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Thinking at Piaget's Stage of Formal Operations

Piaget set the groundwork by describing what children can do at each stage of development; new research focuses on actual use of these capabilities.

Piaget's theory of cognitive development changed the way psychologists and educators view children's intellectual development. However, with the widespread acceptance of Piaget's insight and theory has also come research that modifies and refines his contribution.

According to Piaget, there are four major stages of development: the sensory-motor, the pre-operational, the concrete operational, and the formal operational. Children within each of these stages think about the world and attempt to solve problems in similar ways. Piaget characterized these stages in children's thought using "logico-mathematical models."

Children enter the stage of formal operations at 11 or 12 years of age when their thinking about the world changes (Inhelder and Piaget, 1958). Consider the following task, which has often been used to study formal operational thought.

An individual is presented with a set of rods made of different materials (plexiglass, wood, steel). They also differ in diameter (thin, medium, and thick) and length (short, medium, long). On a table is a stand in which two rods may be placed beside each other, parallel to the table and about 24 inches above it. There are two equal weights that may be hung from the ends of the rods. The individual is given the following instructions:

> Here are some rods that differ from each other. Some of these rods bend more than the others. Find out what characteristics of the rods influence how much they bend. You can place pairs of rods in this stand to try to find out what influences bending. Tell me why you choose each pair of rods you test, and what you can conclude from the test.

John, a child in the concrete operational stage, initially selects a long thin wooden rod and a short thick steel rod simply to find out what happens. After observing that the long wooden rod bends more, John concludes that long rods bend more than short ones. He makes no comment about the other differences. For the

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next comparison, John selects a long steel rod and a short plexiglass rod of equal diameter. When he observes that the plexiglass rod bends more than the longer steel rod, he comments that "glass bends more than steel" and does not notice that the plexiglass rod is *shorter* than the steel rod. In the next comparison, John states ahead of time that he wants to test for the effect of diameter. He selects a thick plexiglass rod and a thin steel rod. The plexiglass rod bends more than the steel rod, so he concludes that thicker rods bend more. When he is asked if a comparison between a thick plexiglass rod and a thin plexiglass rod would be better, he argues that his comparison was better because the rods were "more different."

The performance of the ideal "formal operational" individual is noticeably different. Karen, for example, notes that length, material, and diameter might all be important. She selects a pair of rods that vary on only one characteristic—a long thin steel rod and a short thin steel rod—and states that she wants to see if length influences bending. She then goes on to test for the effects of material and diameter, using the *control-of-variables strategy;* that is, she makes sure the rods are the same except for the one characteristic she is testing.

The difference in the approach of these two individuals demonstrates some of the major features of formal operational thought. First, the formal operational child thinks about the *real* and the *possible* differently than does the concrete operational child, who starts with the real and works toward the possible. John simply selected two pairs that were different "to see what happens." In contrast, Karen, a formal operational thinker, considered what might be possible first; she hypothesized that certain characteristics of the rods might be important, and then attempted to determine if, in reality, they were.

Second, the formal operational individual's thought can be described as *hypothetico-deductive* in nature. The formal thinker is able to construct hypotheses to account for particular phenomena, deduce from these hypotheses that certain events should occur, and test the hypotheses by finding out if the events do occur. For example, Karen hypothesized that length makes a difference, and deduced that if it does, there will be a difference in how much a long and a short rod of the same material and diameter will bend.

Third, the formal thinker is able to combine systematically a set of elements to create all possible combinations. This ability contributes to use of the control-of-variables strategy.

A fourth characteristic, which is not cogently demonstrated in the bending rods task, is the formal thinker's ability to consider only the logical relations between statements while ignoring the concrete content. The formal operational child can even draw logically appropriate conclusions from invalid premises. For example, if given the premises "elephants are smaller than horses" and "horses are smaller than dogs," he or she can conclude that "elephants are smaller than dogs" even though this statement does not coincide with concrete reality. A concrete operational child would find it difficult to ignore the "factual" content.

Additional characteristics are often used to describe formal operational thought, but those given here demonstrate some of its primary features. Although the rods task highlights the importance of formal operational thought for "scientific" tasks, such thought is a part of many other cognitive activities such as advanced reading comprehension, making inferences from information given, and evaluating the adequacy of persuasive arguments. In sum, formal operational skills are important for functioning in a complex, democratic society. Whether one is selecting a political candidate, trying to determine the best buy on a car, or attempting to evaluate alternative explanations of current social events, formal operational skills are essential.

Competence vs. Performance

While the research tends to support Piaget's assertion that formal operational skills are not characteristic of children younger than 11 or 12 years of age, it has led to some doubt that such skills are universal in older children and adults.

Piaget's position has often been used to predict that one who can think in a formal operational manner will always do so. However, only about 50 percent of those over 12 years of age who are presented with tests of formal operations perform in what would be considered a formal operational manner. This is true of college-educated adults as well as adolescents. In addition, even people who use formal operational skills on one task may not use them on another.

These unexpected results have prompted a variety of responses. One is that Piaget was wrong; formal operations is not a stage attained by everyone. A second response came from Piaget himself. He maintained that all individuals attain formal operations, but perhaps only in areas with which they have had much experience (Piaget, 1972). A third approach has been to reexamine the meaning of the term "stage." A stage can be viewed as a description of all cognitive activity that occurs during the stage (or cognitive *performance*), or it can be viewed as a description of the highest level cognitive activity of which one is capable (cognitive *competence*).

The available data tend to support the second and third alternatives rather than the first. Cross-cultural data indicate that even individuals with no formal schooling can think "formally" when dealing with a familiar topic (Tulkin and Konner, 1973). Furthermore, a substantial body of research indicates that children over the age of 12 or so can easily be prompted to use formal operational skills even if they do not spontaneously demonstrate such skills (Stone and Day, 1978). It is much more difficult to teach children under 12 years of age formal operational skills; even if they do learn such skills, younger children are less likely to use them in other situations. Thus it seems appropriate to think of Piaget's stages as descriptions of *competence*—the behavior of which one is capable—rather than of cognitive performance that occurs in all situations.

If Piaget's theory is viewed mainly as a theory of competence, however, some complementary theory is clearly needed to explain why one who can think "formally" may not always do so. Such a theory would be concerned with moment-to-moment cognitive activity on a particular task.

Several theoretical approaches are currently guiding developmental research on the specific cognitive activities that occur during problem solving.

For example, instead of describing the *competence* of children at each stage using logico-mathematical structures, Case describes actual cognitive processes in terms of strategies (Case, 1978b; Pascual-Leone, 1970). He calls them *executive strategies* because they integrate and orchestrate lower-level cognitive skills. Case interprets Piaget's stages as being made up of sets of executive strategies. At the higher stages, the strategies are more complex and more powerful than they are at the lower stages.

The strategies a child can easily use at a given stage are similar in the *number* of pieces of information that have to be remembered while using the strategy to solve a problem. For example, solving a problem in a formal operational manner requires the individual to remember more during its solution than solving it in a concrete operational manner. According to Case, the "working memory" of the child increases gradually until 11 or 12 years of age. At this time the adolescent can hold at least five pieces of information in mind while working on a problem. This change in working memory capacity is slow and is based on general experience. It is because of this increase in "working memory" that older children are able to construct and use more complex strategies. Because children of similar ages have similar "working memories," they attempt to solve problems somewhat similarly, and appear to be in the same stage of mental development.

Case goes beyond Piaget, however, in attempting to specify the factors that influence a child's use of a particular strategy. These factors include (1) the child's experience with the materials involved in a problem; (2) the child's opportunity to learn the needed strategy; (3) the amount of practice a child has had on the basic skills needed to solve the problem; and (4) the child's cognitive style (or habitual approach to defining poorly structured situations). All these factors would influence whether a child with a working memory capacity of five items, for example, is able to and will solve a particular problem in a formal operational way.

According to this theory, a child might have enough "working memory" capacity to solve a problem in a formal operational manner but lack some of the other necessary components. For example, if one knows the control-of-variables strategy but is confronted with a completely novel problem, one might not initially know what variables *might be* important. Imagine that someone who has never worked on cars is trying to figure out why a car won't start. Without some specific knowledge about how the car works, the person would not know how to apply the strategy. Here it would not be at all surprising to see a formal operational thinker perform in a concrete operational manner.

Thus Case's approach, unlike Piaget's, explicitly considers the various cognitive components involved in using a strategy characteristic of any stage of cognitive development.

Others in addition to Case are also focusing on specific cognitive activities involved in problem solving. One area showing special promise and currently receiving much attention is *metacognition*—one's thought about one's own cognitive processes. Thinking about which of several cognitive strategies would be most useful for solving a problem falls under the rubric of metacognition. Obviously such skills are required for good problem solving (Brown and DeLoache, 1978).

Implications for Education

One major benefit of this new direction in developmental theory and research is its direct relevance to education. Piaget's theory emphasized the importance of the child's own activity and the crucial role of experiences slightly above the child's current level of functioning for fostering development. However, Piaget's work did not emphasize instruction in either particular strategies or particular content areas. In contrast, the finer-grain of theories of cognitive performance (like that of Case), with their emphasis on the components of strategy use, do have specific implications for education. If we know what cognitive processes are involved in the use of a particular strategy, we are in a position to teach the processes and therefore the strategy. Indeed, Case has detailed his theory's implications for instruction and successfully tested instructional programs for strategies in several content areas (Case, 1978a).

In summary, Piaget's theory and theories like Case's are complementary. Piaget provides a description of the reasoning of which people are capable at each of his four stages. As research on formal operations has demonstrated, his stage

MAJORING IN THINKING

A graduate program for teachers at the University of Massachusetts uses an interdisciplinary approach and team teaching to provide students with a clear understanding of cognition and to improve their own thinking skills. Students specialize in critical and creative thinking in science, literature and the arts, or in moral decision making. The program also includes courses in cognitive psychology, philosophical thought, and subject area disciplines.

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description does not specify whether people can or will reason spontaneously in a formal operational manner, but only what they *can* do given appropriate experiences, instruction, or motivation. In contrast, theories like Case's are focused on the particular cognitive processes that are integrated in actual strategy use. They deal with cognitive *performance* (for a more detailed discussion of this distinction see Stone and Day, 1980).

The need for complementary competence and performance theories is highlighted (1) by the finding that adolescents and adults do not always and spontaneously think "formally" and (2) by the finding that they can easily be taught formal operational strategies. The apparent ease of learning formal operational strategies after age 12 is encouraging for those who think, as I do, that the use of "formal" thought is critical in everyday situations. ■

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Matching Curriculum to Students' Cognitive Levels

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Although Piaget postulated that most adolescents possess the mental structures required for formal reasoning, Epstein (1978, 1980) reports that only 34 percent of all adolescents attain formal thought. This discrepancy raises the possibility that schools may be able to develop abstract thinking in a greater percentage of students.

To this end, the Shoreham-Wading River School District has implemented a comprehensive program of inservice education in a project called Cognitive Level Matching. To date, approximately 65 of the district's 200 teachers have participated.

Purposes of the inservice education are to sensitize teachers to the process of cognitive development and to enable them to: (1) assess the cognitive abilities of their students; (2) assess the cognitive demands of school-based inputs including curriculum, social interaction, teaching/questioning techniques; and (3) match, as closely as possible, the demands of the curriculum with student cognitive abilities. Creating this match is the cornerstone of our project.

Approximately 600 middle school students have been given Arlin's *Test of Formal Reasoning* (1980) in order to determine their cognitive abilities. Unlike most Piagetian tests, Arlin's is a paper-and-pencil test, requiring only one hour for completion, administered to large groups of students with minimal teacher direction. Simultaneously, participating teachers have been examining existing school-based inputs and making adaptations and modifications, as well as developing new approaches. Peer-teacher observations, teamwork, and the development of new taxonomies are components of their examination.

Although the Cognitive Level Matching project is in its first year, much has already been achieved. Curriculum units have been developed that enable teachers to match inputs to the wide range of cognitive abilities found in most heterogeneously organized classrooms. The curriculum units will become part of a teacher resource file.

At the conclusion of three years, Arlin's test will be readministered to the middle school and high school students. We expect to find a greater percentage of them reasoning on the formal level than our original testing revealed. ■

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