations, and those steps or operations tend to be more fundamental). For example, the procedure for subtraction without borrowing is superordinate to the procedure for subtraction with borrowing; it has fewer steps, and its steps are more fundamental – they are basic components of a larger number of related procedures.

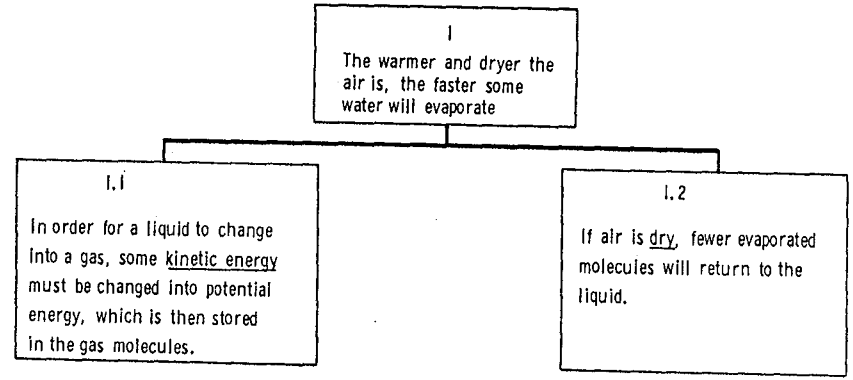
In all three cases the superordinate idea subsumes the idea that is to be learned. In other words, the idea to be learned can be viewed as a more detailed or complex case of the superordinate idea.

Ausubel (1963, 1964) pioneered the notion that a superordinate idea already known by the learner provides "ideational scaffolding" for what is being learned, thereby making it meaningful; and Mayer's (1976, 1977, 1979) assimilation encoding theory extends this notion with the process of "activation of an assimilative set." Superordinate ideas serve to facilitate acquisition by relating



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

Fig. 3. A kinds-conceptual structure, which can serve as a synthesizer.



Principle I is superordinate to principles I.1 and I.2 because it is more inclusive and more simple than principles I.1 and I.2 and it subsumes both of them.

Principle I.1 is coordinate with principle I.2 (and vice versa) because both have the same superordinate principle and their examples are mutually exclusive.

Principles I.1 and I.2 are both subordinate to principle I because principle I is superordinate to both of them.

Fig. 4. An example of superordinate, coordinate, and subordinate relationships among principles.

the new idea to a similar and simpler idea already familiar to the learner (Ausubel, 1968; Mayer, 1979). Knowing what a wire-wound resistor is takes a learner "half way there" to understanding what a variable resistor is (see Fig. 3). Also, superordinate ideas serve to facilitate *retrieval* (especially long-term retention) by helping to *build* more stable cognitive structures, thereby improving the *organization* of new knowledge by creating more and stronger links to the new idea within a learner's memory (E. Gagné, 1978). This is one of many cases where a single instructional process can implement more than one principle of learning and/or cognition.

Unlike Ausubel, Reigeluth (1979) has argued that a superordinate idea should *not* be more abstract than what is being learned, either for facilitating retrieval, or for facilitating acquisition, or for building stable cognitive structures. "Dog" is no more abstract than "collie," and "resistor" is no more abstract than "rheostat" – instances of the superordinate idea are just as concrete as instances of the other idea. But a superordinate idea *is* more general and inclusive. To be most useful, the superordinate idea selected should be one which is closest to the idea that is being learned (e.g., dog, rather than mammal or vertebrate, for relating to collie).

3. COORDINATE KNOWLEDGE

As with "superordinate," the term "coordinate" is used here in the Ausubellian sense of the word. A coordinate idea is one which is on the *same level* of generality or simplicity as the idea that is to be learned. It must also be *closely related* to the idea to be learned. To be more precise, its instances must be mutually exclusive of the new idea's instances, and its closest superordinate idea must be the same as the one for the new idea. In Fig. 3 fixed, tapped, and sliding contact resistors are all coordinate to "variable resistor," and the closest superordinate idea is the same for all of them – "wire-wound resistor."

If the knowledge to be learned is a *concept*, then a coordinate concept is a mutually exclusive concept whose closest superordinate concept is the same. For example, beagle is mutually exclusive of collie (i.e., no beagles are collies and no collies are beagles), and both are dogs.

If the knowledge to be learned is a *principle*, then a coordinate principle is a mutually exclusive principle whose closest superordinate principle is the same. For example, the principle of utility maximization is mutually exclusive of the principle of profit maximization (i.e., no instances of one are instances of the other, and vice versa) and both are subordinate to the law of supply and demand. (See Fig. 4 for an additional example.)

If the knowledge to be learned is a *rule*, then a coordinate rule is a mutually exclusive one that is also a more complex version of the same superordinate (simpler) rule. For example, the rule for subtracting fractions without borrowing is mutually exclusive of the rule for subtracting whole numbers with borrowing (i.e., no instances of one are instances of the other, and vice versa), and both have the same superordinate rule – subtracting whole numbers without borrowing (i.e., both are more complex iterations of the latter, more fundamental rule).

In all cases, two coordinate ideas can be viewed as more detailed or complex cases of the *same* superordinate idea.

Relating "what is to be learned" to a coordinate idea that the learner already knows should facilitate *acquisition* by helping the learner to compare and contrast the new idea to a highly similar one that is known (see e.g., the research on the benefits of "close-in nonexamples" or "matched nonexamples," Markle and Tiemann, 1969; Merrill and Tennyson, 1977). In learning what a variable resistor is (see Fig. 3), it is helpful for the learner to know that it is not a sliding contact resistor – that it is different in certain ways, but that it is also similar in certain ways. Relating a new idea to a known coordinate idea should also help the learner to *organize* memory in a stable way (i.e., to build stable cognitive structures) because the relationships among related ideas will be learned correctly from the beginning (rather than in an idiosyncratic, hit-or-miss manner) and will, therefore, not require subsequent reorganization of memory (Ausubel, 1968). Finally, it should serve to facilitate *retrieval* by creating additional links to the new idea within the learner's memory (E. Gagné, 1978).

To be most useful, the coordinate idea should be as similar as possible to the idea being learned.

4. SUBORDINATE KNOWLEDGE AND 5. EXPERIENTIAL KNOWLEDGE

A *subordinate idea* is the opposite of a superordinate idea. Reigeluth et al. (1978) have identified two major kinds of subordinate ideas (in the Ausubellian sense of the word): those which are *kinds* of the idea to be learned, and those which are *parts* of the idea to be learned. These correspond to the "class" and "has-as-parts" cognitive relationships in Lindsay and Norman (1977). For example, potentiometer and rheostat are two kinds-subordinate concepts for variable resistor (see Fig. 3 above), while wire and sliding contact are two parts-subordinate concepts for sliding contact resistor. For purposes of relating a new idea to what a learner already knows, the kinds-subordinate idea is the only one of real interest [5].

Closely related to the notion of subordinate knowledge is the notion of *experiential knowledge*, which is one's memory of specific objects or events (referred to as instances in instructional theory) and which is stored in the experiential data base. It is the equivalent of what is on the lower or terminal end of the "isa" relation in Lindsay and Norman's (1977) cognitive structures. A child's experiential knowledge of some specific cars makes "car" a meaningful concept to him/her. It is precisely through our experiential knowledge that we avoid the problem of circularity of definitions and, hence, achieve a truly meaningful understanding. As Lindsay and Norman put it, "circularity of the information is avoided by providing reference to real sensory events and real actions" (1977, p. 390). The major difference between subordinate knowledge and experiential knowledge is that the former is always generalizable knowledge (i.e., concepts, principles, and procedures, each of which has more than one instance), whereas experiential knowledge is always specific instances or cases (Merrill et al., 1979).

Instructional Science has long recognized the value of experiential knowledge, as is reflected in its prescriptions for providing instances to facilitate learning new ideas at the application level of knowledge (Gropper, 1974; Markle and Tiemann, 1969; Merrill et al., 1979). Providing instances serves mainly to extend the experiential data base. But it may not always be necessary to *extend* the experiential data base in order for a learner to learn new ideas at the application level, because the learner may already have sufficient experiential knowledge, either in the form of isolated instances or in the form of instances of subordinate knowledge.

If the learner has experiential knowledge in the form *isolated instances*, then that knowledge needs to be activated, and its relationship to the new idea needs to be made explicit. But, if the learner already knows a *subordinate idea* at the application level (which means he or she is able to apply it to instances), then all instances of that subordinate idea are also instances of the idea to which it is subordinate (e.g., all rheostats are variable resistors). Therefore, if a learner already knows one or more kinds-subordinate ideas, then the idea to be learned can be related to the learner's experiential data base more economically by telling the learner that all instances of the kinds-subordinate idea are also instances of the idea to be learned, rather than by actually presenting those instances as instances of the idea to be learned. Of course, if any of the kinds-subordinate ideas are unfamiliar to the learner, then instances of those types should be presented to the learner. If you take one instance from each of the full set of kinds-subordinate ideas, then you have something akin to what Markle and Tiemann (1969) refer to as a "minimum critical subset" of instances. For the application level of knowledge, research has shown that acquisition is enhanced by presenting (or activating) such a full range of instances (see e.g., Merrill and Tennyson, 1977).

Whether by providing new instances, by activating familiar instances, or by relating what is to be learned to a known kinds-subordinate idea, it is important for acquisition and retrieval that new knowledge be related to a learner's experiential data base. It is important for *acquisition* because at the application level of knowledge the learner must learn how to apply a generality to instances (which is clearly more difficult to learn to do if there are no instances available), and at the remember level of knowledge (for remembering a generality) a reference example can facilitate visualization for imaginal encoding. This is amply supported by the rule vs. rule-example studies (see Merrill et al., 1976, for a review). Relating new knowledge to the experiential data base is also important for *retrieval* because a valuable link is created to the new knowledge from the experiential data base (Lindsay and Norman, 1977; E. Gagné, 1978). Finally, it is important for the *organization* of memory that new knowledge be related to subordinate ideas (both kinds and parts), so that the new knowledge will be integrated into stable cognitive structures by subsuming already-mastered, lower-order ideas (Ausubel, 1968; Mayer, 1976, 1977). In this way, the new knowledge will serve as the means for classifying or regrouping prior knowledge.

It should be noted that superordinate and coordinate ideas are also linked to the experiential data base – all ideas (or generalities) have instances. However, the instances of coordinate ideas are never instances of the new idea, and not all instances of the superordinate idea are instances of the new idea. Hence, the utility of those instances is greatly reduced, except that instances of coordinate ideas can serve a useful comparative and contrastive function if they are "matched nonexamples" (Merrill and Tennyson, 1977) or "close-in nonexamples" (Markle and Tiemann, 1969).

6. ANALOGIC KNOWLEDGE

An analogic idea is similar to a coordinate idea except that it is *outside of the content area* of interest. It has the following relationships to the idea to be learned: it has the *same superordinate idea* (which by its nature is broader than the content area of interest), it is on approximately the *same level of generality*, it has important *similarities*, and its instances are *mutually exclusive* of the new idea's instances.

If the knowledge to be learned is a *concept*, then the analogic concept is one outside of the content area of interest that has important similarities with the concept to be learned. For example, if electronics is the content area of interest, then "valve" in a water pipe is outside of the content area, but has important similarities with the concept "resistor" in an electrical circuit.

If the knowledge to be learned is a *principle*, then the analogic principle is one that is outside of the content area of interest, but has important similarities with the principle to be learned. For example, if electronics is the content area of interest, then the principle that "closing a water valve will cause the flow of water to decrease, assuming that the water pressure remains constant" is outside of the content area, but has important similarities with the principle that "increasing resistance in a circuit will cause the current to decrease, assuming that the voltage remains constant."

If the knowledge to be learned is a *rule*, then the analogic rule is also one that is outside of the content area, but has important similarities with the rule to be learned. For example, if mathematics is the content area of interest, then the rule for taking objects off a two-armed scale in such a way that the scale always remains in balance is outside the content area, but has important similarities with the rule for solving an equation.

Relating what is to be learned to an analogic idea that the learner already knows facilitates *acquisition* by helping the learner to compare the new idea to a highly similar one that is known (Ortony et al., 1978; Ritchey and Beal, 1980), but only if the learners have been taught how to use analogies to facilitate learning (Dreistadt, 1969; Raven and Cole, 1978). It also is likely to help the learner to interrelate separate cognitive structures, which should facilitate both a *more stable organization* of memory and the *building of content-free skills and knowledge* (Ausubel, 1968). For example, the learner will learn that there is a superordinate, content-free idea called "resistance," which pervades many different content areas. This should improve the student's ability to transfer this knowledge to new applications, to solve problems better, and even to use analogic reasoning as a powerful learning and thinking tool (see below). Such interrelations among cognitive structures should also facilitate *retrieval* of the new knowledge through the provision of additional links in memory (E. Gagné, 1978).

To be most useful, the analogy should be as similar as possible to the idea that is to be learned. If the differences are greater than the similarities, then the analogy may be more confusing than helpful.

7. COGNITIVE STRATEGIES

Among other things, cognitive strategies provide the mechanisms for developing relationships between new knowledge and previous knowledge (whether related or unrelated in content). A cognitive strategy (R. Gagné, 1977; Rigney, 1978) is a content-free skill (or processing routine) that a person can use to facilitate the acquisition of knowledge (i.e., learning skills) or to facilitate the organization and retrieval of knowledge already acquired (i.e., remembering skills). (There are also cognitive strategies to facilitate manipulation of knowledge already acquired, i.e., thinking skills, but they are not of relevance to this article.) A cognitive strategy is a rule (or processing routine, or algorithm) – i.e., it is an ordered series of mental steps that are performed to achieve a prespecified goal.

With respect to *acquisition*, cognitive strategies (or learning skills, in this case) include (1) primary strategies, which are applied to new knowledge, and (2) support strategies, which allow the primary strategies to operate effectively and efficiently, such as skills for concentrating in the presence of distractions, fatigue, and the like (Dansereau, 1978). Primary strategies also include elaboration skills, by which "learners use a symbolic construction to add meaning to information they must learn" (Weinstein, 1978). Elaboration skills include such activities as forming a mental image, paraphrasing, drawing inferences, and relating material to previous knowledge. The use of analogies would fall into this category of cognitive strategies.

With respect to both *organization* and *retrieval*, cognitive strategies (or memory skills in this case) include a variety of activities that can be performed *during* acquisition: forcing greater depth, or spread, of processing (e.g., by paraphrasing), creating additional links within one's memory (e.g., by relating the new knowledge to previous knowledge), creating important links among ideas already within one's memory (e.g., by taxonomizing), forcing dual encoding (e.g., by creating images, Levin, 1973), and using various other mnemonic techniques (e.g., the peg word method). (See e.g., Craik and Tulving, 1975; Lindsay and Norman, 1977; Dansereau, 1978; Rigney, 1978; Weinstein, 1978.) It is also likely that memory skills include activities which can be performed *after* acquisition: activities to improve retention (e.g., by refreshing memory) and activities to find or reconstruct information at the time of retrieval.

Cognitive strategies can clearly help a learner to better acquire, organize, and retrieve new knowledge, especially in situations where instruction is poorly designed (O'Neil, 1978, 1979).

SUMMARY

We have described seven kinds of knowledge that can be used to facilitate the acquisition, organization, and retrieval of new knowledge: (1) *arbitrarily* meaningful knowledge, (2) a *superordinate* idea, (3) a *coordinate* idea, (4) a *subordinate* idea, (5) knowledge of *instances* (experiential knowledge), (6) an *analogic* idea, and (7) a *cognitive strategy*; and there may well be additional kinds of knowledge to serve the same purposes. In the next section of this paper we will describe some instructional strategies which an instructional designer or teacher can use to help optimize the learner's use of each of these kinds of prior knowledge to acquire, organize, and retrieve new knowledge.

Instructional Strategies

Given that the above-described kinds of prior knowledge can be used to greatly facilitate acquisition, organization, and retrieval of new knowledge, then models and theories of instruction should prescribe optimal strategies (or events of instruction) for making use of any such prior knowledge. Of course, any given learner may not already possess all of these kinds of prior knowledge for each piece of knowledge that is to be learned. This possibility must also be taken into account by models and theories of instruction.

Most models and theories of instruction incorporate strategy components for taking advantage of one or two of these seven kinds of prior knowledge during the instructional process (see e.g., Bruner, 1960; Ausubel, 1968; Aronson and Briggs, 1983; Collins and Stevens, 1983; Gropper, 1983a; Landa, 1983; Scandura, 1983). However, there are very few that prescribe strategies for taking advantage of *all* of these kinds of prior knowledge. This is because relatively few instructional theorists have attempted to systematically integrate the work of others into their theories or models. Because Instructional Science is such a young discipline, it has generated much *piecemeal knowledge* about methods for optimizing desired instructional outcomes. Recently, several investigators have argued that what is needed most at this point in the development of Instructional Science is to build a *common knowledge base* that integrates knowledge from all theoretical perspectives (Gropper, 1983b; Reigeluth, 1983).

Two concerted, systematic attempts have been initiated to integrate knowledge from all theoretical perspectives (e.g., behavioral, cognitive, humanistic) and all related disciplines (e.g., learning theory, cognitive theory, communication theory, motivation theory, and epistemology). These two complementary (i.e., non-overlapping) instructional theories – the Elaboration Theory of Instruction (Reigeluth and Stein, 1983) and the Component Display Theory (Merrill, 1983) – have integrated strategies for utilizing all seven kinds of prior knowledge described above. Hence, many of the instructional strategies described below are taken from these two theories. (It should be noted that these two instructional theories also include many important strategy components in addition to those that are intended to relate new knowledge to prior knowledge.)

MNEMONICS

Mnemonics are simple arbitrary memory aids of various kinds that are provided in, or activated by, the instruction. Some mnemonics are totally unrelated to prior knowledge of the learner, such as rhymes (e.g., Thirty days have September, . . .). However, other kinds of mnemonics serve to facilitate memory by arbitrarily relating new knowledge to meaningful knowledge that the learner already has. Such mnemonics include the *method of places*, whereby items on a list are associated by imagery with geographical places along a familiar route, the *method of key words* (or peg words), whereby each of the items on the list is associated by imagery with such key words as bun (one), shoe (two), tree (three), etc., the *story method*, whereby each of the items is associated in a fairly natural way with aspects of a story that is invented to facilitate such associations, and the *first letter method*, whereby the first letter of each item is combined with the other first letters to form a meaningful word or phrase (such as "Every Good Boy Does Fine" to remember the order of the notes on the scale: EGBDF). For examples of each of these kinds of mnemonics see Dansereau (1978), pp. 5–6, and Lindsay and Norman (1977), pp. 359–364.

Mnemonics represent a valuable instructional strategy for relating rote, or non-meaningful, knowledge on the remember level to prior meaningful knowledge (Craik and Lockhart, 1972). Although the relationship is "arbitrary" (i.e., it is not a semantic relationship), it is still a very powerful way to facilitate retention (Pressley et al., 1981).

GENERAL-TO-DETAILED SEQUENCING

A general-to-detailed sequence is simply one in which superordinate knowledge is taught first – no idea is taught before its superordinate idea has been taught (unless its superordinate idea is already known). In this manner, superordinate knowledge will always be prior knowledge, so it will always be possible to relate new knowledge to superordinate knowledge. General-to-detailed sequencing does not *explicitly* relate the two – it merely makes it possible to relate the two.

Ausubel's subsumptive sequence is one kind of general-to-detailed sequence. Other kinds include Norman's (1972, 1973) notion of "web learning," Bruner's (1960) notion of a "spiral curriculum," and the Reigeluth–Merrill notion of an "elaboration" sequence (Reigeluth et al., 1980; Reigeluth and Stein, 1983). The Elaboration Theory's prescription for a general-to-detailed sequence differs in several important ways from Ausubel's (Reigeluth, 1979). First, the subsumer does not need to be, and in fact should not be, more *abstract* than the new idea. "Resistor" is no more abstract than "rheostat". The law of supply and demand is no more abstract than the principle of profit maximization. And the procedure for subtraction without borrowing is no more abstract than the procedure for subtraction with borrowing. Second, neither should the way in which an idea is presented be more abstract. Rather than presenting a *generality* alone (which is abstract by nature), instruction in the superordinate idea should include *examples* showing the application of the generality to specific instances and *practice* in applying the generality to new instances, as well as the generality (Merrill, 1983; Merrill et al., 1979).

A second difference from Ausubel's subsumptive sequence is that the Elaboration Theory provides *precise guidelines* for creating its general-to-detailed sequence (e.g., see Reigeluth, Merrill, Wilson and Spiller, 1978; Reigeluth and Rodgers, 1980; Reigeluth and Darwazeh, 1982; Sari and Reigeluth, 1982). A third difference is that some advance organizers *summarize* the content that is to be learned rather than *epitomizing* it. Epitomizing differs from summarizing in two important ways: epitomizing involves teaching (1) a small number of ideas, (2) at the application level, whereas summarizing entails touching lightly on a large number of ideas at an abstract, remember level (Reigeluth and Stein, 1983).

SYNTHESIZERS

A synthesizer is a strategy component that shows relationships among concepts, principles, or procedures – that is, it shows the logical structure of knowledge – in an attempt to create an isomorphic psychological structure (Ausubel, 1964). Very little guidance exists in the literature about how best to teach such relationships. According to the Elaboration Theory, there are a variety of types of synthesizers (Reigeluth and Stein, 1983). Some show superordinate, coordinate, and subordinate relationships among ideas (see Fig. 3 above), others show linear or branching chains of "change relationships" (i.e., principles) in the form of theoretical models, and still others show linear or branching chains of "purposive actions" (i.e., procedures) in the form of procedural models or procedural hierarchies (not to be confused with learning hierarchies). Hence, this strategy component can *make explicit* the relationships between a new idea and its superordinate, coordinate, and subordinate ideas. The Elaboration Theory calls for presenting (1) a simplified version of the synthesizer for a lesson *before* the lesson, and (2) a complete version of the synthesizer *after* the lesson.

INSTANCES

Instances are specific cases to which a generality can be applied. They may be examples of a concept, demonstrations of a procedure, or applications of a principle. An instance may be given to the student in the form of an *example*, which explains how the generality applies to the instance, or in the form of a *practice item*, which requires the student to apply the generality to the instance. Also, noninstances may be given to the student, either in the expository mode (as nonexamples) or in the inquisitory mode (as "distractor" practice items). Hence, an instance may be an expository example, an expository nonexample, an inquisitory example, or an inquisitory nonexample (see Fig. 5 for examples of each). Either way, since all four kinds of instances are specific cases, they are stored in a person's experiential data base and serve as knowledge to which ideas can be related in order to help make them meaningful.

Depending on the required richness of the instruction, Merrill's (1983; Merrill et al., 1979) Component Display Theory calls for the presentation of all four kinds of instances along with each generality. Examples and practice with feedback serve to provide links between a generality in semantic memory and instances (of that generality) in the experiential data base. Also "matched" nonexamples – nonexamples that are as similar as possible to examples – help the learner to compare and contrast the new idea with highly similar coordinate ideas.

ANALOGIES

An analogy is a strategy component which serves to make new knowledge familiar by relating it to highly similar knowledge outside of the immediate content area of interest. Ideally, the learner will already be familiar with the analogy. However, if the analogy is unfamiliar to the learner but is relatively easy to learn, then teaching it before teaching the new knowledge will save more student time and effort than it will cost. Analogies should be used most often

EXPOSITORY EXAMPLES	EXPOSITORY NONEXAMPLES	INQUISITORY EXAMPLES	INQUISITORY NONEXAMPLES
1. $3x^2-2=0$ is a quadratic equation.	$3x-2=0$ is not a quadratic equation	Is $3x^2+3x-2=0$ a quadratic equation?	Is $2x^3+2x-3=0$ a quadratic equation?
2. In the following sentence, "fast" is an adjective:	In the following sentence "fast" is not an adjective:	If there is an adjective in the following sentence, underline it:	If there is an adjective in the following sentence, underline it:
Sally is a fast runner	Sally runs fast.	Sally looks pretty.	Sally looks quickly.

Fig. 5. Examples of four kinds of instances.

when the same analogy facilitates the learning of more than one concept, principle, or rule. For example, in the hydrology–electricity analogy mentioned above, water is analogous to electrons, a water valve is analogous to a resistor, electromotive force (or voltage) is analogous to water pressure, water flow is analogous to electric current, and the principles specifying change relations among electromotive force (or water pressure), current (or flow), and resistance (or valve closure) are also analogous.

An analogy should be described (either to activate it or to teach it) *before* the new knowledge is taught, and references to the analogy should be made at various times *during* the lesson (Raven and Cole, 1978). Also, it is important to point out aspects where the analogy breaks down so as to avoid overgeneralization from the analogy to the new knowledge (e.g., a power supply does not work the same way as a pump works). Sometimes Ausubel's comparative advance organizers have been analogies (coordinate ideas outside of the content area of interest).

COGNITIVE STRATEGY ACTIVATORS

A cognitive strategy activator can be activated in either of two basic ways (Rigney, 1978): (1) by designing the instruction in such a way that the learner is forced to use it (called an "embedded" strategy), in which case the learner is often unaware that he or she is using it, or (2) by telling the learner to use it (called a "detached" strategy), in which case the learner has to have already learned how to use it. A *detached activator* tells the learner to use a certain cognitive strategy, such as "Now draw a diagram showing the processes just described," or "Think of an analogy," or "Create an image of what was just described," or "Think up a mnemonic to help you remember this." An *embedded activator* forces the learner to use a given cognitive strategy and therefore makes the learning considerably easier for the learner. Embedded activators include pictures, diagrams, mnemonics, and analogies. Adjunct questions (Rothkopf, 1976) are intended to serve a similar purpose, and they are usually embedded activators (although occasionally they are detached).

Since learners frequently have not learned how to use most cognitive strategies, those strategies must usually be *taught* before detached activators can be effective (Crouse and Idstein, 1972; Bernstein, 1973; Frase and Schwartz, 1975; Owens, 1977). However, it is not necessary for all learners to have learned a cognitive strategy in order for its corresponding detached activator to improve the quality of the instruction. In fact, since such an activator is so short a piece of the instruction, it may be cost-effective to include it even if just a few students can benefit from it.

Figure 6 summarizes the above-described kinds of instructional strategies for making use of the seven kinds of prior knowledge shown in Fig. 1.

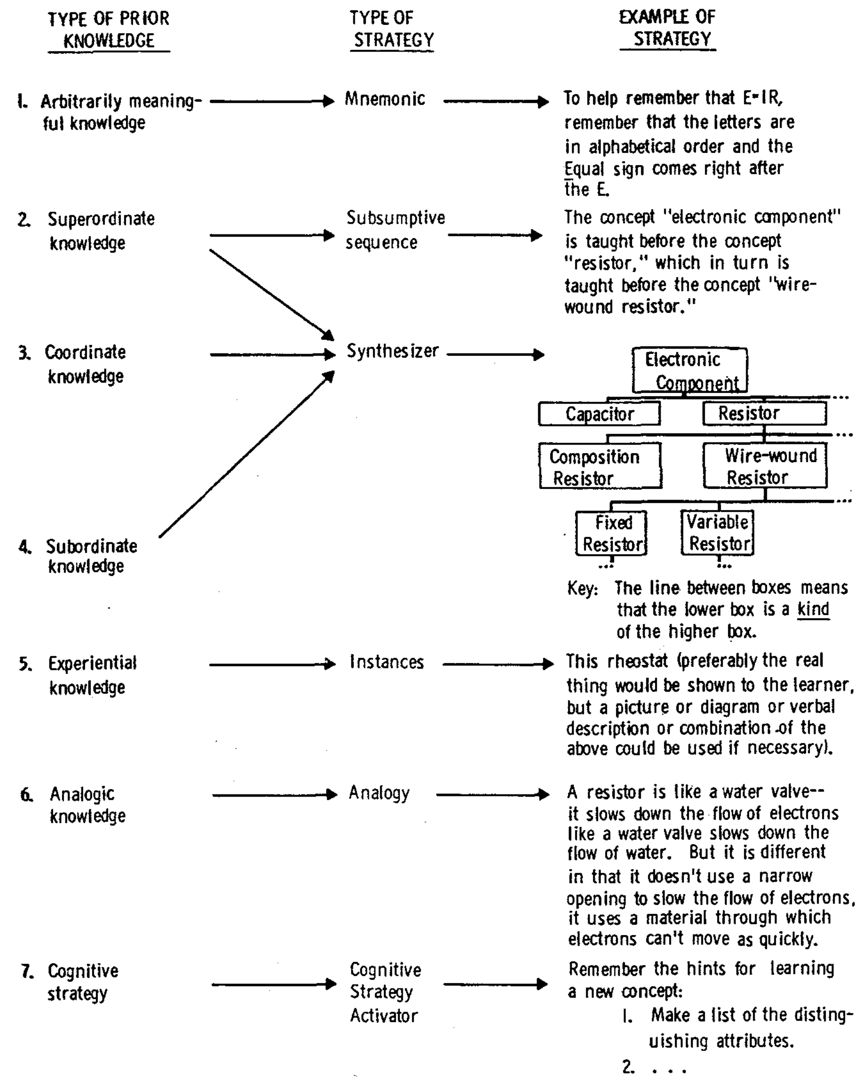


Fig. 6. Several kinds of instructional strategies for making use of the seven kinds of prior knowledge shown in Fig. 1.

SUMMARY

Any comprehensive theory of instruction must include ways to optimize the acquisition, organization, and retrieval of new knowledge. An important concern in this regard is making new knowledge meaningful by relating it to prior knowledge. Although meaningfulness is usually thought of in terms of relating new knowledge to prior *superordinate* knowledge (as with the advance organizer), there are at least six other kinds of prior knowledge that can facilitate the acquisition, organization, and retrieval of new knowledge: *coordinate* knowledge, *subordinate* knowledge, *experiential* knowledge, *arbitrary* knowledge, *analogic* knowledge, and *cognitive strategies* (see Fig. 1).

Any theory of instruction that is intended to be at all comprehensive should prescribe strategies for making optimal use of these seven kinds of prior knowledge. Such strategies might include the following: mnemonics, general-to-detailed sequencing, synthesizers, instances, analogies, and cognitive strategy activators (see Fig. 5). Mayer (1979) points out that it is not always helpful to use advance organizers. The same may be true of many of the above-described strategies, and an instructional theory's prescriptions should take this into account.

It is important to keep in mind that relating new knowledge to prior knowledge is only one of several important concerns of instructional theories and models. Other kinds of concerns include: motivating the learner, focusing his or her attention on important aspects of the instruction, facilitating dual encoding, providing appropriate kinds of information to effect an appropriate level of cognitive processing that will result in the desired level of student behavior, and providing a variety of other kinds of instructional support (e.g., shaping and systematic review). Each of these other kinds of concerns should be incorporated into any comprehensive instructional theory in the form of prescriptions for when to use appropriate strategy components for each.

Some efforts have been (and continue to be) made to integrate this broad spectrum of concerns by combining strategy components from diverse theoretical perspectives into "optimal" models of instruction for different goals and conditions, and by developing useful bases for prescribing when to use each of these models (see e.g., Reigeluth, 1983, for a sample of major integrative efforts). Although progress has been made, much work remains to be done by many investigators to help build a common knowledge base in instruction – a complete and comprehensive instructional theory that will indeed prescribe optimal models of instruction for diverse sets of goals, students, content, and institutional constraints.

Notes

1 We believe this statement holds only for knowledge that is acquired at the remember level in Merrill's taxonomy.

2 A CONCEPT is a *set* of examples (objects, events, or symbols) that share some *common characteristics*. To decide if an idea is a concept, ask yourself if one can *classify* examples as belonging or not belonging to a set.

3 A PRINCIPLE indicates how a *change* in something is related to a *change* in something else. It is usually a cause-and-effect relationship that is expressed with the words "if . . . then . . . ," "explain," "predict," "cause," "effect," "results," "because," "why," etc.

4 A RULE is an ordered set of *actions* that are intended to achieve a *goal*. Synonyms include technique, skill, method, and procedure. To decide if an idea is a rule, (1) see if there is a *goal* and (2) see if there is an ordered set of *operations* (physical or mental) for achieving it.

5 Parts-subordinate ideas play an important role primarily with respect to learning prerequisites for an idea (Gagné, 1977). For more about that role, see Reigeluth, Merrill and Bunderson (1978) and Reigeluth et al. (1980).

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