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Child Development and Education

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they can envision multiple approaches to the same problem and recognize that each approach may be valid from a particular perspective (Cartwright, Galupo, Tyree, & Jennings, 2009; Sinnott, 2009; P.-L. Wu & Chiou, 2008). Other theorists disagree, arguing that adult life simply poses different kinds of problems than the academically oriented ones that adolescents encounter at school (Schaie & Willis, 2000).

Effects of Prior Knowledge and Experience

Piaget acknowledged that as children gain new logical thinking skills, they may apply the skills in one content area but not necessarily in another (Chapman, 1988; Piaget, 1940). It is becoming increasingly apparent that for people of all ages, the ability to think logically in a particular situation depends on background experiences relevant to the situation. Children as young as age 4 or 5 begin to show class inclusion and conservation after having practice with such tasks, especially if they can actively manipulate the task materials and discuss their reasoning with someone who already exhibits these logical abilities (D. Field, 1987; Halford & Andrews, 2006; Siegler & Svetina, 2006). Children ages 10 to 12 years old can solve logical problems involving hypothetical ideas if they are taught relevant problem-solving strategies, and they become increasingly able to separate and control variables when they have numerous experiences that require them to do so (Kuhn & Dean, 2005; Kuhn et al., 2009; S. Lee, 1985; Schauble, 1990). Adolescents and adults as well often apply advanced reasoning to topics about which they have a great deal of knowledge and yet think concretely about topics with which they are unfamiliar (Klein, 2006; Kuhn, 2008; M. C. Linn, Clement, Pulos, & Sullivan, 1989). Thus it appears that what young people learn, with support, is how to think systematically about a few particular concepts rather than how to use all-purpose logical principles in all circumstances.

As an illustration of how prior knowledge affects formal operational thinking, consider the fishing pond shown in Figure 4. In a study by Pulos and Linn (1981), 13-year-olds were shown a similar picture and told, "These four children go fishing every week, and one child, Herb, always catches the most fish. The other children wonder why." If you look at the picture, it is obvious that Herb is different from the three other children in several ways, including the bait he uses, the length of his fishing rod, and his location by the pond. Children who had fished frequently more effectively separated and controlled variables for this situation than they did for the pendulum problem described earlier, whereas the reverse was true for children without fishing experience. In the "Cognitive Development" videos for middle childhood and late adolescence in MyEducationLab, 10-year-old Kent and 14-year-old Alicia both consider the problem as they look at the picture in Figure 4. Notice how Kent, who appears to have some experience with fishing, considers several possible variables and remains open minded about the causal one. In contrast, Alicia, who is older but admittedly unfamiliar with fishing strategies, considers only two variables and jumps to a conclusion about causation:

Kent: He has live . . . live worms, I think. Fish like live worms more, I guess 'cause they're live and they'd rather have that than the lures, plastic worms. . . . Because he might be more patient or that might be a good side of the place. Maybe since Bill has a boombox thing [referring to the radio], I don't think they would really like that because . . . and he doesn't really have anything that's extra. . . . But he's the standing one. I don't get that. But Bill, that could scare the fish away to Herb because he's closer. . . .

Alicia: Because of the spot he's standing in, probably. . . . I don't know anything about fishing. Oh, OK! He actually has live worms for bait. The other girl's using saltine crackers [she misreads *crickets*]. . . . She's using plastic worms, he's using lures, and she's using crackers and he's actually using live worms. So obviously the fish like the live worms the best.

MyEducationLab

Observe how experience with fishing affects Kent's and Alicia's ability to identify variables in the "Cognitive Development" videos. (Find Video Examples in Topic 6 of MyEducationLab.)

One general factor that promotes more advanced reasoning is formal education. Going to school and receiving instruction are associated with mastery of concrete operational and formal operational tasks (Artman & Cahan, 1993; Gauvain & Munroe, 2009; Rogoff, 2003). For instance, you may be happy to learn that taking college courses in a particular area (in

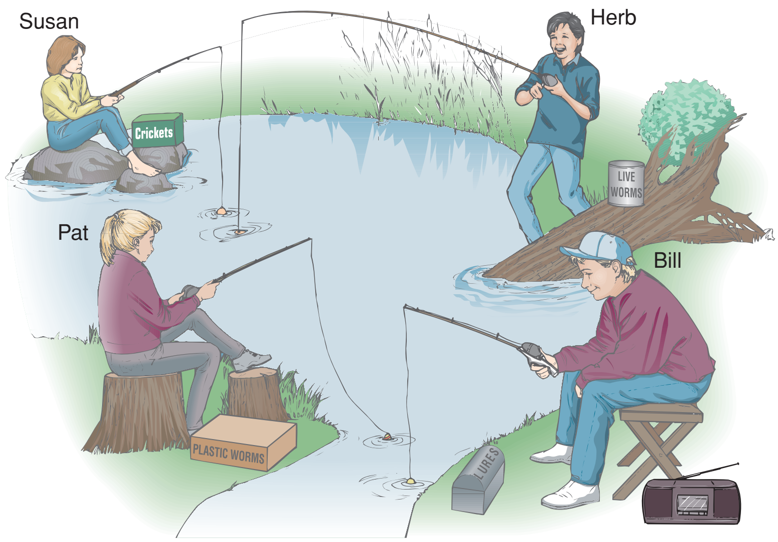


FIGURE 4 **Gone fishing.** What are some possible reasons why Herb is catching more fish than the others?
Based on Pulos & Linn, 1981.

child development, perhaps?) leads to improvements in reasoning skills related to that area (Lehman & Nisbett, 1990; T. M. McDevitt, Jobes, Sheehan, & Cochran, 2010).

Effects of Culture

Piaget acknowledged that children grow intellectually as they reflect on their exchanges with people and objects in their cultural environments. He further recognized that cultural variations in intellectual opportunities could lead to modest differences in children's skills (Piaget, 1972). Yet many contemporary theorists now conclude that Piaget did not fully understand how powerfully culture shapes children's minds or how strongly his own theory reflected the Western position that scientific reasoning is the pinnacle of human development (Maynard, 2008).

Considerable research indicates that Piaget was more on target about younger children developing similar abilities in a wide range of cultural situations than he was in his assumption about universal advancements in older children. Infants in all known cultures learn a lot from exploring their physical environment, and young children in the preschool years universally represent their ideas with language and intuitive logic. In comparison, concrete and formal operational abilities are more susceptible to particular cultural experiences. For example, Mexican children whose families make pottery for a living seem to acquire conservation skills earlier than Piaget found to be true for Swiss children (Price-Williams, Gordon, & Ramirez, 1969). Apparently, creating pottery requires children to make frequent judgments about needed quantities of clay and water—judgments that must be fairly accurate regardless of the specific form of the clay or water container. In other cultures, especially in some where children don't attend school, conservation may appear several years later than Piaget proposed, and some aspects of formal operational reasoning—at least as measured by Piaget and colleagues—do not appear when abstract reasoning has little relevance to people's daily lives (M. Cole, 1990; Fahrmeier, 1978; Maynard, 2008; J. G. Miller, 1997). For instance, adults in some Asian societies find little purpose in applying rules of logic to artificial, contrary-to-fact situations and so don't nurture such thinking in children (Norenzayan, Choi, & Peng, 2007).

Does Cognitive Development Occur in Stages?

In light of all the evidence, does it still make sense to talk about discrete stages of cognitive development? Even Piaget acknowledged that the characteristics of any particular stage don't necessarily hang together as a tight, inseparable set of abilities (Chapman, 1988; Piaget, 1940). Most contemporary developmental theorists now believe that children do *not* universally go through stages in all-encompassing logical structures. Today's theorists further suggest that Piaget's evidence about children's abilities may better describe how children *can* think, rather than how they typically *do* think (K. W. Fischer, Stein, & Heikkinen, 2009; Halford & Andrews, 2006; Klaczynski, 2001).

In addition to reformulating the essence of thinking, contemporary scholars are recasting the nature of developmental change. One group of theorists, *information processing theory* scholars, subscribe to the view that development can be described in terms of gradual *trends*—for instance, in gradual movements toward increasingly abstract thought—rather than discrete stages (e.g., Flavell, 1994; Kuhn & Franklin, 2006; Siegler & Alibali, 2005).[4] Another group, *developmental systems* scholars, believe that each child's thinking is unique and develops at an uneven pace, at any given moment improving rapidly, slowly or through a combination of progressions and temporary regressions (K. W. Fischer, 2008; Hohenberger & Peltzer-Karpf, 2009).

Despite their reservations about Piaget's global structures and stages, present-day developmental scholars remain sympathetic to Piaget's search for qualitative transformations in children's constructivist thinking. They believe that, by entirely rejecting Piaget's search for stages and constructivist ideas, we may be throwing the baby out with the bath water. Some of these psychologists have combined Piaget's ideas with precise research methods to construct **neo-Piagetian theories** of how children's learning and reasoning capabilities change over time.

Key Ideas in Neo-Piagetian Theories

Neo-Piagetian theorists share Piaget's belief that children's skills and understandings change in distinct, qualitative ways over time. Unlike Piaget, however, they suggest that children's abilities are strongly tied to personal experiences in particular contexts. Following are several principles that are central to neo-Piagetian approaches:

Cognitive development is constrained by the maturation of information processing mechanisms. Neo-Piagetian theorists have echoed Piaget's belief that cognitive development depends on brain maturation. A mechanism in the brain known as **working memory** is especially important for cognitive development (e.g., Case, 1985, 1991; Davidse, de Jong, Bus, Huijbregts, & Swaab, 2011; Morra et al., 2008). Working memory is that part of the human memory system in which people hold and actively think about new information. (For instance, you are using your working memory right now to make sense of what you're reading about cognitive development.) Children's working memory capacity increases with age, and so their ability to think about several things simultaneously increases as well. Neo-Piagetian theorists propose that young children's limited working memory capacity restricts their ability to acquire complex thinking, reasoning, and language skills (Barrouillet, Gavens, Vergauwe, Gaillard, & Camos, 2009; K. W. Fischer & Bidell, 1991; Morra & Camba, 2009).

Children acquire new knowledge through both unintentional and intentional learning processes. Many contemporary psychologists agree that children learn some things with little or no conscious awareness or effort. Consider this question about household pets: "On average, which are larger, cats or dogs?" Even if you've never intentionally thought about this issue, you can easily answer "Dogs" because of the many characteristics (including size) you've learned to associate with both species. Children unconsciously learn the consistent patterns and associations that characterize many aspects of their world.

Yet, especially as children's brains mature in the first year or two of life, they increasingly think actively about their experiences, and they begin to devote considerable mental

neo-Piagetian theory
Theoretical perspective that combines elements of Piaget's theory with more contemporary research findings and suggests that development in specific content domains is often stagelike in nature.

working memory
Component of memory that enables people to actively think about and process a small amount of information.

[4] *Information processing theory* characterizes the general trends in cognitive processes that we are likely to see as children develop.

attention to solving the little problems that come their way each day (Case & Okamoto, 1996; Pascual-Leone, 1970). As they do so, they draw on what they've learned (some of which they have absorbed unconsciously) about common patterns in their environment, and they may simultaneously strengthen their knowledge of those patterns. Thus both the unintentional and intentional learning processes work hand in hand as children tackle day-to-day tasks and, in the process, enhance their knowledge about the world (Case, 1985; Case & Okamoto, 1996; Weinert, 2009).

Children acquire cognitive structures that affect their thinking in particular content domains. Neo-Piagetian theorists reject Piaget's proposal that children develop general-purpose systems of mental processes (operations) that they can apply to a broad range of tasks and content domains. Instead, they suggest, children acquire more specific systems of concepts and thinking skills that influence reasoning in particular areas.

Canadian psychologist **Robbie Case** (1944–2000) and his colleagues have proposed that integrated networks of concepts and cognitive processes, called **central conceptual structures**, form the basis for much of children's thinking, reasoning, and learning in certain areas (Case, 1991; Case & Okamoto, 1996; S. Griffin, 2009). A central conceptual structure related to *number* underlies children's ability to reason about and manipulate mathematical quantities. This structure reflects an integrated understanding of how such mathematical concepts as numbers, counting, addition, and subtraction are interrelated. A central conceptual structure related to *spatial relationships* underlies children's performance in such areas as drawing, construction and use of maps, replication of geometric patterns, and psychomotor activities (e.g., writing in cursive, hitting a ball with a racket). This structure enables children to align objects in space according to one or more reference points (e.g., the *x*- and *y*-axes used in graphing). A central conceptual structure related to *social thought* underlies children's reasoning about interpersonal relationships, their knowledge of common patterns in human interaction, and their comprehension of short stories and other works of fiction. This structure includes children's general beliefs about human beings' thoughts, desires, and behaviors. Case has found evidence indicating that the three conceptual structures develop in a wide variety of cultural and educational contexts (Case & Okamoto, 1996).

Development in specific content domains can sometimes be characterized as a series of stages. Although neo-Piagetian theorists reject Piaget's notion that a single series of stages characterizes cognitive development, they speculate that cognitive development in specific content domains often has a stagelike nature (e.g., Case & Okamoto, 1996; K. W. Fischer & Immordino-Yang, 2002; Morra et al., 2008). Children's entry into a particular stage is marked by the acquisition of new abilities, which children practice and gradually master over time. Eventually, they integrate these abilities into more complex structures that mark their transition into a subsequent stage.

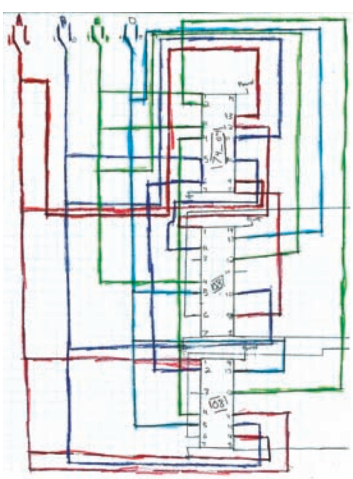
Even in a particular subject area, however, cognitive development is not necessarily a simple sequence of stages through which children progress as if they were climbing rungs on a ladder. In some cases development might be better characterized as progression along "multiple strands" of skills that occasionally interconnect, consolidate, or separate in a weblike fashion (K. W. Fischer, 2008; K. W. Fischer & Daley, 2007; K. W. Fischer & Immordino-Yang, 2002). From this perspective, children may acquire more advanced levels of competence in a particular area through any one of several pathways. For instance, as they become increasingly proficient in reading, children may gradually develop word decoding skills, comprehension skills, and so on and draw on these assorted skills when reading a book. However, the rate at which each of the skills is mastered will vary from one child to the next.

central conceptual structure
Integrated network of concepts and cognitive processes that forms the basis for much of one's thinking, reasoning, and learning in a specific content domain.

CENTRAL CONCEPTUAL STRUCTURES. According to Robbie Case's neo-Piagetian perspective, children develop central conceptual structures in number, spatial relationships, and social thought (and perhaps in other areas as well). These structures affect children's reasoning and performance on a variety of relevant tasks. (left) © Ariel Skelley/Corbis; (center) Getty Images, Inc - PhotoDisc; (right) © Radius Images/Alamy

Preparing for Your Licensure Examination

Your teaching test might ask you about Piaget's major contributions to educational practice.



ARTIFACT 1 Habtom's circuit board. Fifteen-year-old Habtom designed a circuit board with the help of his engineering teacher, who advised him about the characteristics of electronic chips (see vertical boxes with internal numbers toward the middle-right of the artifact) and connections among the binary switches. Using formal reasoning, Habtom designed the circuit board, built it, and confirmed that it actually worked.

Applying the Ideas of Piaget and His Followers

Educators and practitioners who have taken Piaget's theory to heart respect the natural curiosity of children, give children many opportunities to make choices, and appeal to children's interests. Adults who are inspired by Piaget have tried these specific strategies:

• **Provide opportunities for children to experiment with physical objects.** Learners of all ages, but particularly children, can learn a great deal by exploring the physical world in a hands-on fashion (Ginsburg et al., 2006; Parton & Hancock, 2008; B. Y. White & Frederiksen, 1998). In infancy this might involve having regular access to objects with visual and auditory appeal, such as mobiles, rattles, stacking cups, and pull toys. At the preschool level, it might involve playing with water, sand, wooden blocks, and age-appropriate manipulative toys. During the elementary school years, hands-on exploration might entail throwing and catching balls, working with clay and watercolor paints, and constructing Popsicle-stick structures. Despite their increased capability for abstract thought, adolescents also benefit from opportunities to manipulate and experiment with concrete materials—perhaps equipment in a science laboratory, food and cooking utensils, or wood and woodworking tools. Such opportunities allow teens to discover laws of the natural world firsthand and to tie their newly emerging abstract ideas to the concrete physical world.

A potential downside, however, is that children and adolescents sometimes misinterpret what they observe, either learning the wrong thing or confirming their existing misconceptions about the world (M. H. Lee & Hanuscin, 2008; Myant & Williams, 2008; Schauble, 1990). Consider the case of Barry, an 11th grader whose physics class was studying the idea that an object's mass and weight do *not,* in and of themselves, affect the speed at which the object falls. Students were asked to design and build an egg container that would keep an egg from breaking when dropped from a third-floor window. They were told that on the day of the egg drop, they would record the time it took for the eggs to reach the ground. Convinced that heavier objects fall faster, Barry added several nails to his egg's container. Yet when he dropped it, classmates timed its fall at 1.49 seconds, a time very similar to that for other students' lighter containers. He and his teacher had the following discussion about the result:

Teacher:	So what was your time?
Barry:	1.49. I think it should be faster.
Teacher:	Why?
Barry:	Because it weighed more than anybody else's and it dropped slower.
Teacher:	Oh really? And what do you attribute that to?
Barry:	That the people weren't timing real good. (Hynd, 1998, p. 34)

At the elementary and secondary levels, the misconceptions that can arise from spontaneous explorations can be addressed by adding structure to the activities. Carefully planned lessons that allow both exploration and guided interpretation can help children construct appropriate understandings (R. G. Fuller, Campbell, Dykstra, & Stevens, 2009; Hardy, Jonen, Möller, & Stern, 2006; D. T. Hickey, 1997). The Development and Practice feature "Facilitating Discovery Learning" illustrates several recommendations for enhancing the effectiveness of discovery learning activities.

• **Explore children's reasoning with problem-solving tasks and probing questions.** By presenting a variety of Piagetian tasks involving either concrete or formal operational thinking skills and probing students' reasoning with a series of follow-up questions—that is, by

DEVELOPMENT AND PRACTICE

Facilitating Discovery Learning

Make sure students have the necessary prior knowledge for discovering new ideas.

- A first-grade teacher asks students what they already know about air (e.g., people breathe it, wind is air that moves). After ascertaining that the students have some awareness that air has substance, she and her class conduct an experiment in which a glass containing a crumpled paper towel is turned upside-down and completely immersed in a bowl of water. The teacher eventually removes the glass from the water and asks students to explain why the paper towel didn't get wet. (You can see part of this lesson in the "Properties of Air" video in MyEducationLab.) (Middle Childhood)
- Before asking students to study an interactive website on earth science and build a simulated volcano, a high school science teacher introduces types of magma and defines important terms such as *cinder cone*, *lava dome*, *caldera*, and *flood basalt*. (Late Adolescence)

Show puzzling results to create disequilibrium.

- A middle school science teacher shows her class two glasses of water. In one glass an egg floats at the water's surface. In the other glass an egg rests on the bottom. The students give a simple and logical explanation for the difference: One egg has more air inside and so must be lighter. But then the teacher switches the eggs into opposite glasses. The egg that the students believe to be "heavier" now floats, and the "lighter" egg sinks to the bottom. The students are quite surprised and demand to know what is going on. (Ordinarily, water is less dense than an egg, so an egg placed in it will quickly sink. But in this demonstration, one glass contains salt water—a mixture denser than an egg and so capable of keeping it afloat.) (Early Adolescence)
- A high school social studies teacher asks students to decide whether adolescents in the past 60 years can be better characterized as conforming and obedient or rebellious and innovative. The teacher distributes two sets of readings that support each of the conclusions and asks students to study the evidence, determine why there might be a discrepancy in viewpoints, and ultimately justify a position. (Late Adolescence)

Structure a discovery session so that students proceed logically toward discoveries you want them to make.

- Many students in an eighth-grade science class believe that some very small things (e.g., a tiny piece of Styrofoam, a single lentil bean) are so light that they have no weight. Their teacher asks them to weigh a pile of 25 lentil beans on a balance scale, and the students discover that all of the beans together weigh approximately 1 gram. In the ensuing class discussion, the students agree that if 25 beans have weight, a single bean must also have weight. The teacher then asks them to use math to estimate how much a single bean weighs. (Early Adolescence)
- Students in a high school chemistry class bring in samples of household water and beverages and then analyze the amount of carbon dioxide and other chemicals in the fluids. After it is determined that the fluids contain unhealthful levels of acid, the teacher asks the students to brainstorm ways that society can reduce acid rain. (Late Adolescence)

Help students relate their findings to concepts in the academic discipline they are studying.

- A teacher distributes slices of five kinds of apples—Granny Smith, Golden Yellow, Red Delicious, Fuji, and McIntosh—for purposes of taste testing. The teacher asks the children to indicate their first preference for apples, and together they aggregate the results into a graph. The class identifies the most and least favorite apples. Afterwards, the teacher shows the class other examples of graphs and explains how these diagrams are used in various fields of study. (Middle Childhood)
- After students in a social studies class have collected data on average incomes and voting patterns in different counties within their state, their teacher asks, "How can we interpret these data using what we've learned about the relative wealth of members of the two major political parties?" (Late Adolescence)

Sources: Blevins, 2010 (apple chart example); Bruner, 1966; Center for History and New Media, 2006 (teenage conformists and rebels example); de Jong & van Joolingen, 1998; Frederiksen, 1984; Hardy et al., 2006; D. T. Hickey, 1997; R. E. Mayer, 2004; Minstrell & Stimpson, 1996; Palmer, 1965 (egg example); C. L. Smith, 2007 (Styrofoam example); Smithsonian National Museum of Natural History, 2010 (volcano example); Water Educational Training Science Project, 2002 (acid rain example); B. Y. White & Frederiksen, 1998, 2005.