Changes in Instructional Development: The Aftermath of an Information Processing Takeover in Psychology

William C. Low
Instructional Developer
Instructional Design and Development
Park Library, 102
Central Michigan University
Mount Pleasant, MI 48859

EDITOR'S NOTE

At the 1978 AERA Convention, a panel of experts in the fields of learning and instruction "officially" announced the fall from favor of the mechanistic, black-box approach of behaviorism, and the rise to favor of the cognitive approach to learning—with its emphasis on what occurs inside the learner's head during the learning process.

One of the speakers indicated that this shift from behaviorism to cognitivism would have a profound impact on instructional development—to the point that there would be very little new in the field of ID for several years. He argued that because ID was based on the behavioristic learning model, it would take a while for ID to shift gears, to find a scientific grounding in cognitive learning theory, and to derive useful design principles from cognitive theory.

While instructional developers knew about, wrote about, and used cognitive learning theory even before this "official pronouncement" (see, for example, Wilson's article in *JID*, *1*(2), spring 1978), and while *JID* is willing to leave it to its readers to decide how stagnant the ID field has been for the last 2 years, it did seem that a systematic and extensive analysis of the implications of cognitive psychology for ID had been missing.

And then, simultaneously, two excellent manuscripts discussing this very topic arrived at *JID*. Though they are similar in some respects, they are quite different in their orientations and emphases. Because of these differences, the excellence of the articles, and the importance of the topic, *JID* decided to publish both articles—one in this issue, and one in the spring issue.

The Low article, which appears here, explains cognitive learning theory in a concrete manner, using examples to illustrate its principles, and then provides a set of implications which seem to be oriented to a direct translation of these principles into the tasks an instructional developer performs.

The second article, by Wildman and Burton (to be published in the spring), explains cognitive learning theory in a more abstract, theoretical manner, and derives implications in the form of a set of questions which will probably be of more interest to those involved in theory, research, and teaching of ID.

Whether or not you, as a reader, agree with this distinction between the two articles, we are sure you will find reading *both* of them an important and enlightening experience. We also believe that they will set you to thinking about how ID is already changing, and must change in the future, as its learning theory base grows and changes.

Abstract. The characteristics of instructional development are determined in part by assumptions about learning drawn from psychology. If psychologists change those assumptions how will instructional development change? In particular, if instructional developers were to adopt the assumptions represented in information processing and schemata representation approaches to learning, how would testing, objectives, instructional strategies, instructional taxonomies, and analysis be affected? Each of these components would still be useful, it was concluded, but their nature would change substantially in almost every case.

If the basic postulates of learning psychology eventually prove unfruitful will instructional development wither? In other words, is instructional development merely an application of learning psychology that rises or falls with it? Or is instructional development independent—an enterprise in and of itself—able to exchange certain concepts and findings from the behaviorist tradition any time a more effective set becomes available?

The questions posed are not purely academic. Instructional development grew up in the 1960s with strong ties to the behaviorist tradition. In the 1970s developers have been out in the universities, industries, and armed services applying this new profession. Psychologists, meanwhile, have not been extending and refining learning theory to any great extent. Rather, they have been leaving their rat labs in droves to tinker with computers, hobnob with linguists, and muse over complex information processing in humans. The major thrust of work in psychology in the past few years has been in cognitive psychology (e.g., Glaser, 1978).

The time has come to identify what might result in instructional development if psychology leaves the behaviorist tradition by the wayside. Three major possibilities come quickly to mind. It may simply mean the demise of instructional development. Or it may mean that the behaviorist tradition will be kept alive in instructional development and that we will continue with business as usual. We would then be similar to lens makers who find the classical optics of the 1800s quite sufficient for the grinding of good lenses although physics, with the advent of the theory of relativity, has taken a whole new direction in the study of light. The third possibility is that instructional development may be able to live as comfortably with cognitive psychology as it has with the behaviorist tradition.

The purpose of this paper is to examine the third possibility and, in particular, the implications cognitive psychology holds for some of the most fundamental components of instructional development—objectives, evaluation, instructional taxonomies, content analysis, and instructional strategies. First it is necessary to establish, at least in a general way, the type of science that instructional development is and how it relates to psychology.

Simon (1969) speaks of two types of sciences: natural science and design science. The role of natural science is to discover order and pattern in phenomena, to better understand our world and the creatures that inhabit it. The usefulness of the pattern or law is of secondary importance. Of primary importance is the discovery of what there is and how it works. Basic physics, chemistry, and biology are natural sciences. The role of the other type of science, design science, is the synthesis of useful products. Engineering, architecture, and medicine are design sciences.

Design scientists draw insight from the findings of natural scientists; that insight influences the product. Consider, for instance, the changes in the design of electronic devices over the past 30 years that have resulted from an increased understanding of basic electronics—a case of electrical engineering drawing insight from basic physics. However, insight provided by the basic science is not the sole determiner of the product. The use to which the product is put will dictate some of its characteristics, and if the use remains the same then some of the basic characteristics will still be necessary. For instance, the design of the modern radio, in spite of changes in our knowledge of electronics, must still incorporate many of the functions of its 1930 counterpart. It must have a means of receiving radio waves, of selecting the wave length to receive, of amplifying electronic impulses, and of converting these into sound waves. Thus, as long as the need for a component of a design science exists (e.g., electronic amplifier) that component will remain, although the means of producing the component may be modified as progress is made in the natural sciences.

Instructional development is more akin to a design science than to a natural science. Its purpose is the synthesis of useful educational products rather than the search for fundamental laws of human cognition and learning. In the synthesis of their products, instructional developers have drawn insight from basic psychology.[1] But the characteristics of the instructional developer's products are dictated not only by this insight but by the use to which the product is to be put. Thus, as new insights are gained from basic psychology we might expect changes in the nature of some components of the instructional development process; we might also expect that those components would still be present as long as a need for them persists. How components might change in the light of recent work in psychology is the theme of this paper.

What Are Cognitive Psychologists Studying?

Two areas of work in cognitive psychology have potential impact upon instructional development: The development of information processing models of knowledge acquisition and the use of schemata to describe the organization of knowledge. Both will be described briefly here. For more extensive discussion see, for example, Anderson, 1977; Atkinson & Shiffrin, 1968; and Lindsay & Norman, 1972.

Basic differences between the behavioral approach and the information processing approach begin with how a learning event is described and what is presumed to be important. In behavioral psychology learning is described in terms of observable responses; these responses are presumed to result from certain stimulus situations. It is presumed that any learning event, even a very complex one, may be described entirely by relating sets of stimuli to responses. Any descriptions of internal events are avoided.

In an information processing approach the internal, covert events are seen as of prime importance. Because by their nature these events are not observable, no one knows exactly what they are like and the best that can be done is to attempt to model them.

[1]This is not meant to imply that psychology is the only area from which instructional development has drawn. Systems theory, for instance, is another. This paper, however, is limited to examination of the ties between psychology and instructional development and the results of changes in the former upon the latter.

This is not a unique approach in science—physicists followed the same path in attempting to describe the nature of matter. It was postulated that matter was composed of minute particles—atoms—too small to be directly observable. Later, models were proposed to describe the nature of the atom itself. These evolved from early planetary models (i.e., an atom is like a miniature solar system) to modern quantum mechanical models that are more mathematical than visual in their description.

Borrowing concepts about how computers process information, psychologists have developed information processing models of cognition. The main features of most models are a working memory or short-term memory of limited capacity, and a long-term storage of very large capacity. (See for instance Atkinson & Shiffrin, 1968; Lindsay & Norman, 1972.) A frequent example of working memory involves retention of a telephone number from the time when it is read until it is dialed. The number of digits (about seven) and the amount of time they can be retained (a few seconds without rehearsal) is limited.

Long-term storage is evidenced by, for example, trying to remember the events of last Christmas. The items of information are not immediately present in working memory but after some searching the events are recalled—they become activated in working memory. A major area of work with these modes is to determine how information is transferred back and forth between short-term and long-term memory—storage and retrieval.

The test of a model, of course, is whether it explains anything. We have already seen how it might explain why short numbers (e.g., phone numbers) are easier to retain momentarily than long numbers (e.g., social security numbers). But can it explain anything else? As might be expected, psychologists have been applying the model to a variety of situations in an attempt to explain what can be observed in learning processes. Only one of these attempts will be described here, the attempt to model the subjective experience called comprehension or understanding. This one is chosen not only because of its potential importance to instruction (knowing what makes the difference between students comprehending or not comprehending instructional materials should be of some use to developers) but because it leads us to the notion of schemata.

Consider the following four sentences taken from Bransford and McCarrell (1974):

1. The office was cool because the windows were closed.

2. The car was moved because he had no change.

3. The trip was not delayed because the bottle shattered.

4. The haystack was important because the cloth ripped.

Your subjective experience in reading the first two is probably somewhat different than in reading the last two. The first two seem to "make sense," but the last two do not—even though you can probably define all the words in the last two. Now think of a ship being christened and reread sentence 3. Then think of a parachutist and reread sentence 4.

An information processing model may be used to account for the experience: When information enters working memory (short-term storage) a context that may account for the information is selected from long-term storage. If there is a good match between incoming information and context then comprehension has occurred. For instance, most of us have a context or set of conditions and situations related to parking lots and parking meters. When reading the second sentence, we hypothesize that this is a parking meter context or situation. That context is brought to bear upon the information, and the features of the sentence seem to match enough of the features of a parking meter context that we are confident that we understand. All of this happens so quickly and effortlessly that we are unaware of it until we come up against sentences like numbers 3 or 4. Here there doesn't seem to be enough information to guide us in the selection of an appropriate context. When we see the word parachutist in conjunction with sentence 4 we have a clue to the context, and comprehension occurs. Lindsay and Norman (1972) explain the process in considerably more detail.

If this model is correct, some interesting implications for comprehension result. First, comprehension is dependent upon material in long-term memory storage. If an appropriate context is not present, comprehension doesn't occur. This occurs frequently during instruction—it is often called talking over the students' heads. Second, comprehension is an active process. It is a continual checking of the data against the hypothesized context—a sort of goodness-of-fit test. It is a form of hypothesis testing considered by many a type of problem solving.

The way information is structured in memory seems to be important in comprehension. It is evidently necessary to retrieve an entire context—at times a very large group of items with complex interrelationships—in order to comprehend. One does not just retrieve a simple association for each word in the sentence and somehow add those associations up. If that were the case, it would be easy to understand sentences 3 and 4 above at first reading.

Psychologists have chosen to call these contexts *schemata* (some call them *frames* or *scripts*), a usage borrowed from Kant, Bartlet, and Piaget. Simply, a schema is a semantic network that describes several concepts and/or events and how they are related.

Perhaps an example will make the concept of schema more understandable. Most of us possess a set of items and events in memory related to a trip to the grocery store. This grocery store schema contains such knowledge as what items may be located in the dairy products section, the bakery, and the deli; the usefulness of a cart when several items are to be purchased; how to choose the most promising line at the checkout counter; and the sequence of events that relate to going through the checkout. Because of this schema we know what to do if we are told, "Pick up a gallon of milk at the grocery store." We do not need to be told in detail every step to take from the "In" door to the "Out" door.

Many will undoubtedly consider the constructs presented here too fuzzy and unscientific, and will opt for a return to measurable responses and associated stimuli. Psychologists, however, have not abandoned the measurement of responses. From models, one generates hypotheses that can be tested in observable, measurable ways. The models stand only so long as those hypotheses continue to be confirmed. So far, the constructs discussed here have withstood those tests. Nor need we be unduly rigid as to what a model should be. Simon (1978) noted that:

> We are so accustomed to taking Newton's Laws of Motion as a model of what a theory should look like—or Maxwell's equations, or quantum mechanics—that it is worth reminding ourselves that a large number of important scientific theories do not resemble those in form. Instead, they consist of qualitative statements about the fundamental structure of some set of phenomena (Newell & Simon, 1976). An excellent example is the germ theory of disease, which, as announced by Pasteur, amounted to the following: If you encounter a disease, especially one that spreads rapidly, look for a microorganism. Darwinian evolution is another example, as are the tectonic plate theory of continental drift, the atomic theory of matter, and the cell theory. Sometimes, laws of qualitative structure are later expanded into quantitative theories, sometimes they are not. (p. 273)

With that brief introduction, let's go to the task at hand. If an instructional developer shifts orientation from the behaviorist tradition to information processing and schemata concepts, what will change in the way instructional development is done? If one stops assuming that students learn responses and starts assuming that students learn information, then what will become of objectives, test items, instructional taxonomies, learning strategies, and content analysis in instructional development?

Instructional Objectives

Objectives are descriptions of the intended outcomes of instruction. If the outcomes of instruction are responses (as the behaviorist believes) then objectives should describe those responses—they should be behavioral. If the outcome of instruction is knowledge (as almost everyone believes) then objectives should describe or model in some way that knowledge.

From within the behaviorist tradition, Mager (1962) has given a good prescription for writing objectives. No such simple prescription is available for describing outcomes in information processing terms; however, Greeno (1976) provides some examples of what such descriptions look like. They have the appearance of flowcharts like those used in the preparation of computer programs, or of network representations of complex semantic relationships. For example, Figure 1 is an adaptation

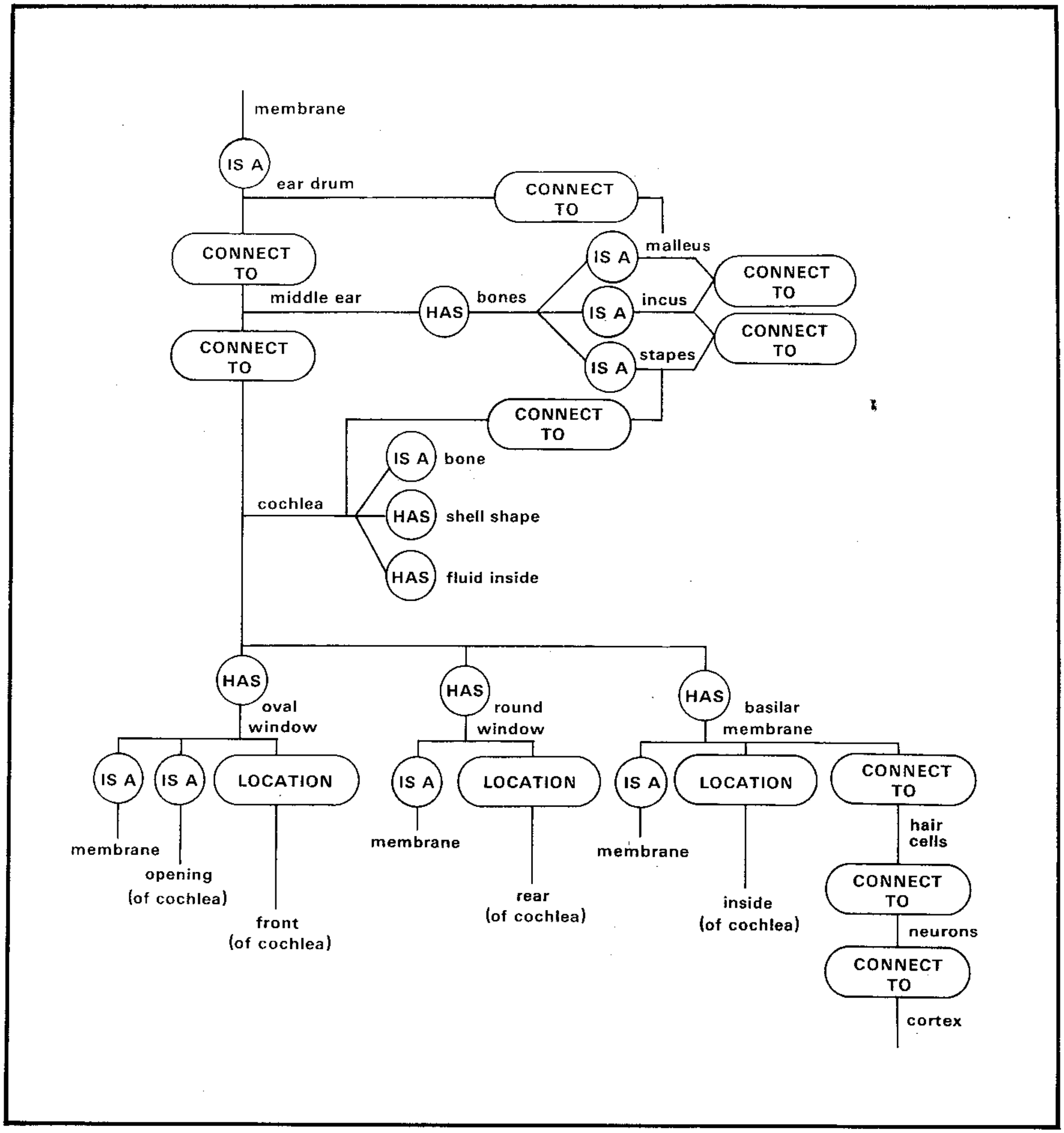


FIGURE 1. Network for anatomy of hearing (adapted from Greeno, 1976).

from Greeno (1976) showing a network on the anatomy of hearing. Such flowcharts are more complex than the typical behavioral objective.

If instruction's goal is for the student to obtain certain knowledge, then a description of the content and structure of that knowledge should be quite useful to anyone helping the student (e.g., an instructional developer). From that description the developer can infer the elements of instruction. Behavioral objectives, on the other hand, aid only in testing the student—the developer must decide how a student would be led to successful test completion. Similarly, a carpenter finds a detailed description (blueprint) of a structure much more helpful in day-to-day work than a description of criteria by which the completed structure is judged adequate.

Consider an example. The topic of instruction is simultaneous equations; a behavioral objective might be the following:

> Given 10 sets of simultaneous equations (none with more than 3 unknowns) write the correct value of each unknown in at least 8 sets.

In developing instruction for this objective does the developer have the student practice writing solutions? Probably not. Instead, the developer makes assumptions about the knowledge that the student must have in order to solve the equation. Thus, the instructional materials are full of computational algorithms and relationships—exactly the things information processing people talk about—presumed necessary to enable students to generate the appropriate responses.

If instructional developers find it necessary to address students as though they had minds and knowledge, then they should find it useful to work from descriptions of the desired states of knowledge.

All this does not mean that behavioral objectives are of no use. Where the outcome of instruction is a specific set of behavioral responses, the behavioral objective may still be the most appropriate form of expression. Nor does all this mean the abandonment of measuring the attainment of objectives. The attainment of the type of cognitive objectives described here can be measured. The simple difference is that the objective need no longer be just a description of a test. (Essentially, that's what a Mager objective is.)

Instructional Taxonomies

An important part of the instructional development process has been the classification of objectives according to one taxonomy or another. Of the taxonomies that are based upon experimental work in behavioral psychology, Gagné's (1970) is the most widely used. It has been so useful because its classes correspond to clusters of experimental research (e.g., research on pair associates, concepts, problem solving). Thus, if an instructional developer can classify an objective in one of the classes, the relevant behavioral research can be brought to bear.

A taxonomy based upon research in information processing is not currently available. Learning is viewed as the storage of information. If two tasks are different, it is because the content and structure of the information are different. From a behaviorist point of view, if one student responds with a memorized definition (verbal chain) and another responds by correctly selecting examples (classification) after studying the same topic, then different classes of learning have occurred. From an information processing point of view, the learning process is essentially the same; it's just that each student is selected to store different information. So, until someone demonstrates that it is worthwhile to classify information on some basis, there will be no taxonomy.

It is clear that a developer does not use the same instructional approach for every task. A behaviorally based taxonomy seems consistent with that since different types of learning suggest different approaches. An information processing approach accounts in a different way for differences in instruction between tasks. The instruction must somehow relate the content and structure of the information to be stored with that which is already stored. Because the content and structure differ from task to task and from student to student, differences in approach are required.

For example, suppose the topic is even numbers. Taking a behaviorist approach, the task may be classified as a concept and structured as follows: Research has demonstrated that concepts may be taught by presenting a definition and a series of examples; so this is a possible approach. Using an information processing approach might result in the following structure: The students have a very large set of digits stored already. If they can be given some sort of algorithm or other definition for determining when something is an even number, and a set of examples to clarify the definition, then they should know what an even number is. Notice that in terms of instruction, both orientations result in the same approach.

In teaching odd numbers, from a behavioral orientation the process described above (definition and examples) could be repeated. From the other orientation, it might be reasoned that because the students now know what all the even digits are, they can learn what odd digits are simply by being told they are not even. For some situations both orientations might yield the same instructional approach; in other situations they may not.

Although there is no taxonomy as yet, information processing does not exclude the possibility of different types of information processing. Tulving (1972) speaks of episodic and semantic memory. Episodic memory is memory of episodes or facts (for example, remembering a birth date or remembering that particular canyon is an example of the geological concept of a youthful valley). Semantic memory, on the other hand pertains to information that has been generalized beyond specific instances (for example, methods of solving all algebra problems of a particular class).

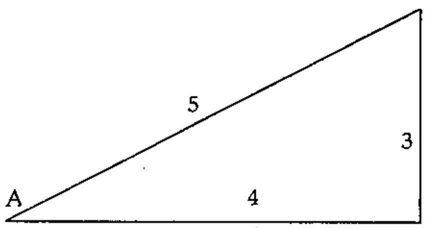
A problem often encountered in teaching involves students who try to incorporate into episodic memory information that should be in semantic memory. Trying to memorize a few specific solutions to problems rather than storing the solution process is an example. Those who have worked on instruction from the perspective of Gagné's taxonomy will probably recognize these as new terms for familiar ideas.

Test Item Construction

When behavioral objectives are used the test item (or set of items) becomes the direct evidence of the attainment of the objective. When learning is defined in terms of information processing and schemata, performance on test items allows one to infer whether the appropriate schemata have been established. In that respect, the role of the test item is very similar in both approaches.

Some researchers who have described knowledge in terms of schemata have not only used test items to infer whether the schemata are established but to diagnose just what schema or algorithm the learner is using when responding incorrectly. McKnight (1979), for instance, detected "bugs" in algorithms used to multiply quadratic equations. In one example, he detected a "bug" in a girl's algorithm, and gave a simple explanation of what she was doing wrong. She was then able to do all other problems of the same class. Collins, Beranek, and Newman (1978) reported a similar, but more sophisticated approach—examining tests with a computer program for particular algorithmic errors. Brown and Burton (1975) have developed a program that enables a student to try out ideas in a learning situation. The program critiques "current solution paths," generates alternative hypotheses, and in general helps the student to "debug" ideas.

This type of approach is reminiscent of the attempts at intrinsic or adaptive programing made a few years ago. One problem experienced with the intrinsic approach was deciding exactly what to do with the students who made errors. Often they were merely recycled through a more detailed explanation and given more examples. There were, however, some attempts similar to the information processing approaches described above. Consider an example given in Markle (1969, p. 190):



The tangent of angle A is:

.60 . . . . go to page 19
.75 . . . . go to page 6
.80 . . . . go to page 12

If the students apply the correct formula or algorithm they divide 3 by 4 and answer .75. It is quite easy to see how the two incorrect answers were derived (one by dividing 3 by 5 and one by dividing 4 by 5). Both are the result of applying algorithms similar to the correct one.

At the time intrinsic programing was introduced, it was argued that the student's response determined where the student was to go next. That is only partly true. It was the student's response coupled with the programer's hypothesis or model of what cognitive manipulations the learner went through to obtain that incorrect answer. This is very clear from the Markle example.

Information processing models hold some implications for another aspect of test construction—the writing of technically correct items. For years writers (e.g., Green, 1963) have produced guidelines for developing a correct item. Examples of such guidelines include making all choices in a multiple choice item grammatically consistent and avoiding patterns of responses. For true/false tests items should be entirely true or entirely false (not ambiguous) and trivial details should not make an item false. These rules—some 40 to 50 of them depending upon the author—seem to be derived from a mixture of experience and common sense. There is no mention of theoretical basis in the literature.

Greeno (1976) provided an information processing context for greatly simplifying these rules when he conceptualized testing in the following way:

> Some information resides in memory as a substructure of a person's knowledge. A question is asked, and the question contains components that match components of stored information. A person retrieves the pattern, including components that were not in the question, and the new retrieved components constitute an answer to the question. (p. 155)

By way of example consider the following questions:

1. In an internal combustion engine what part converts the straight-line motion of the pistons into the circular motion of the drive shaft?

2. The sum of a father's age and his son's age is 46. The difference in their ages is 28. How old is each?

In the first question, the student who has done his work well retrieves the complex of information about the mechanical workings of internal combustion engines. Part of that complex or schemata is the relationship between the piston and the crankshaft, and the crankshaft with the parts in the drive train. He knows that as the piston goes up and down it turns the crankshaft in a circular motion. Thus, the answer is crankshaft.

In the second question the student recognizes that there are two algebraic equations:

$$f + s = 46$$
$$f - s = 28$$

This is recognized as a set of simultaneous equations. Stored with the concept of simultaneous equations is a solution procedure. When applied it yields the correct ages (37 and 9).

In both cases the questions provide enough information for the student to retrieve the appropriate context or schema from long-term storage. The student retrieves the entire context, not just those particular elements in the question. If the student has done his work and the schema is complete enough then the needed information is present and the answer (or the path to the answer) is apparent.

If the preceding is a correct description of how a student comes up with an answer then the trick of testing is to have a student respond by use of the appropriate schema or pattern, and only the appropriate schema. To do this two general rules of test item construction become apparent. First, one must provide enough information to allow the student unambiguous selection of the appropriate schema; second, the item should be devoid of extraneous information that would allow the correct answer based upon something other than the appropriate schema.

Many of the rules provided in a work such as Green's (1963) may be conceptualized as specific instances of these two general rules. For instance, avoiding grammatical clues, patterns of answers, and implausible choices are specific means of preventing test takers from answering questions on some basis other than the appropriate schema. If a student discovers that the correct answer is always choice b, then he or she answers on that basis—a pattern schema—rather than upon the intended basis.

"The time has come to identify what might result in instructional development if psychology leaves the behaviorist tradition by the wayside."

Instructional Strategies

From a behaviorist point of view, it is the response that is learned. As a result early instructional development efforts stressed the importance of eliciting the correct response and reinforcing it—usually with feedback. With this general approach some rather specific guidelines for instructional strategies grew up: Divide instruction into small segments; have students respond at the end of the segment; structure the segment so that the student responds correctly, and so on.

No such specific guidelines for instruction have come out of the work in information processing. In fact, Glaser (1978) specifically cautions against such specific guidelines, at least at this time, and suggests that a "by the numbers" approach may never be appropriate. Thus, a formula for design cannot be presented. Instead some important cognitive processes will be discussed that may be used as a knowledge of map reading is used when taking a trip. Each trip is unique and must be considered by itself. However, being able to interpret maps enables one to sort out the more promising routes.

As mentioned earlier, a cognitive process of central importance is comprehension. Rumelhart and Ortony (1977) describe comprehension as selecting schemata that account for the stimulus material. They add:

> In this view, when a person uses a schema to comprehend some aspects of the situation, the schema constitutes a kind of theory about those aspects. Thus, in general, the process of comprehension can be regarded rather like the process a scientist goes through in testing a theory; evidence is sought which either tends to confirm it, or which leads to its rejection. Upon finding a theory which, to our satisfaction, accounts for the observations we have made, we feel that we understand the phenomenon in question. (p. 112)

If comprehension involves bringing to bear the appropriate schema or schemata to account for information, then one of the concerns in instructional design is to make material comprehensible in terms of the learner's existing schemata. This accounts for the emphasis in cognitive psychology upon introducing a general framework for the material to be learned (i.e., advance organizer) as a means of tying new information to old. It also accounts for the importance ascribed to metaphor (Ortony, 1975) as a means of integrating the new information into some existing schemata.

Rumelhart and Ortony (1977) have done some work on the creation of new schemata or the modifying of existing ones. They advance the concepts of schema generalization and specialization as two means of doing this. In schema specialization some variables of the schema are fixed or constrained to form a less abstract schema. Consider the youngster, for instance, who has a schema of attributes for the concept bird. In developing the new concept of bluejay many of the attributes of the bird schema are maintained but some of the attributes are constrained (e.g., size, color, head shape) so that they now define only the bluejay and no other bird. Schema generalization is the opposite of this.

Instructional guidelines based upon behavioristic concepts looked promising when the idea was new; it is only from a perspective of several years experience and research that they have waned in appeal. It is premature to say that information processing will provide anything better. However, there are at least two factors that suggest the potential for a longer-lasting influence upon the practice of instruction.

First, the studies in information processing almost always deal with learning tasks encountered in schools (Collins, 1977; Meyer, 1977). Thus, any insights gained through research should be easily applicable by instructional developers. Studies in behavioral psychology, on the other hand, usually involve tasks deliberately simplified beyond anything resembling school tasks and carried out on nonhuman subjects. As a result of this weakness in the behavioral approach, a finding such as backward chaining may originally be hailed as a great insight for instructional development but find very little application in educational settings.

Second, there is a body of literature from the late 1960s and early 1970s that demonstrates the tremendous power of appropriate schemata in the process of retention. These are the studies of mnemonic devices (see, for instance, Bower, 1970; Wood, 1967). What such a device does for a learner is to provide a schema or set of schemata for the integration of otherwise unrelated items of information, and its use results in substantial gains. If such gains can be made by the use of a somewhat artificial schema, then integration of information into a set of natural schemata in a cognitive discipline such as chemistry should be at least as impressive. This is congruent with our everyday experience. Chemists with well developed sets of schemata in a particular area of chemical research have little difficulty comprehending a research article in their areas and in remembering substantial detail from it. A novice takes longer to read it, understands less, and retains little. This seems to be what James (1891) was referring to when he wrote the following:

> Most men have a good memory for facts connected with their own pursuits. The college athlete who remains a dunce at his books will astonish you by his knowledge of men's "records" in various feats and games, and will be a walking dictionary of sporting statistics. The reason is that he is constantly going over these things in his mind, and comparing and making series of them. They form for him not so many odd facts, but a concept-system—so they stick. So the merchant remembers prices, the politician other politicians' speeches and votes, with a copiousness which amazes outsiders, but which the amount of thinking they bestow on these subjects easily explains. The great memory for facts which a Darwin and a Spencer reveal in their books, is not incompatible with the possession on their part of a brain with only a middling degree of physiological retentiveness. Let a man early in life set himself the task of verifying such a theory as that of evolution, and facts will soon cluster and cling to him like grapes to their stem. Their relations to the theory will hold them fast; and the more of these the mind is able to discern, the greater the erudition will become. Meanwhile the theorist may have little, if any, desultory memory. Unutilizable facts may be unnoted by him and forgotten as soon as heard. An ignorance almost as encyclopaedic as his erudition may coexist with the latter, and hide, as it were, in the interstices of its web. Those who have had much to do with scholars and "savants" will readily think of examples of the class of mind I mean.
>
> In a system, every fact is connected with every other by some thought-relation. The consequence is that every fact is retained by the combined suggestive power of all the other facts in the system, and forgetfulness is well-nigh impossible. (pp. 662-663)

Analysis

The most common approach to content analysis in instructional development is built upon Gagné's (1968) work with hierarchies of learning. Resnick (1976) provides a good, brief description:

> Learning hierarchies are nested sets of tasks in which positive transfer from simpler to more complex tasks is expected. The "simpler" tasks in a hierarchy are not just easier to learn than the more complex; they are in-

cluded in—components of—the more complex ones. Acquisition of a complex capability, then, is a matter of cumulation of capabilities through successive levels of complexity. Transfer occurs because of the inclusion of simpler tasks in the more complex. Thus, learning hierarchies embody a special version of a "common elements" theory of transfer. (p. 55)

In practice the more complex task would usually be described by the terminal objective and simpler tasks as the intermediate or supporting objectives. These intermediate objectives are usually discovered when one asks of the terminal objective: "What do the students need to be able to do before they can be expected to begin mastery of this objective?" The same question is then asked of the supporting objectives and so on until skills already possessed by the learner are reached.

In the behavioral approach described above, the relationships between responses are analyzed. In the information processing approaches to analysis less attention is given to the responses. Rather, attempts are made to describe or model the information and algorithms that must reside in memory before a student can accomplish a task.

The types of models used reflect the two disciplines that have contributed much to recent work in cognitive psychology—computer science (or, more specifically, artificial intelligence) and linguistics. Some models of cognitive processes remind one of computer programs. They are simple step-by-step descriptions of the algorithms sufficient to do the task. Some of Resnick's (1976) tasks are of this type.

The other models are logical networks with nodes representing concepts with lines and with other symbols, such as brackets, representing relations between the concepts. These may be very detailed descriptions of a sentence (e.g., Norman, Gentner, & Stevens, 1976; Rumelhart & Ortony, 1977) or much more global descriptions (Greeno, 1976; Merrill, 1973).

In information processing approaches to instructional development, analysis may well become the most important phase. Simon (1969) points this out with an analogy suggesting that we consider the path of an ant moving across a wavy beach. "He moves ahead, angles to the right to ease his climb up a steep dunelet, detours around a pebble, stops for a moment to exchange information with a compatriot. Thus he makes his weaving, halting way back to his home" (p. 23). Simon points out that if the ant's path were sketched it would have an overall direction but would be quite complex.

Simon then makes the following observation and hypothesis: The ant's path is not complex because the ant is a complex behaving system; rather, it is a reflection of the complexity of the beach. Similarly, man is relatively simple as a behaving system. "The apparent complexity of his behavior over time is largely a reflection of the complexity of the environment in which he finds himself" (p. 25). When a student concentrates upon a particular body of information (e.g., a chapter in a textbook) the complexity of the learning process (if we agree with Simon) is due to the complexity of the structure of the subject matter. Thus, if we can describe the subject matter and the starting point for the individual—the existing knowledge structure—we can account for the learning path.

Conclusion

The trend in psychological theory and research is to move away from behaviorism (see, for instance, Brewer, 1974; Weimer, 1974). At the same time there is considerable theoretical development and research on information processing and schemata. Instructional developers cannot view these events with disinterest because their profession has taken inspiration from behaviorism for many years. This paper has been an attempt to sort out major features of the instructional development approach that would probably change and a few advantages that might result if the profession were to change points of view and begin to look for insight from this recent movement.

Instructional development is a design science. As such, its methods are determined both by the use to which its products are put and the natural sciences from which it draws insight. It is not surprising, then, to find that the major elements of instructional development will persist even though behavioral psychology may not. However, the nature of these elements may well change.

"Instructional development is more akin to a design science than to a natural science. Its purpose is the synthesis of useful educational products rather than the search for fundamental laws of human cognition . . ."

Specifically, we may find that:

1. Careful analysis and the specification of objectives will continue to be an essential step in the development of effective instruction. However, the nature of cognitive objectives will change from the description of responses to the description of information networks or schemata.

2. Because there is no basis for a taxonomy as yet in an information processing approach, each learning task will need to be considered as more or less unique.

3. It will still be necessary to have students respond to test items in order to infer their mastery, but the inference in many cases will regard the adequacy of schemata.

4. Prerequisites will be defined in terms of the learner's existing schemata.

5. Advance organizers and metaphor will assume a new importance in instructional strategies; new strategies such as schema generalization and specialization will become common.

Implications for Instructional Developers

There is no denying that instructional development has been associated with the behavioral tradition in psychology (although that is not a necessary association). Because of old wars between cognitive and behavioral psychologists most instructional developers tend to think that an acceptance of anything cognitive amounts to a total abandonment of the instructional development process. This is not necessarily true. In fact, it is appropriate to view the shift of research to cognitive areas in psychology as having a positive effect upon instructional development processes. An information processing approach to instructional development would still use the same major steps (objectives, instructional strategies, and so on). From the behaviorist tradition, instructional developers have evolved means for effectively carrying out each of these steps. These means will always be effective no matter what direction research in psychology takes. At the same time, information processing provides an alternative means for carrying out each of the steps. It adds to rather than replaces the instructional developer's set of tools. And for the practicing developer, the more tools the better.

Thus, the instructional developer is in the favorable position of having a variety of tools from which to select; those that best fit the situation or the developer's personal preferences can be used. When (and if) psychological research definitely demonstrates that one conceptualization of the learning process is more fruitful than the others, then instructional development may consider the abandonment of a particular set of tools.

References

Anderson, R. C. The notion of schemata and the educational enterprise: General discussion of the conference. In R. C. Anderson, R. J. Spiro, & W. E. Montague (Eds.), *Schooling and the acquisition of knowledge*. Hillsdale, N. J.: Lawrence Erlbaum, 1977.

Atkinson, R. C., & Shiffrin, R. Human memory: A proposed system and its control processes. In K. W. Spence & J. T. Spence (Eds.), *The psychology of learning and motivation: Advances in research and theory* (Vol. 2). New York: Academic Press, 1968.

Bower, G. H. Analysis of a mnemonic device. *American Scientist*, 1970, *58*, 496-510.

Bransford, J. D., & McCarrell, N. S. A sketch of a cognitive approach to comprehension. In W. Weimer & D. Palermo (Eds.), *Cognition and the symbolic process*. Hillsdale, N.J.: Lawrence Erlbaum, 1974.

Brewer, W. F. There is no convincing evidence for operant or classical conditioning in adult humans. In W. B. Weimer & D. S. Palermo (Eds.), *Cognition and the symbolic process*. Hillsdale, N. J.: Lawrence Erlbaum, 1974.

Brown, J. S., & Burton, R. R. Multiple representations of knowledge for tutorial reasoning. In D. G. Bobrow & A. Collins (Eds.), *Representation and understanding: Studies in cognitive science*. New York: Academic Press, 1975.

Collins, A. Processes in acquiring knowledge. In R. C. Anderson, R. J. Spiro, & W. E. Montague (Eds.), *Schooling and the acquisition of knowledge*. Hillsdale, N. J.: Lawrence Erlbaum, 1977.

Collins, A., Beranek, B., & Newman. *Explicating the tacit knowledge in teaching and learning*. Paper presented at the annual meeting of the American Educational Research Association, Toronto, 1978.

Gagné, R. M. Learning hierarchies. *Educational Psychology*, 1968, *6*, 1-9.

Gagné, R. M. *The conditions of learning* (2nd ed.). New York: Holt, Rinehart and Winston, 1970.

Glaser, R. Introduction: Toward a psychology of instruction. In R. Glaser (Ed.), *Advances in instructional psychology*. Hillsdale, N. J.: Lawrence Erlbaum, 1978.

Green, J. A. *Teacher-made tests*. New York: Harper and Row, 1963.

Greeno, J. G. Cognitive objectives of instruction: Theory of knowledge for solving problems and answering questions. In D. Klahr (Ed.), *Cognition and instruction*. Hillsdale, N. J.: Lawrence Erlbaum, 1976.

James, W. *Principles of psychology* (Vol. 1). New York: Henry Holt, 1891.

Lindsay, P. H., & Norman, D. A. *Human information processing*. New York: Academic Press, 1972.

Mager, R. F. *Preparing instructional objectives*. Belmont, Calif.: Fearon, 1962.

Markle, S. *Good frames and bad* (2nd ed.). New York: John Wiley and Sons, 1969.

McKnight, C. *The use of "frames" in conceptualizing learning and problem solving in mathematics*. Paper presented at the annual meeting of the American Educational Research Association, San Francisco, 1979.

Merrill, M. D. Content and instructional analysis for cognitive transfer tasks. *AV Communication Review*, 1973, *21*, (1) 109-125.

Meyer, B. J. F. The structure of prose: Effects on learning and memory and implications for educational practice. In R. C. Anderson, R. J. Spiro, & W. E. Montague (Eds.), *Schooling and the acquisition of knowledge*. Hillsdale, N. J.: Lawrence Erlbaum, 1977.

Newell, A., & Simon, H. A. Computer science as empirical inquiry: Symbols and search. *Communications of the Association for Computing Machinery*, 1976, *19*, 113-126.

Norman, D. A., Gentner, D. R., & Stevens, A. L. Comments on learning schemata and memory representation. In D. Klahr (Ed.), *Cognition and instruction*. Hillsdale, N. J.: Lawrence Erlbaum, 1976.

Ortony, A. Why metaphors are necessary and not just nice. *Educational Theory*, 1975, *25*, 45-53.

Resnick, L. B. Task analysis in instructional design: Some cases from mathematics. In D. Klahr (Ed.), *Cognition and instruction*. Hillsdale, N. J.: Lawrence Erlbaum, 1976.

Rumelhart, D. E., & Ortony, A. The representation of knowledge in memory. In R. C. Anderson, R. J. Spiro, & W. E. Montague (Eds.), *Schooling and the acquisition of knowledge*. Hillsdale, N. J.: Lawrence Erlbaum, 1977.

Simon, H. A. *The sciences of the artificial*. Cambridge, Mass.: M.I.T. Press, 1969.

Simon, H. A. Information-processing theory of human problem solving. In W. K. Estes (Ed.), *Handbook of learning and cognitive processes*, (Vol. 5). Hillsdale, N. J.: Lawrence Erlbaum, 1978.

Tulving, E. Episodic and semantic memory. In E. Tulving & W. Donaldson (Eds.), *Organization of memory*. New York: Academic Press, 1972.

Weimer, W. B. Overview of a cognitive conspiracy: Reflections on the volume. In W. B. Weimer & D. S. Palermo (Eds.). *Cognition and the symbolic process*. Hillsdale, N. J.: Lawrence Erlbaum, 1974.

Wood, G. Mnemonic systems in recall. *Journal of Educational Psychology*, 1967, *58* (6), 1-27.