

Chapter 1

Contributions of Learning to Human Development²

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The following article, published during Gagné's tenure at The University of California, at Berkeley, presents his explanation of the nature of human intellectual development, cumulative learning theory. This article emphasizes the contrasts between his theory and other prominent explanations of intellectual development and his continuing concern with transfer of training. It also reflects Gagné's involvement in the development of an innovative school science curriculum. Much of the research that stimulated this position was completed during his Princeton years. Cumulative learning theory, in effect, provided alternatives to the program med instruction orientation to instructional sequencing which was so popular at the time.



One of the most prominent characteristics of human behavior is the quality of change. Among those who use the methods of science to account for human behavior are many whose interest centers upon the phenomena of behavioral change, and more specifically, on change in behavior capabilities. Sometimes, changes in behavior capabilities are studied with respect to relatively specific forms of behavior, usually over relatively limited periods of time—hours, days, or weeks. In such instances, the investigator names the processes he studies *learning and memory*. Another major class of phenomena of capability change comprises general classes of behavior observed over longer periods of time—months and years. The latter set of events is usually attributed to a process called *development*.

The reality of these two kinds of capability change is obvious in everyday experience, and requires no special experimentation to verify. The capabilities of the young child, for

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example, change before our eyes every day, as he learns new names for things, new motor skills, and new facts. In addition, his more general capabilities develop, over the months, as he becomes able to express his wants by means of word phrases, and later to communicate in terms of entire sentences and even longer sequences of ideas, both in oral and printed form. From these common observations one can distinguish in at least an approximate sense between the specific short-term change called learning, and the more general and long-term change called development.

To distinguish learning and development is surely a practically useful thing, for many purposes. At the same time, the two kinds of processes must be related to each other in some way. The accumulation of new names for things that the child learns is quite evidently related to the capability he develops for formulating longer and more complex sentences. The specific printed letters he learns to discriminate are obviously related to the development of his reading skills. The question is, how? What is the nature of the relation between the change called learning, on the one hand, and the change called development, on the other?

Over a period of many years, several different answers have been proposed for this question of the relation between learning and development. Investigators in this field have in general been concerned with accumulating evidence that they interpret as being consonant or dissonant with certain theories, or models. Usually the model they have in mind is fairly clear, even though it may not be explicitly represented in their writings.

Models of Human Behavioral Development

It is my purpose here to consider what certain of these models are, and what their implications are for continuing research on human learning and development. Specifically, I am interested in contrasting certain features of models that appear to be of commanding interest in present-day research. I hope by this means to clarify some issues so that they may, perhaps, be subjected to experimental testing in a manner that will allow us to sharpen and strengthen our inferences about the nature of human behavioral development.

It is inevitable that the theme of genetically determined growth, or maturation, as opposed to influences of the environment, will run through any discussion of the nature of behavioral development. Everyone will agree, surely, that development is the result of an interaction of growth and learning. There are enormous practical consequences associated with this issue—for example, in designing education for the young. If growth is the dominant theme, educational events are designed to wait until the child is ready for learning. In contrast, if learning is a dominant emphasis, the years are to be filled with

systematically planned events of learning, and there is virtually no waiting except for the time required for bringing about such changes.

It will be clear enough that my own views emphasize the influence of learning, rather than growth, on human behavioral development. But this is not because I deny the importance of growth. Rather it is because I wish to come to grips with the problem of what specific contributions learning can make to development, and by inference, what kinds of learned capabilities enter into the process of development. I want particularly to contrast a model of development that attempts to account specifically for learning effects with certain other models that do not do so. When I describe this model, you will perhaps agree that it can be conveyed briefly by means of the statement: Within limitations imposed by growth, *behavioral development results from the cumulative effects of learning.*

To set the stage for a model of this sort, it seems desirable first to mention two other models that are more or less in current use, and which have been in existence for some time. The first of these may be called the *growth readiness model*, which has been associated in previous times with such theorists as G. Stanley Hall (1907) and Arnold Gesell (1928), among others. Briefly, it states that certain organized patterns of growth must occur before learning can effectively contribute to development. Major evidence for this theory comes primarily from studies of the development of physical and motor functions in young children. A prototype study in this field (Gesell & Thompson, 1929) involved special training in stair-climbing for one of a pair of identical twins at the age of 46 weeks, no special training for the other twin. At 53 weeks, the untrained twin did not climb as well as the trained twin. But after 2 weeks of training, one-third as much as the total given to the trained twin, she actually surpassed the trained twin in performance. What this and many similar studies are usually interpreted to mean is that training for a motor performance might as well wait, in fact had better wait, until the child is maturationally "ready," before beginning the specific regime of training leading to the desired proficiency. The findings are consistent with this model. Other writers have pointed out that giving the untrained twin no special training doesn't mean that the child is learning nothing during this period. Unfortunately, the study is not therefore a truly critical one for testing predictions from the theory. Actually, it must be said that much other evidence bearing upon this model suffers from this kind of defect.

A second model of considerable importance, particularly because it has attracted much attention, is that of Piaget. Although the interaction of the child with his environment is given a specific role in this theory, it is well to recognize that it is in some fundamental sense a theory which assigns only a contributory importance to the factor of learning (Flavell, 1963, p.46; Sonstroem, 1966, p.214). The model may be summarized, briefly in

the following statements:

1. Intellectual development is a matter of progressive internalization of the forms of logic. The sequence of development manifests itself at first through motor action, later through concrete mediation of ideas, and still later through complete symbolic representation.
2. Progress in development is affected by the interaction of the child with his environment. New experiences are *assimilated* into existing cognitive structures, and newly acquired structures in turn make possible *accommodation* to the demands imposed by the environment. The total process, as Flavell (1963, p. 47) points out, may be considered one of *cognitive adaptation*.

This theory has been accompanied by a great mass of observational evidence, gathered over a period of many years, by Piaget and his colleagues in Geneva. They have observed children's performance of a variety of tasks, including those having to do with number, quantity, time, movement, velocity, spatial and geometrical relations, the operations of chance, and reasoning, among others. Generally speaking, the method has been to present the child with a concrete situation, say, two arrays of beads differing in spatial arrangement, and to ask probing questions in the attempt to determine the nature of the child's understanding of the situation. The behavior of the same child may then be tested again at a later age; or his behavior may be compared with that of older children on the same task.

There have been a number of confirming studies of Piaget's findings carried out by several investigators in various countries of the world (Dodwell, 1961; Elkind, 1961; Lovell, 1961; Peel, 1959). More important for present purposes, however, are the several studies that have attempted to induce particular kinds of intellectual development by means of specific instruction (or learning). Many of these are described by Flavell (1963, p.370 ff.), and need not be reviewed here. One prototype investigation, by Wohlwill and Lowe (1962), took the following form: Kindergarten children were tested on a task dealing with "conservation of number," requiring them to recognize that the rearrangement of a set of objects in space does not alter their number. Three different groups of the children were given three different varieties of training, each designed to provide them with a mediational way of arriving at conservation of number. A fourth group served as a control, and was given no training. The results were that no effects could be shown of any of the kinds of training. The group improved their performance somewhat, but the experimental groups gained no more than the control group. Other experiments by Smedslund (1961a, 1961b, 1961c, 1961d, 1961e) lead to much the same conclusion.

Another example is provided by a recent experiment reported by Roeper and Sigel (1966), this time concerned with the tasks of conservation of quantity, using standard situations described by Piaget and Inhelder (1964) for conservation of substance, liquid substance, weight, and volume. In this case the trained groups of 5-year-old children were given fairly extensive general training in classifying, in reversibility, in seriation, three mental operations identified by Piaget as involved in the development of ideas of conservation in children. To summarize individual results very briefly, it was found that some trained children did improve on some tasks, but not on all of them. In contrast, the untrained control children showed no improvement. But the effectiveness of training was by no means general—one child might achieve a success in conservation of weight, but not in conservation of volume.

There have been quite a number of experiments using conservation-type tasks, and I have only mentioned here what seem to me a couple of representative examples. Generally speaking, the results seem to be summarizable as follows. Tasks which require young children to respond to situations reflecting conservation of substance, volume, weight, and number do not appear to be readily modifiable by means of instruction and training which is aimed rather directly at overcoming the typical deficiencies exhibited by children. Where such training has been shown to have some effect, it is usually a very specific one, tied closely to the situation presented in training, and not highly generalizable. On the whole, any impartial review of these studies would doubtless be forced to conclude that they do not contradict Piaget's notions of cognitive adaptation, and in fact appear to lend some support to the importance of maturational factors in development.

It is my belief that there is an alternative theory of intellectual development to which many students of child behavior would subscribe. In particular, it is one that would be favored by those whose scientific interest centers upon the process of learning. Naturally enough, it is one that emphasizes learning as a major causal factor in development, rather than as a factor merely involved in adaptation. It is easy enough to identify the philosophical roots of such a theory in American psychology. Perhaps the proponents who most readily come to mind are John B. Watson (1924) and B. F. Skinner (1953), both of whom have given great weight to the importance of environmental forces of learning in the determination of development.

But philosophy is not enough. As Kessen (1965, p. 271) points out, for some reason not entirely clear, those theorists who have generally emphasized the influences of environment, as opposed to growth, have also generally espoused a rather radical type of associationism. Thus, they have maintained not only that learning is a primary

determinant of intellectual development, but also that what is learned takes the form of simple “connections” or “associations.” To account for how a child progresses from a stage in which he fails to equate the volume of a liquid poured from one container into a taller narrower container, to a stage in which he succeeds in judging these volumes equal, seems to me quite impossible to accomplish on the basis of learned “connections.” At the least, it must be said that there is no model that really does this. Furthermore, the experiments, which have tried to bring about such a change, largely on the basis of “associationistic” kinds of training, have not succeeded in doing so.

In contrast to a weak and virtually empty “associationistic” model, it is not surprising that a theory like Piaget’s has considerable appeal to students of development. It tells us that there are complex intellectual operations, which proceed generally from stages of motor interaction through progressive internal representation to symbolic thought. As an alternative, we may choose a theory like Bruner’s (1965), which conceives the developmental sequence to be one in which the child represents the world first inactively (through direct motor action), then iconically (through images), and finally symbolically. These are models with a great deal of substance to them, beside which the bare idea of acquiring “associations” appears highly inadequate to account for the observed complexities of behavior.

Cumulative Learning Model

The point of view I wish to describe here states that learning contributes to the intellectual development of the human being because it is cumulative in its effects. The child progresses from one point to the next in his development, not because he acquires one or a dozen new associations, but because he learns an ordered set of capabilities which build upon each other in progressive fashion through the processes of differentiation, recall, and transfer of learning. Investigators of learning know these three processes well in their simplest and purest forms, and spend much time studying them. But the cumulative effects that result from discrimination, retention, and transfer over a period of time within the nervous system of a given individual have not been much studied. Accordingly, if there is a theory of *cumulative learning*, it is rudimentary at present.

If one cannot, as I believe, put together a model of cumulative learning whose elements are associations, what will these entities be? What is it that is learned, in such a way that it can function as a building block in cumulative learning? Elsewhere (Gagné, 1965) I have outlined what I believe to be the answer to this question, by defining a set of learned capabilities which are distinguishable from each other, first, as classes of human performance, and second, by their requirements of different conditions for their

acquisition. These are summarized in Figure 1.1.

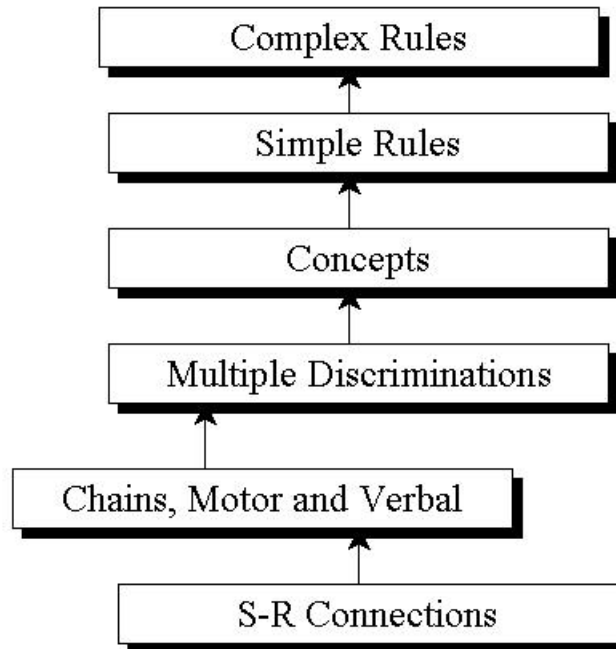


Figure 1.1 A General Sequence for Cumulative Learning.

The basic notion is that much of what is learned by adults and by children takes the form of complex rules. An example of such a rule is, "Stimulation of a neural fiber changes the electrical potential of the outer surface of the neural membrane relative to its inner surface." I need to emphasize that "rule" refers to what might be called the "meaning" of such a statement, and not to its verbal utterance. These ideas are learned by individuals who have already learned, and can recall, certain simpler rules; in this instance, for example, one of these simpler rules would be a definition of electrical potential. Simple rules, in their turn, are learned when other capabilities, usually called concepts, have been previously learned. Again, in this instance, one can identify the presence of concepts like "stimulation," "fiber," "electric," "surface," and "membrane," among others. In their turn, the learning of concepts depends upon the availability of certain discriminations; for example, the idea of surface has been based in part on prior learning of discriminations of extent, direction, and texture of a variety of actual objects. In the human being, multiple discriminations usually require prior learning of chains, particularly those which include verbal mediators. And finally, these chains are put together from even simpler learned capabilities which have traditionally been called "associations" or "Stimulus-Response (S-R) connections."

The identification of what is learned, therefore, results in the notion that all these kinds of capabilities are learned, and that each of them is acquired under somewhat different external conditions. By hypothesis, each of them is also learned under different *internal* conditions; the most important of these being what the individual already has available in his memory. It is clear that associations, although they occupy a very basic position in this scheme, are not learned very frequently by adults, or even by 10-year-olds. Mainly, this is because they have already been learned a long time ago. In contrast, what the 10-year-old learns with great frequency are rules and concepts. The crucial theoretical statement is that the learning of such things as rules and concepts depends upon the recallability of previously learned discriminations, chains, and connections.

Examples of Cumulative Learning

Some verification of the idea of cumulative learning has come from studies of mathematics learning, an example of which is Gagné, Mayor, Garstens, and Paradise (1962). Seventh-grade students acquired a progressively more complex set of rules in order to learn the ultimate performances of adding integers, and also of demonstrating in a logical fashion how the addition of integers could be derived from number properties. The results of this study showed that with few exceptions, learners who were able to learn the capabilities higher in the hierarchy also knew how to do the tasks that were reflected by the simpler rules that were lower in the hierarchy. Those who had not learned to accomplish a lower-level task generally could not acquire a higher level capability to which it was related.

These results illustrate the effects of cumulative learning. They do so, however, in a very restricted manner, since they deal with a development period of only two weeks. Another form of restriction arises from the fact that only rules were being learned in this study, rather than all of the varieties of learned capabilities, such as concepts, discriminations, chains, and connections. In another place (Gagné, 1965, p. 181) I have attempted to spell out in an approximate manner a more complete developmental sequence, applicable to a younger age, pertaining to the final task of ordering numbers. In this case it is proposed that rules pertaining to the forming of number sets depend upon concepts such as joining, adding, and separation. These rules in turn are dependent upon simpler capabilities like multiple discriminations in distinguishing numerals; and these depend upon such verbal chains as naming numerals and giving their sequence. Following this developmental sequence to even earlier kinds of learning, it is recognized that children learn to draw the numerals themselves, and that at an even earlier stage they learn the simplest kinds of connections such as orally saying the names of numerals and marking with a pencil.

It should be quite clear that this cumulative learning sequence is only a suggested, possible one, and not one that has received verification, as was true of the previous example. I doubt that it is at all complete. It attempts to show that it is possible to conceive that all of the various forms of learned capabilities are involved in a cumulative sense in the first-grade task of ordering numbers. Not only are specific rules directly connected with the task, but also a particular set of concepts, discriminations, chains, and connections which have been previously learned. Normally, such prior learning has taken place over a period of several years, of course. And this means that it would be quite difficult to establish and verify a cumulative learning sequence of this sort in its totality. If such verification is to be obtained, it must be done portion by portion.

A Cumulative Learning Sequence in Conservation

Can a cumulative learning sequence be described for a task like the conservation of liquid, as studied by Piaget (cf. Piaget & Inhelder, 1964)? Suppose we consider as a task the matching of volumes of liquids in rectangular containers like those shown in Figure 1.2. When the liquid in A is poured into Container B, many children (at some particular age levels) say that the taller Container B has more liquid. Similarly, in the second line of the figure, children of particular ages have been found to say that the volume in the shallower Container B, exhibiting a larger surface area, is the greater.

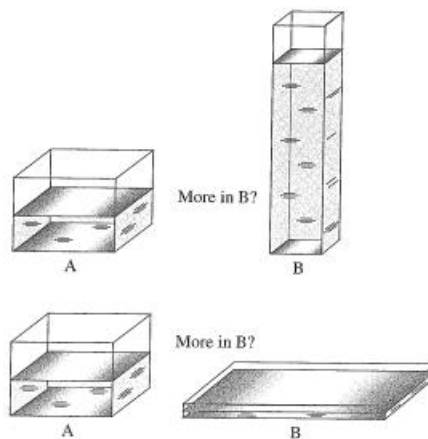


Figure 1.2 Two Tasks of “Conservation of Liquid” of the Sort Used by Piaget and Other Investigators.

What is it these children need to have learned, in order to respond correctly to such situations as these? From the standpoint of the cumulative learning model, they need to have learned many things, as illustrated in Figure 1.3.

First of all, you may want to note that “conservation of liquid” is not a behaviorally defined task; accordingly I have attempted to state one that is, namely, “judging equalities and inequalities of volumes of liquids in rectangular containers.” However, such behavior is considered to be rule-based, and could be restated in that form.

“Nonmetric” is also a word requiring comment. What this diagram attempts to describe is a cumulative learning sequence (in other words, a developmental sequence), that obtains approximate volume matchings without the use of numbers, multiplication, or a quantitative rule. I believe such a learning sequence can occur, and perhaps sometimes does occur, in children uninstructed in mathematical concepts of volume. Choosing this particular sequence, then, has the advantage of application to children who are more like those on whom Piaget and others have tried the task. But let it be clear that it is by no means the *only* learning route to the performance of this task. There must be at least several such sequences, and obviously, one of them is that which *does* approach the final performance through the multiplication of measured quantities.

The first subordinate learning that the child needs to have learned is the rule that length, width, and height determine the volume of a liquid (in rectangular containers). A change in any of these will change volume. This means that the child knows that any perceived change in any of these dimensions means a different volume. Going down one step in the learning required, we find three rules about compensatory changes in two dimensions when another dimension remains constant. That is, if the height of a liquid remains the same in two different containers one can have the same volume if a change in width is compensated by a change in length. This is also similar for the other instances of compensatory change.

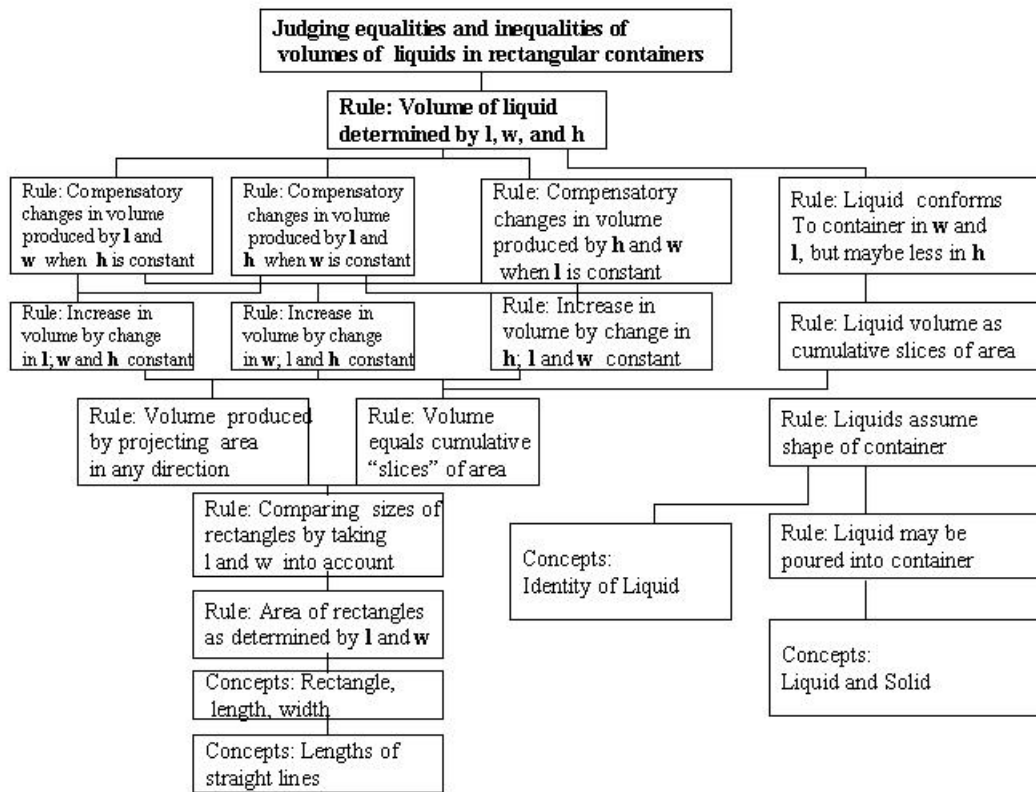


Figure 1.3 A Cumulative Learning Sequence Pertaining to the Development of Nonmetric Judgments of Liquid Volume

Now, in order for a child to learn these compensatory rules, the model says, he must have previously learned three other rules, relating to change in only one dimension at a time. For example, if length is increased while width and height remains constant, volume increases. Again, similarly for the other single dimensions. These rules in turn presuppose the learning of still other rules. One is that volume of a container is produced by accumulating “slices” of the same shape and area; and a second is that volume can be projected from area in any direction, particularly, up, to the front or back, and to the right or left. Finally, one can work down to considerably simpler rules, such as those of comparing areas of rectangles by compensatory action of length and width; and the dependence of area upon the dimensions of length and width. If one traces the development sequence still farther, he comes to the even simpler learned entities, concepts, including rectangle, length, width, and an even simpler one, the concept of length of a straight line.

Just to complete the picture, the model includes another branch which has to do with liquids in containers, rather than with the containers themselves, and which deals on simpler levels with rules about liquids and the concept of a liquid itself. This branch is necessary because at the level of more complex rules, the child must distinguish between the volume of the liquid and the volume of the container. Of particular interest also is the concept of liquid identity, the recognition by the child that a given liquid poured into another container is still the same liquid. Such a concept may fairly be called a “logical” one, as Piaget does. Bruner (1966) presents evidence tending to show that identity of this primitive sort occurs very early in the child’s development, although its

communication through verbal questions and answers may be subject to ambiguities.

Having traced through the “stages” in learning, which the model depicts, let me summarize its characteristics as a whole, and some of their implications.

1. First, it should be pointed out that this model, or any other derived in this manner, represents the hypothesis-forming part of a scientific effort, not the verification part. This specific model has not been verified, although it would seem possible to do so. In the process of verification, it is entirely possible that some gaps would be discovered, and this would not be upsetting to the general notion of cumulative learning.
2. According to this way of looking at development, a child has to learn a number of subordinate capabilities before he will be able to learn to judge equalities of volume in rectangular containers. Investigators who have tried to train this final task have often approached the job by teaching one or two, or perhaps a few, of these subordinate capabilities, but not all of them in a sequential manner. Alternatively, they may have given direct practice on the final task. According to the model, the incompleteness of the learning programs employed accounts for the lack of success in having children achieve the final task.
3. In contrast to other developmental models, some of them seemingly based on Piaget's, the cumulative learning model proposes that what is lacking in children who cannot match liquid volumes is not simply logical processes such as “conservation,” “reversibility,” or “seriation,” but concrete knowledge of containers, volumes, areas, lengths, widths, heights, and liquids.

Generalization and Transfer

There is still another important characteristic of a cumulative learning model remaining to be dealt with. This is the fact that any learned capability, at any stage of a learning sequence, may operate to mediate other learning that was not deliberately taught. Generalization or transfer to new tasks, and even to quite unanticipated ones, is an inevitable bonus of learning. Thus the child who has been specifically instructed via the learning sequence shown in the previous figure has actually acquired a much greater learning potential than is represented by the depicted sequence itself.

Suppose, for example, we were to try to get a child who had already learned this sequence to learn another requiring the matching of volumes in cylindrical containers. Could he learn this second task immediately? Probably not, because he hasn't yet learned enough about cylinders, volumes of cylinders, and areas of circles. But if we look for useful knowledge that he *has* acquired, we find such things as the rule about

liquids assuming the shapes of their containers, and the one about volumes being generated by cumulative “slices” of areas. The fact that these have been previously learned means that they do not have to be learned all over again with respect to cylinders, but simply recalled. Thus a cumulative learning sequence for volumes of liquids in cylinders could start at a higher “stage” or “level” than did the original learning sequence for rectangular containers. Cumulative learning thus assumes a built-in capacity for transfer. Transfer occurs because of the occurrence of specific identical (or highly similar) elements within developmental sequences. Of course, “elements” here means rules, concepts, or any of the other learned capabilities I have described.

It will be noted that the final tasks of the developmental sequences I have described are very specific. They are performances like “matching volumes in rectangular containers.” Does the existence of transfer imply that if enough of these specific tasks are learned, the child will thereby attain a highly general principle that might be called substance conservation? The answer to this question is “no.” The model implies that an additional hierarchy of higher-order principles would have to be acquired before the individual might be said to have a principle of substance conservation. Transferability among a collection of such specific principles will not, by itself, produce a capability, which could be called the principle of *substance conservation*, or the principle of conservation.

What is possible with a collection of specific principles regarding conservation, together with the transfer of learning they imply, is illustrated in Figure 1.4.

Suppose the learner, making use of transfer of learning where available, has acquired all four of the specific conservation principles shown in the bottom row—dealing with conservation of number, conservation of liquid volumes in both rectangular and cylindrical containers, and conservation of solid volumes. Others could be added, such as conservation of weight, but these will do for present purposes. The property of learning transfer makes possible the ready acquisition of still more complex principles, such as the example given here—judging the volumes of liquids, in irregularly shaped containers. It is easy to see that by *combining* the principles applicable to volume of rectangular containers, and others applicable to cylindrical containers, a learner could easily acquire a capability of estimating volumes of irregularly shaped containers. Other kinds of combinations of previously acquired knowledge are surely possible. As I have pointed out, this is the kind of generalizing capability made possible by the existence of learning transfer.

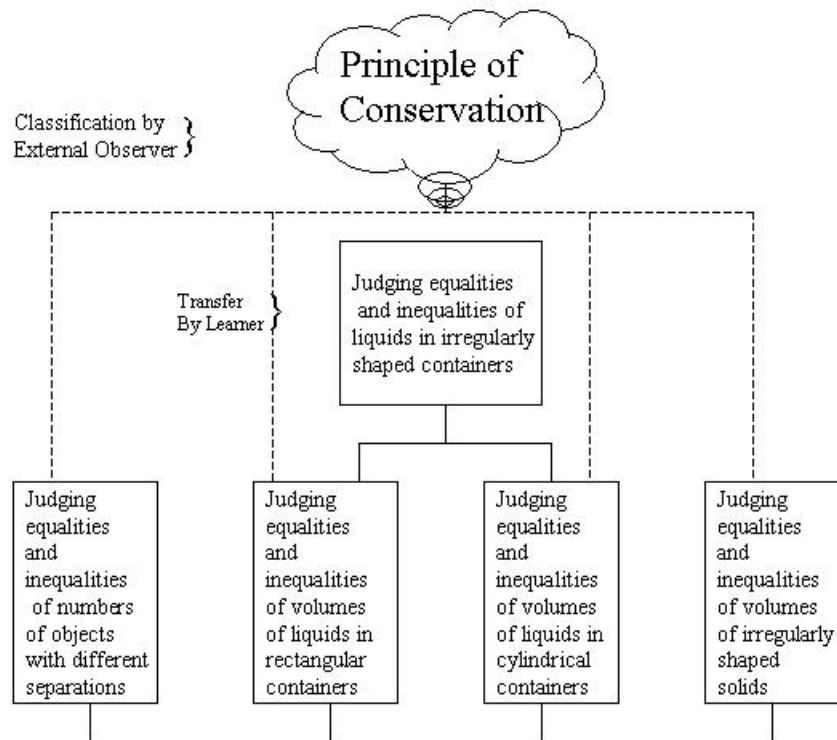


Figure 1.4 The Contrast Between a Principle Acquired by the Learner Through Transfer From Previously Learned Principles, and a “Principle of Conservation” Used as a Classificatory Aid by an external Observer.

In contrast to this new entity in the developmental sequence, an external observer may, if he wishes, look at the collection of what the individual has learned about conservation, and decide he will call this *collection* the principle of conservation. An external observer is perfectly capable of doing this, and he may have legitimate reasons for doing so. But what he achieves by so doing is still an abstraction which exists in his mind, and not in the mind of the learner. If the external observer assumes that because he can make this classification of such an entity as a principle of conservation, the same entity must therefore exist as a part of the learner’s capabilities, he is very likely making a serious mistake. The learner has only the specific principles he has learned, along with their potentialities for transfer.

I believe that many of the principles mentioned by Piaget, including such things as reversibility, seriation, and the groupings of logical operations, are abstractions of this sort. They are useful descriptions of intellectual processes, and they are obviously in Piaget’s mind. But they are not in the child’s mind.

Another example of how such abstractions may be useful for planning instructional sequences, but not as integral components of intellectual development, may be seen in

exercises in science for elementary school children, titled *Science—A Process Approach*, developed by the Commission on Science Education of the American Association for the Advancement of Science (1965). One of the processes these exercises intend that young school children learn is called observation. But it would be incorrect to think that the designers of this material believe that something like the Principle of Observation is to be directly taught to children as an intellectual entity. Observation in this case is an abstraction, which exists in the minds of the designers, but not in the minds of children. What the children do learn is a rather comprehensive collection of specific capabilities, which enable them to identify several fundamental properties of the world of objects—tastes, odors, sounds, the solid-liquid distinction, color, size, shape, texture, as well as changes in these. Each is a fairly specific capability, applying to a class of properties only one step removed in abstraction from the objects themselves. At the same time, transfer of learning makes it possible for the child to build upon these things he has learned, and to learn to identify objects or changes in them in a manner which requires the use of several senses at once.

These instructional materials make it clear that the specific capabilities of observation are considered to have transfer value to other kinds of things which are learned later on—to classifying and measuring and predicting and inferring, as well as to other activities involved in scientific experimentation. Transfer of these specific capabilities takes place in many ways and in many directions. But the processes themselves are not acquired as a part of the child's mental constitution. They are merely external names for a collection of capabilities, as well as for the developmental sequences on which these are built.

Returning to the general theme, it should be clear that the various kinds of capabilities that children learn cumulatively, despite their relative specificity, provide a totality of transferable knowledge that is rich in potentialities for further learning. New combinations are possible at any time between principles acquired, let us say, in a context of containers of water, on the one hand, and in the very different context of exchanges of money, on the other. Furthermore, it is recognized that such generalizations can readily occur when the individual himself initiates the intellectual activity; the new learning does not have to be guided by external instruction. The process of cumulative learning can involve and be contributed to by the operations of inductive and deductive thinking. The cumulative learning model obviously does not provide a theory of thinking; but it suggests the elements with which such a theory might deal.

Summary

What I have attempted to describe is a model of human intellectual development based

upon the notion of cumulative learning, which contrasts in a number of respects with developmental theories whose central theme is maturational readiness, as well as with those (of which the best known is Piaget's) of cognitive adaptation. This model proposes that new learning depends primarily upon the combining of previously acquired and recalled learned entities, as well as upon their potentialities for transfer of learning.

As for the entities which are learned, the model assumes that complex principles are formed from combinations of simpler principles, which are formed by combining concepts, which require prior learning of discriminations, and which in turn are acquired on the basis of previously learned chains and connections. The "stage" in which any individual learner finds himself with respect to the learning of any given new capability can be specified by describing (a) the relevant capabilities he now has; and (b) any of a number of hierarchies of capabilities he must acquire in order to make possible the ultimate combination of subordinate entities which will achieve the to-be-learned task. In an oversimplified way, it may be said that the stage of intellectual development depends upon what the learner knows already and how much he has yet to learn in order to achieve some particular goal. Stages of development are not related to age, except in the sense that learning takes time. They are not related to logical structures, except in the sense that the combining of prior capabilities into new ones carries its own inherent logic.

The entities that are acquired in a cumulative learning sequence are relatively specific. They are specific enough so that one must specify them by naming the class of properties of external objects or events to which they will apply. At the same time, they possess great potential for generalization, through combination with other learned entities by means of a little understood, but nevertheless dependable, mechanism of learning transfer.

This kind of generalization through learning transfer is internal to the learner, and thus constitutes a genuine and measurable aspect of the learner's intellectual capability. Another kind of generalization is not necessarily a part of the learner. This is the classification an external observer may make of a collection of learned capabilities. While the observer naturally has the capability of making such a generalization (and often does so), the learner may not have such a capability. Thus, an external observer may classify a collection of learner capabilities as "the conservation principle," or "the principle of reversibility." Such abstractions have a number of uses in describing intellectual capabilities. Because they are so described, however, does not mean that the learner possesses them, in the same sense that the external observer does.

Intellectual development may be conceived as the building of increasingly complex and

interacting structures of learned capabilities. The entities, which are learned, build upon each other in a cumulative fashion, and transfer of learning occurs among them. The structures of capability so developed can interact with each other in patterns of great complexity, and thus generate an ever-increasing intellectual competence. Each structure may also build upon itself through self-initiated thinking activity. There is no magic key to this structure—it is simply developed piece by piece. The magic is in learning and memory and transfer.

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