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# Chapter 1: Piaget's Theory and College Teaching

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# CHAPTER ONE

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Consider the following examples of individuals exploring the physical world:

> Laurent (age 10 months) is lying on his back but nevertheless resumes his experiments of the day before. He grasps in succession a celluloid swan, a box, etc., stretches out his arms and lets them fall. He distinctly varies the positions of the fall. Sometimes he stretches out his arm vertically, sometimes he holds it obliquely, in front of or behind his eyes, etc. When the object falls in a new position (for example on his pillow), he lets it fall two or three times more on the same place, as though to study the spatial relation; then he modifies the situation. (Piaget, 1963, p.269).

> Dei (age 16 years) "Tell me first (after experimental trials) what factors are at work here."—"Weight, material, the length of the rod, perhaps the form."—"Can you prove your hypothesis?"—(She compares the 200 gram and 300 gram weights on the same steel rod.) "You see, the role of weight is demonstrated. For the material, I don't know." - "Take these steel ones and these copper ones." - "I think I have to take two rods with the same form. Then to demonstrate the role of the metal I compare these two (steel and brass, square, 50 cm long and 16 $mm^2$ cross-section with 300 grams on each) or these two here (steel and brass, round, 50 and 22 cm by 16 $mm^2$): for length I shorten that one (50 cm brought down to 22). To demonstrate the role of the form, I can compare these two" (round brass and square brass, 50 cm and 16 $mm^2$ for each.) "Can the same thing be proved with these two?" (brass, round and square, 50 cm long and 16 and 7 $mm^2$ cross-section). - "No, because that one (7 $mm^2$) is much narrower." - "And the width?" - "I can compare these two" (round, brass, 50 cm long with 16 and 7 $mm^2$ cross-section). (Inhelder & Piaget, 1958).

It is difficult to decide whether it is the similarities or differences between the two explorers that are more striking. For Piaget, there is significance both in those aspects of cognition that change strikingly as one's development progresses and in those aspects that appear in the cognitive functioning of all complex organisms throughout their lifespans. In fact, he regards the two facets - change and invariance - as so closely interdependent that one could hardly produce a reasonably complete and cohere account of either without including the other. Any account of people's cognitive structures at different levels of development would be seriously incomplete unless it is embedded in an account of how these structures function, while any account of general principles underlying the intellectual functioning of organisms would be incomplete unless it included a look at the succession of qualitatively distinct and relatively enduring cognitive structures to which that functioning inevitably gives rise.

Accordingly, we will begin this chapter with a discussion of Piaget's account of general intellectual functioning at all levels of development: the nature of schemes, and the processes of assimilation and accommodation. This will lead us to his equally general (non-stage-specific) conception of how new knowledge is constructed: the processes of learning, development, and equilibration. At this point we will be ready to consider the stages of development that result from the equilibration process, with an emphasis on the state of formal operational reasoning. Finally, we will attempt to better understand the scope and limitations of Piaget's psychological work by comparing it to other psychological theories and by viewing it within the broader perspective of "genetic epistemology," Piaget's developmental theory of knowledge. (For more extensive introductions to Piaget, see Cowan, 1978; Furth, 1969; Ginsburg & Opper, 1979).

The nature of intellectual functioning

Our central task in this section is to determine what the above examples have in common; What is the general nature of cognitive activity at all ages? Simply in this formulation of the question, I have already presupposed part of Piaget's answer. The essence of cognition, for Piaget, likes in the fact that it is an action. In fact, Piagetians prefer to speak not of knowledge, which has the unfortunate connotation of passive elements in some sort of mental receptacle, but rather of knowing, which better connotes an action performed by a knower on a known thing. In each of the above examples, we see the individual knowing the object by acting upon it, though the nature of those actions naturally varies with age.

The fundamental units of knowing, for Piaget, are schemes. A scheme is a class of physical or mental actions one can perform on the world, a potential transformation by which one is able to know the world. When a scheme "does its thing," we say that the individual is (a) assimilating reality to that scheme, and (b) simultaneously accommodating the scheme to reality. Thus for example, we see how the infant knows the celluloid swan by assimilating it to his grasping and dropping schemes. Inevitably linked to these assimilation processes are corresponding accommodations: in order to grasp a celluloid swan one must accommodate one's grasping scheme to the unique properties of the swan. Similarly, we see the adolescent assimilating the bending rod to the very sophisticated mental scheme of isolating variables in order to test their effects; simultaneously the isolation-of-variables scheme must be accommodated to the particular variables relevant to a bent rod - weight, length of rod, etc. (rather than, say, melting point or gender).

Knowing, the, for Piaget, always involves the assimilation of reality to the schemes on brings to the situation and a corresponding accommodation of those schemes to the thing-to-be-known. A plausible question at this point would be how the adequacy of one's knowledge may be assessed: Does intelligent knowing reside primarily in the assimilation aspect of cognition or in its accommodation aspect? One's answer to this question turns out to depend on one's epistemology, that is, on one's fundamental assumptions about the nature of knowledge. From an empiricist point of view -- and this is the unexamined epistemology of most people raised in our culture - the basis for knowledge likes in the pre-existing structures of reality, and the essence of objective knowing likes in conforming our minds, through experience, to those structures. Thus, using Piaget's terminology, knowing would be most adequate (adapted, intelligent) when accommodation is predominant, since it is the accommodation process that involves adjusting one's schemes to reflect, as closely as possible, the properties of the reality being assimilated. The most obvious alternative to empiricism would be a nativist or idealist sort of position, in which the basis for knowledge likes in the pre-existing structures of our minds, and intelligent knowing would consist of conforming experience to these prior structures, patterns, or categories. Thus, the essence of intelligent knowing would like in assimilation, since it is by assimilating the anarchic confusion of reality to our schemes that we impose order on it.

Piaget, operating from what he calls a constructivist epistemology, rejects both of these extreme positions. Instead, he argues that knowledge is no preformed either in the mind or in the environment, but rather is constructed at their interface. Thus, intelligent knowing consists not of a primacy of either assimilation or accommodation, but rather of an equilibrium between the two. When assimilation of reality to our minds is predominant, our cognizing of that reality is playful, distorting, egocentric, or even autistic (a danger of completely unstructured educational activities). When accommodation of our minds to reality is predominant, our cognizing of that reality is passive and imitative (e.g. mindless note-taking and rote memory). True understanding, for Piaget, consists of neither assimilation nor accommodation in isolation, but rather of a dynamic equilibration of both that makes it possible to assimilate reality without distorting it and simultaneously to accommodate to that reality without compromising the integrity of present cognitive structures. Thus, for example, equilibrated functioning with respect to the manipulation of variables, maintains the integrity of both (a) the mental scheme for isolating and controlling variables and (b) the physical reality of the variables and their relations.

Intellectual change

The subtle but crucial concept of equilibration provided the link between Piaget's views on how schemes function and his closely related views on how, during the course of their functioning, new schemes are constructed. The equilibration concept is probably best understood when viewed within its biological context. Biologists have long understood that the functioning and development of an organism within its environment cannot be understood simply as the sum of the organism's effects on that environment (in Piaget's terms, its assimilation of the environment) and the environment's effects on the organism (that is, the organism's forced accommodations to the environment). Rather, it is the nature of living systems to maintain their internal coherence or equilibrium in the fact of environmental intrusions via complex feedback mechanisms involving interaction between organism and environment rather than unidirectional causal effects of each on the other. Piaget argues that cognition is simply a highly sophisticated aspect of a biological organism's adaptation to its environment, and thus involves analogous equilibratory mechanisms. In the fact of new environmental demands, then, the essential aspect of the construction of new knowledge lies not in the accommodation of old schemes to the altered environment (as empiricists would have it) or in the assimilation of the new environment to old schemes (as extreme nativists would have it), but rather in the active construction of new schemes that maintain an equilibrium between these assimilatory and accommodatory aspects of knowing and thus maintain the integrity of the organism as a living, knowing system. In order to be more specific about this, we need to look in some detail at Piaget's views on the differences between learning and development and the nature of the relation between them.

First we need to distinguish between two sorts of aspects of knowledge. Consider, for example, a student testing hypotheses about a pendulum Suppose she incorrectly believes that weight is directly related to rate of oscillation. To test this, she manipulates the weight while holding all other variables constant and finds no effect. Presumably, a mature thinker would at this point reject her original theory. Why, however, doesn't she maintain her theory and regain consistency by instead rejecting the strategy of isolating variables? The reason, it would seem is her recognition that her theory about the pendulum is an empirical sort of knowledge which may be rejected on the basis of inconsistent data, while her knowledge about the isolation of variables is a logical sort of knowledge, relatively impervious to the empirical data it results in.

Piaget argues that the developing thinker is able to distinguish logical from empirical knowledge because the two sorts of knowledge are constructed by different processes. Recall that, for Piaget, knowing is an action of a subject (biological organism) on an object (environment). There are two general mechanisms by which such knowing can result in new knowledge. The first, empirical abstraction, involves the abstraction of empirical knowledge from the object as a result of assimilating it to one's current knowledge. Empirical abstraction corresponds fairly well to the usual notion of learning in that it involves the production of knowledge about the world via the abstraction of knowledge from that world. It should be emphasized, of course, that empirical abstraction is by no means a direct copying of the true nature of reality. Reality is only known by acting upon it, that is, by assimilating it to one's current knowledge, and even empirical knowledge is thus actively constructed rather than simply copied. Since most learning theories in contemporary psychology, unlike their behavioristic ancestors of several decades ago, stress the role of the active, cognitive knower in assimilating new information to old, Piaget's conception of empirical abstraction is fairly consistent, at least at a general level, with the prevailing conceptions of modern cognitive learning theories.

It is in his differentiation of logical from empirical knowledge and in his account of the construction of logical knowledge that Piaget's theory is most radical and controversial. Piaget argues that in the course of acting upon objects, the subject abstracts knowledge not only from those objects (empirical abstraction) but also from the intricate coordinations of the actions themselves, a process he calls reflective abstraction. This involves the progressive dissociation of form from content as the subject reconstructs his or her knowing at progressively more abstract levels. For example, the student with the pendulum would not be said to understand the concept of isolating variables until she has successfully coordinated her various manipulations of variables and abstracted the underlying form of this coordination from the variables (weight, string length, etc.) particular to the pendulum. What Piaget emphasizes here is that the resulting abstract of isolation-of-variables scheme is not an empirical knowledge of pendulum to be empirically abstracted from the pendulum itself but rather a logical intercoordination of the subject's own activities and eventually dissociated entirely from the particular content of the pendulum. Logical knowledge such as the isolation of variables, then does not consist of empirical facts about the world to be learned and remembered, but rather consists of a necessary coordination of cognitive actions to be constructed and understood.

It is in the construction of logical knowledge that Piaget sees the essence of cognitive development (as opposed to learning). This is not to say that absence of an environment. All new knowledge, according to Piaget, derives from interaction with an environment. Rather, Piaget's point is that logical knowledge is not abstracted from the particularities of the environment with which the subject interacts but rather from the underlying form of the subject's own actions on that environment. Thus there tend to be certain invariant sequences in the construction of logical knowledge, each stage building on the one before, regardless of particularities of the environment. It is in this sense, and this sense only, that logical knowledge, in contrast to empirical knowledge, is said to develop rather than to be learned.

<u>The stages of development</u>

Having differentiated logical from empirical knowledge and produced a theory of the reflective abstraction mechanism that makes logical knowledge possible, Piaget's research program then focuses on distinguishing various sorts of logical and quasilogical knowledge and describing as precisely as possible the stages in their development. Three points should be emphasized in this connection. First, Piaget's focus on logical knowledge should not be taken to imply that the empirical abstraction of empirical knowledge (i.e. learning) is simple, unimportant, or already understood. This emphasis is, however, based on his belief that all learning involves assimilation to basic logical schemes and that psychologists studying the learning process have generally ignored the problem of the construction of these underlying schemes that make learning possible. Second, it should be emphasized that Piaget's focus on stages of development does not reflect a belief that <u>all</u> knowledge proceeds through stages of development but rather is a consequence of his focus on logical knowledge, which he believes does develop through qualitatively distinct stages of structural reorganization. Third, any ages given in connection with Piagetian stages should be taken as very rough norms. As we have seen, the construction of knowledge, for Piaget, is not an age-determined maturational process but rather results from each other with respect to their experience in various domains, and these differences are reflected in different rates of development for different children and for different aspects of knowledge within a given child.

It would be impossible even to quickly survey, in this brief chapter, the extraordinary variety of concepts whose genesis Piaget has studied. These include knowledge of classes, relations, and propositional reasoning, which may be described as logical concepts in the narrow sense. Second, Piaget has dealt with such related mathematical concepts as number, probability proportionality, combination and permutation. Third, there are concepts of time, space, causality, and objects which are basic to construing the physical world but which Piaget labels as infralogical to indicate that they do not rest on acquired knowledge of particular objects, places, durations, or causes and effects but rather form the general infralogical framework within which such physical particulars may be understood. And, finally Piaget has studied such concepts as force, speed, weight, and distance which, though obviously of physical import, are still sufficiently abstract and general to have a considerable logico-mathematical basis. Piaget's massive empirical research has provided us with a remarkably novel and detailed picture of the invariant stages children and adolescents go through in constructing and understanding of each of these concepts. His results have been reported in literally dozens of books written over the course of some six decades. For the present, however, it will have to suffice to give a very broad and sketchy overview of the first three major periods in cognitive development, followed by a more detailed look at the fourth.

The four major periods of development differ most fundamentally in the nature of the cognitive schemes the individual is in the process of constructing. The first period, extending from birth to about 18 to 24 months, is called the sensorimotor period. The infant's schemes are sensorimotor in that they involve physical, observable actions performed on the physical environment. Cognitive development during infancy consists of the construction, from simple, reflexive schemes such as sucking and grasping, of complex means/end coordinations and exploratory behaviors, as well as sensorimotor action-concepts of time, space, causality, and permanent objects.

The second major period, extending from about 1 1/2 to 7 years, is usually labeled the preoperational period, though it might be more revealing to think of it as the first stage of representational intelligence. It begins as the infant gradually constructs internal, mental representations of objects and interiorized mental actions that may be performed on these mental representations. Though sensorimotor activity naturally continues throughout the lifespan, the growing point of intelligence now likes in the construction of such interiorized, mental - as opposed to overt physical - schemes. This is the period of life when language and other symbolic activities develop rapidly.

Beginning about the age of 7 is the period of concrete operations. During this period, schemes are coordinated into higher-order systems (cognitive structures) which render them increasingly powerful. Piaget calls such schemes operations and emphasizes the fact that they are now reversible by virtue of their relation to other schemes within the system. For example, the concrete operational thinker can mentally divide the class of animals into the class of dogs and the class of animals other than dogs and immediately reverse this operation to reconstruct the class of animals from its subclasses. The integration of such inverse operations within the higher-order cognitive structure of classification yields a more sophisticated grasp of the relation between subclasses and superclasses. This would include, for example, the understanding that the class of dogs is necessarily no larger than its superclass of animals, whereas the class of dogs is smaller than the class of insects only as a matter of empirical fact.

Finally, beginning about the age of 11, we see the gradual construction of higher-order operational structures, those associated with the period of formal operations.

The theory of formal operations

Empirical study of post-childhood cognitive development has blossomed since the 1958 English translation of Inhelder & Piaget's classic The growth of logical thinking from childhood to adolescence, which presented a series of ingenious and influential studies of scientific reasoning by Inhelder as well as Piaget's definitive elaboration of his theory of formal operations. The preponderance of research in the area since then has consisted of attempts to support, refute, extend, or refine this extremely influential and controversial theory. We will not even attempt to review the hundreds of empirical studies inspired by Inhelder and Piaget’s work (for recent review and analyses of this literature, see Berzonsky, 1978; Brainerd, 1978; Broughton, 1977; Ginsburg and Opper, 1979; Keating, 1979; Kuhn, 1979 a,b; Labouvie-Vief, 1980; Moshman & Neimark, 1981; Moshman & Thompson, 1981; Neimark, 1975, 1979, 1980; Piaget, 1972; Stone & Day, 1980; Strauss & Kroy, 1977; Tomlinson-Keasey, 1980; Wason, 1977). Suffice it to note the overwhelming evidence that, contrary to what Inhelder and Piaget originally suggested, the construction of formal operational reasoning seems to be far from complete by the age of 14 or 15 but, rather, extends at least through the college years. Thus, the following account of formal operational thinking should be viewed not as a description of the typical reasoning of college students but rather as an ideal toward which their cognitive development is tending.

Piaget, in order to be as precise as possible about the structure of formal operations attempts to characterize it in terms of a highly abstract logico-mathematical model embodying the “group” and “lattice” properties explored by twentieth-century structural mathematicians. We will not discuss the model here, however, since it would take considerable space and presentations of it are available elsewhere (e.g., Neimark, 1975). Moreover, the relation of the model to the empirical phenomena of formal operational thinking is unclear and it is reported that even Piaget himself is unhappy with the model and has been working on an alternative. Instead, we will attempt to characterize formal reasoning in terms of three basic and closely interrelated properties: (a) the inversion of reality and possibility; (b) hypothetico-deductive reasoning; and (c) operations on operations.

Of course, it is the first that Piaget sees as most fundamental:

There is no doubt that the most distinctive feature of formal thought stems from the role played by statements about possibility relative to statements about empirical reality (Inhelder & Piaget, 1958, p. 245).

Without question, preformal thinkers—even very young children—frequently consider possibilities. These possibilities, however, are extensions of, or alternatives to, reality. Only at the formal level, does the individual systematically construct possibilities for use as a backdrop against which to view reality. Reality, then, is not abandoned in favor of fantasy but, rather, reconstrued with greater depth and subtlety as a result of seeing it as a particular realization within a broader set of possibilities. Thus, for example, the preformal thinker has generally learned certain moral values, political ideologies, role systems, and so forth from the surrounding culture. To the extent that alternatives are considered (e.g., through learning about the moral values or sex role arrangements or another culture or subculture), these are likely to be seen with reference to the learned reality and thus evaluated as unorthodox, probably as somewhat peculiar, and perhaps as positively deviant. The formal thinker, by contrast, is able to construct a variety of possible moral systems, sex role arrangements, political ideologies, etc., and evaluate those with which she or he is familiar from this broader perspective. There is thus a radical reversal of perspectives in that rather than considering the possibilities with respect to reality, reality is considered with respect to the possibilities. The central difference between the preformal and formal thinker, then, lies in the ability to spontaneously and systematically generate possibilities and, even more important, to rethink realities in the light of these possibilities.

Integral to this new use of possibilities is hypothetico-deductive reasoning, the ability to pursue a logical line of though that begins with a purely hypothetical—or even contrary to fact—assertion. The difference between this and concrete reasoning is not in the ability to make a deductive inference but in the understanding that such an inference can be made even from a false or uncertain premise. Thus, for example, even a concrete thinker would recognize the logic of the transitive inference, "If elephants are bigger than dogs, and dogs are bigger than mice, then elephants are bigger than mice." Such a thinker would, however, be dubious of the argument "If mice are bigger than dogs, and dogs are bigger than elephants, then mice are bigger than elephants," pointing out that mice are not bigger than dogs, dogs are not bigger than elephants, etc. Only a formal thinker would recognize that although the premises in the second argument are false, and the conclusion thus cannot be counted on, the form of the second argument is identical to that of the first, and thus equally valid.

Hypothetico-deductive reasoning is central to the reductio ad absurdum strategy in logic. This is a technique used in cases where a proposition cannot be directly disconfirmed. Instead it is assumed to be true and its implications are deduced. If one of those deductions leads to an outright falsity, it can be assumed that the initial assumption which enabled that falsity to be logically inferred must have been in error and thus the initial proposition can be rejected. The identical technique is basic to inferential statistics, in which a null hypothesis is assumed and its implications calculated and compared to the actual empirical results of the experiment. The intent, in most cases, is to find a discrepancy and thus reject the null hypothesis. In cases such as these the central difficulty for the preformal reasoner is likely to be not the particular deductions or calculations to be made but rather than entire concept of beginning a line of reasoning with an assumption whose truth is uncertain and in many cases explicitly doubted. To take the simplest possible example, when asked about the assertion “If grass is pink, then grass is pink” (Osherson & Markman, 1975), the prototypical formal response would be “Yes, if it’s pink, then obviously it’s pink,” while the prototypical (content-oriented) concrete response would be “No, it’s green.”

One additional characteristic of formal operations, closely related to both the preceding, is that they are operations on operations, or second-order operations. That is, whereas concrete operations act directly on representations of reality, formal operations involves a coordination of these direct, first-order operations into more abstract higher-order systems. Thus, for example, a concrete thinker could divide a set of books into fiction and nonfiction, or into hardbound and paperbound, or could multiply these two classifications to yield four: hardbound fiction, hardbound nonfiction, softbound fiction, and softbound nonfiction. Only at the formal level, however, is it possible to classify these classes themselves. Thus, for example, the formal thinker would understand that the first three of these four classes may be classified together as involving books that are hardbound and/or fiction. Similarly, it is a simple enough task to put a number of items in a series, but formal operations are required to engage in second-order seriation, that is, to seriate a number of series in such a way as to systematically and efficiently produce all the possible permutations of the items involved (e.g. how many license plates can be made from the letters A, B, C, and D?). One last example of second-order operations is the comprehension of proportionality (2 is to 4 as 3 is to 6), which require that one not simply consider two relations at once (2/4 and 3/6) but consider a particular second-order relation (equality, in this case) between the two relations.

Cognitive development and genetic epistemology

In concluding this necessarily sketchy account of Piaget’s theory of cognitive development, it may be helpful to place it in broader perspective in two ways: First, by considered alternative approaches to cognitive development, and second, by placing Piaget’s approach within the broader context of his life’s work. Both perspectives may help us get a better sense of both the scope and limitations of Piaget’s work for the college instructor.

There is no dearth of theoretical approaches to the study of cognitive development, each of which leads to a somewhat different view of the nature and development of post-childhood cognition. The most influential current alternative to Piaget’s constructivism/structuralism is the information-processing approach (e.g. Siegler, 1976), which attempts to precisely specify current knowledge and processing capacities of the individual, processing demands of various cognitive tasks, and the interaction between these which determines the sequence of real-time mental operations involved in cognition. Other current approaches include (a) the dialectical approach, emphasizing the dynamic interactions of an active, developing individual and an equally active and changing environment (e.g., Riegel, 1979); (b) the social learning approach, emphasizing the influence of social models (e.g., Rosenthal & Zimmerman, 1978); and (c) the psychometric approach, analyzing the sources of variance in cognitive ability (e.g., Keating, 1979). Moreover, there have been some attempts to synthesize different approaches—most notably, (a) Pascual-Leone's Theory of Constructive Operators, a neo-Piagetian synthesis of Piagetian and information-processing considerations (e.g., Case, 1974), and (b) Sternberg's Componential Analysis, a synthesis of information-processing and psychometric concerns (e.g., Sternberg & Rifkin, 1979). Though many of these alternative perspectives are interesting and potentially important, however, none of them seems yet to have provided a well worked-out alternative to Piaget's insightful and broadly applicable account of changes in the organization of cognition or to match the wealth of empirical data accumulated with the Piagetian framework.

It thus seems reasonable to use Piaget's theory as the basis for educational application. Nevertheless, it is important to keep in mind that Piaget is not primarily an educational researcher, nor even a psychologist: He is first and foremost the founder of a new discipline that he calls genetic epistemology. Epistemology, the study of knowledge, has traditionally been a branch of philosophy. The term "genetic" is used here by Piaget not in the sense of genes (heredity, etc.) but in the sense of genesis (origins, development, etc.). By focusing on the development of knowledge, rather than logically analyzing its static manifestations, Piaget hopes to turn the study of knowledge into an empirical discipline, a branch of science rather than a branch of philosophy. His six decades of work on the development of knowledge has encompassed topics as seemingly diverse as the evolution of species, the cognitive development of children, and the history of scientific disciplines, though always within the unifying perspective of genetic epistemology. For the genetic epistemologist, the development of knowledge—whether within a species, a culture, a scientific discipline, or an individual mind—is always an active process of construction, yielding increased equilibrated (organized and adapted) schemes of knowing, though without ever attaining any sort of absolute truth.

As a result of this genetic epistemological perspective, Piaget has been relatively uninterested in social, moral, and affective development, in individual differences, and in the particularities of learning, as opposed to the universalities of development. Though all of these issues have received some attention in his voluminous writings, it is clear that we need to go beyond his work in dealing with these areas. The following chapters will attempt to do precisely that.

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