COGNITIVE AND LANGUAGE DEVELOPMENT

chapter **outline**

1 An Overview of Child Development

Learning Goal 1 Define development and explain the main processes, periods, and issues in development, as well as links between development and education.

Exploring What Development Is

Processes and Periods

Developmental Issues

Development and Education

2 Cognitive Development

Learning Goal 2 Discuss the development of the brain and compare the cognitive developmental theories of Jean Piaget and Lev Vygotsky.

The Brain

Piaget's Theory

Vygotsky's Theory

3 Language Development

Learning Goal 3 Identify the key features of language, biological and environmental influences on language, and the typical growth of the child's language.

What Is Language?

Biological and Environmental Influences

How Language Develops

Connecting with **Teachers** Donene Polson

In this chapter, you will study Lev Vygotsky's sociocultural cognitive theory of development. Donene Polson's classroom reflects Vygotsky's emphasis on the importance of collaboration among a community of learners. Donene teaches at Washington Elementary School in Salt Lake City, an innovative school that emphasizes the importance of people learning together (Rogoff, Turkanis, & Bartlett, 2001). Children as well as adults plan learning activities. Throughout the day at school, students work in small groups.

Donene loves working in a school in which students, teachers, and parents work as a community to help children learn (Polson, 2001). Before the school year begins, Donene meets with parents at each family's home to prepare for the upcoming year, getting acquainted and establishing schedules to determine when parents can contribute to classroom instruction. At monthly teacher-parent meetings, Donene and the parents plan the curriculum and discuss children's progress. They brainstorm about community resources that can be used to promote children's learning.

Many students come back to tell Donene that experiences in her classroom made important contributions to their development and learning. For example, Luisa Magarian reflected on how her experience in Donene's classroom helped her work with others in high school:

> From having responsibility in groups, kids learn how to deal with problems and listen to each other or try to understand different points of view. They learn how to help a group work smoothly and how to keep people interested in what they are doing. . . . As coeditor of the student news magazine at my high school, I have to balance my eagerness to get things done with patience to work with other students. (Rogoff, Turkanis, & Bartlett, 2001, pp. 84–85)

As Donene Polson's story shows, theories of cognitive development can form the basis of innovative instructional programs.

Preview

Examining the shape of children's development allows us to understand it better. This chapter—one of two on development—focuses on children's cognitive and language development. Before we delve into these topics, though, we need to explore some basic ideas about development.

1 AN OVERVIEW OF CHILD DEVELOPMENT

- Exploring What Development Is
- Processes and Periods
- Developmental Issues
- Development and Education

Twentieth-century Spanish-born American philosopher George Santayana once reflected, "Children are on a different plane. They belong to a generation and way of feeling properly their own." Let's explore what that plane is like.

EXPLORING WHAT DEVELOPMENT IS

Why study children's development? As a teacher, you will be responsible for a new wave of children each year in your classroom. The more you learn about children's development, the more you can understand at what level it is appropriate to teach them.

Just what do psychologists mean when they speak of a person's "development"? **Development** is the pattern of biological, cognitive, and socioemotional changes that begins at conception and continues through the life span. Most development involves growth, although it also eventually involves decay (dying).

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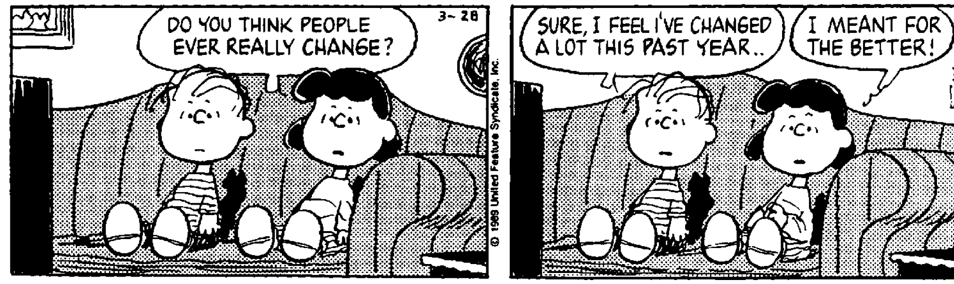
PROCESSES AND PERIODS

The pattern of child development is complex because it is the product of several processes: biological, cognitive, and socioemotional. Development also can be described in terms of periods.



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Biological, Cognitive, and Socioemotional Processes *Biological processes* produce changes in the child's body and underlie brain development, height and weight gains, motor skills, and puberty's hormonal changes. Genetic inheritance plays a large part.

Cognitive processes involve changes in the child's thinking, intelligence, and language. Cognitive developmental processes enable a growing child to memorize a poem, imagine how to solve a math problem, come up with a creative strategy, or speak meaningfully connected sentences.

Socioemotional processes involve changes in the child's relationships with other people, changes in emotion, and changes in personality. Parents' nurturance toward their child, a boy's aggressive attack on a peer, a girl's development of assertiveness, and an adolescent's feelings of joy after getting good grades all reflect socioemotional processes in development.

Biological, cognitive, and socioemotional processes are intertwined. Consider a child smiling in response to a parent's touch. This response depends on biological processes (the physical nature of the touch and responsiveness to it), cognitive processes (the ability to understand intentional acts), and socioemotional processes (the act of smiling often reflects a positive emotional feeling and smiling helps to connect us in positive ways with other human beings). Two rapidly emerging fields are exploring connections across biological, cognitive, and socioemotional processes:

- *developmental cognitive neuroscience,* which explores links between development, cognitive processes, and the brain (de Haan & Johnson, 2016). For example, later in this chapter you will learn about connections between developmental changes in regions of the brain and children's thinking.
- *developmental social neuroscience,* which examines connections between socioemotional processes, development, and the brain (Decety & Cowell, 2016; Monahan & others, 2016). Later in this chapter you will read about developmental changes in the brain and adolescents' risk-taking behavior and peer relations.

DEVELOPMENT

Periods of Development For the purposes of organization and understanding, we commonly describe development in terms of periods. In the most widely used system of classification, the developmental periods are infancy, early childhood, middle and late childhood, adolescence, early adulthood, middle adulthood, and late adulthood.

Infancy extends from birth to 18 to 24 months. It is a time of extreme dependence on adults. Many activities are just beginning, such as language development, symbolic thought, sensorimotor coordination, and social learning.

Early childhood (sometimes called the "preschool years") extends from the end of infancy to about 5 years. During this period, children become more self-sufficient, develop school readiness skills (such as learning to follow instructions and identify letters), and spend many hours with peers. First grade typically marks the end of early childhood.

Middle and late childhood (sometimes called the "elementary school years") extends from about 6 to 11 years of age. Children master the fundamental skills of reading,

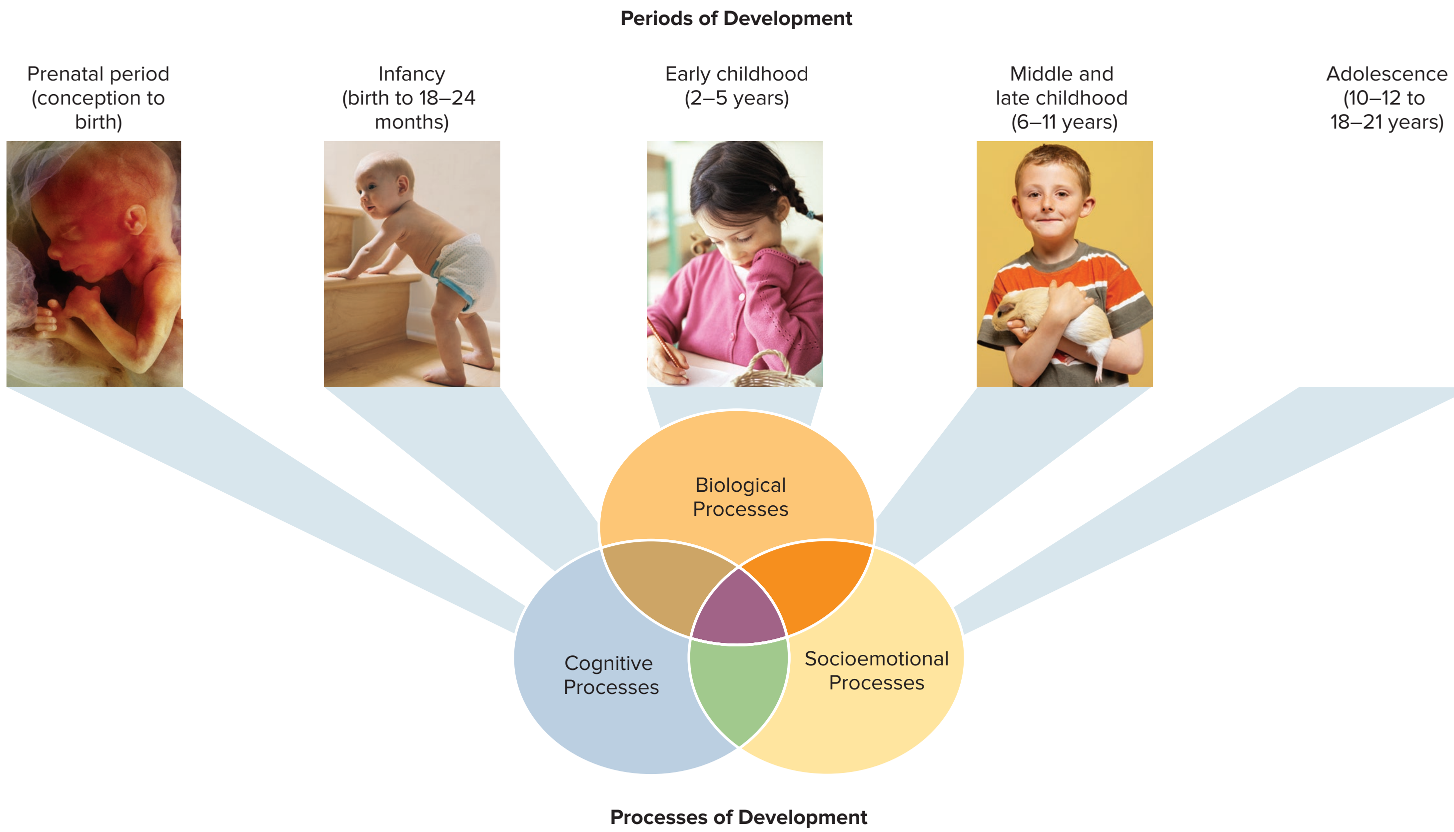


FIGURE 1 PERIODS AND PROCESSES OF DEVELOPMENT

Development moves through the infancy, early childhood, middle and late childhood, and adolescence periods. These periods of development are the result of biological, cognitive, and socioemotional processes.

(*Left to Right*) © Brand X Pictures/PunchStock RF; © Digital Vision RF; © Laurence Mouton/Photoalto/PictureQuest RF; © Stockbyte RF; © SW Productions/Getty Images RF

writing, and math, achievement becomes a more central theme, and self-control increases. In this period, children interact more with the wider social world beyond their family.

Adolescence is the development period that goes from childhood to adulthood, beginning around ages 10 to 12 and ending in the late teens. Adolescence starts with rapid physical changes, including height and weight gains and development of sexual functions. Adolescents intensely pursue independence and seek their own identity. Their thought becomes more abstract, logical, and idealistic.

In the 21st century, a transitional period—*emerging adulthood,* which occurs from approximately 18 to 25 years of age—has been described (Arnett, 2006, 2012, 2015). Experimentation and exploration characterize the emerging adult. At this point in their development, many individuals are still exploring which career path they want to follow, what they want their identity to be, and which lifestyle they want to adopt (for example, being single, cohabiting, or getting married).

Adult developmental periods have been described, but we have confined our discussion to the periods most relevant for children's and adolescents' education. The child and adolescent periods of human development are shown in Figure 1 along with the processes of development (biological, cognitive, and socioemotional). The interplay of these processes produces the periods of human development.

DEVELOPMENTAL ISSUES

Despite all of the knowledge that developmentalists have acquired, debate continues about the relative importance of factors that influence the developmental processes and about how the periods of development are related. The most important issues in the study of children's development include nature and nurture, continuity and discontinuity, and early and later experience.

Children are busy becoming something they have not quite grasped yet, something which keeps changing.

—Alastair Reid
American poet, 20th century

Nature and Nurture The **nature-nurture issue** involves the debate about whether development is primarily influenced by nature or by nurture (Belsky & Pluess, 2016). *Nature* refers to an organism's biological inheritance, *nurture* to its environmental experiences. Almost no one today argues that development can be explained by nature or nurture alone. But some ("nature" proponents) claim that the most important influence on development is biological inheritance, and others ("nurture" proponents) claim that environmental experiences are the most important influence.

According to the nature proponents, the range of environments can be vast, but an evolutionary and genetic blueprint produces commonalities in growth and development (Audesirk, Audesirk, & Byers, 2017; Buss, 2015). We walk before we talk, speak one word before two words, grow rapidly in infancy and less so in early childhood, and experience a rush of sexual hormones in puberty. Extreme environments—those that are psychologically barren or hostile—can stunt development, but nature proponents emphasize the influence of tendencies that are genetically wired into humans.

By contrast, other psychologists emphasize the importance of nurture, or environmental experiences, in development (Burt, Coatsworth, & Masten, 2016). Experiences run the gamut from the individual's biological environment (nutrition, exercise, medical care, drugs, and physical accidents) to the social environment (family, peers, schools, community, media, and culture) (Gonzales & others, 2016; Pianta, 2016).

The **epigenetic view** states that development is the result of an ongoing, bidirectional interchange between heredity and the environment. Let's look at an example that reflects the epigenetic view. A baby inherits genes from both parents at conception. During childhood, environmental experiences such as nutrition, stress, learning, child care, and encouragement can modify genetic activity and the activity of the nervous system that directly underlies behavior. Heredity and environment thus operate together—or collaborate—to produce a child's intelligence, temperament, health, ability to read, and so on (Moore, 2015).

Thus, if an attractive, popular, intelligent girl is elected president of her high school senior class, is her success due to heredity or to environment? Of course, the answer is "both." The relative contributions of heredity and environment are not quantifiable. That is, we can't say that such-and-such a percentage of nature and such-and-such a percentage of experience make us who we are. Nor is it accurate to say that full genetic expression happens once, at the time of conception or birth, after which we carry our genetic legacy into the world to see how far it takes us. Genes produce proteins throughout the life span, in many different environments. Or they don't produce these proteins, depending in part on how harsh or nourishing those environments are.

In developmental psychologist David Moore's (2013, 2015) view, the biological systems that generate behaviors are extremely complex but too often these systems have been described in overly simplified ways that can be misleading. Thus, although genetic factors clearly contribute to behavior and psychological processes, they don't determine these phenotypes independently from the contexts in which they develop. From Moore's (2013, 2015) perspective, it is misleading to talk about "genes for" eye color, intelligence, achievement, personality, or other characteristics. Moore commented that in retrospect we should not have expected to be able to make the giant leap from DNA's molecules to a complete understanding of human behavior any more than we should anticipate being able to easily link air molecules in a concert hall with a full-blown appreciation of a symphony's wondrous experience.

Imagine for a moment that there is a cluster of genes that are somehow associated with youth violence. (This example is hypothetical because we don't know of

nature-nurture issue Nature refers to an organism's biological inheritance, nurture to environmental influences. The "nature" proponents claim biological inheritance is the most important influence on development; the "nurture" proponents claim environmental experiences are the most important.

epigenetic view Development is seen as an ongoing, bidirectional interchange between heredity and the environment.

any such combination.) The adolescent who carries this genetic mixture might experience a world of loving parents, regular nutritious meals, lots of books, and a series of competent teachers. Or the adolescent's world might include parental neglect, a neighborhood in which gunshots and crime are everyday occurrences, and inadequate schooling. In which of these environments are the adolescent's genes likely to manufacture the biological underpinnings of criminality?

Are children completely at the mercy of their genes and environment as they develop? Their genetic heritage and environmental experiences are pervasive influences on their development (Raeff, 2017). However, children not only are the outcomes of their heredity and the environment they experience, but they also can author a unique developmental path by changing the environment.

> In reality, we are both the creatures and creators of our worlds. We are . . . the products of our genes and environments. Nevertheless, . . . the stream of causation that shapes the future runs through our present choices…
>
> Mind matters . . . Our hopes, goals, and expectations influence our future. (Myers, 2010, p. 168)

Continuity and Discontinuity The **continuity-discontinuity issue** focuses on the extent to which development involves gradual, cumulative change (continuity) or distinct stages (discontinuity). For the most part, developmentalists who emphasize nurture usually describe development as a gradual, continuous process, like the seedling's growth into an oak. Those who emphasize nature often describe development as a series of distinct stages, like the change from caterpillar to butterfly.

Consider continuity first. A child's first word, though seemingly an abrupt, discontinuous event, is actually the result of weeks and months of growth and practice. Puberty, another seemingly abrupt, discontinuous occurrence, is actually a gradual process occurring over several years.

Viewed in terms of discontinuity, each person is described as passing through a sequence of stages in which change is qualitatively rather than quantitatively different. A child moves at some point from not being able to think abstractly about the world to being able to. This is a qualitative, discontinuous change in development, not a quantitative, continuous change.

Early and Later Experience The **early-later experience issue** focuses on the degree to which early experiences (especially in infancy) or later experiences are the key determinants of the child's development. That is, if infants experience harmful circumstances, can those experiences be overcome by later, positive ones? Or are the early experiences so critical—possibly because they are the infant's first, prototypical experiences—that they cannot be overridden by a later, better environment?

The early-later experience issue has a long history and continues to be hotly debated among developmentalists (Kuhn & Lindenberger, 2016). Some developmentalists argue that unless infants experience warm, nurturing care during the first year or so of life, their development will never quite be optimal (O'Connor, 2016). In contrast, later-experience advocates argue that children are malleable throughout development and that later sensitive caregiving is just as important as earlier sensitive caregiving (Masten, 2016).

Evaluating the Developmental Issues Most developmentalists recognize that it is unwise to take an extreme position on the issues of nature and nurture, continuity and discontinuity, and early and later experiences. Development is not all nature or all nurture, not all continuity or all discontinuity, and not all early or later experiences. However, there is still spirited debate about how strongly development is influenced by each of these factors (Grigorenko & others, 2016).

continuity-discontinuity issue The issue regarding whether development involves gradual, cumulative change (continuity) or distinct stages (discontinuity).

early-later experience issue Involves the degree to which early experiences (especially infancy) or later experiences are the key determinants of the child's development.

DEVELOPMENT AND EDUCATION

In the introductory chapter, we briefly described the importance of engaging in developmentally appropriate teaching practices. Here we expand on this important topic and discuss the concept of splintered development.

Developmentally appropriate teaching takes place at a level that is neither too difficult and stressful nor too easy and boring for the child's developmental level (NAEYC, 2009). One of the challenges of developmentally appropriate teaching is that you likely will have students with an age range of several years and a range of abilities and skills in the classes you teach. Competent teachers are aware of these developmental differences. Rather than characterizing students as "advanced," "average," and "slow," they recognize that their development and ability are complex, and children often do not display the same competence across different skills.

Thinking Back/Thinking Forward

New guidelines exist for developmentally appropriate education Connect to "Social Contexts and Socioemotional Development."

Splintered development refers to the circumstances in which development is uneven across domains (Horowitz & others, 2005). One student may have excellent math skills but poor writing skills. Within the area of language, another student may have excellent verbal language skills but not have good reading and writing skills. Yet another student may do well in science but lack social skills.

Cognitively advanced students whose socioemotional development is at a level expected for much younger children present a special challenge. For example, a student may excel at science, math, and language but be immature emotionally. Such a child may not have any friends and be neglected or rejected by peers. This student will benefit considerably from having a teacher who helps him or her learn how to manage emotions and behave in more socially appropriate ways.

As we discuss development in this chapter and the next, keep in mind how the developmental changes we describe can help you understand the optimal level for teaching and learning. For example, it is not a good strategy to try to push children to read before they are developmentally ready—but when they are ready, reading materials should be presented at the appropriate level.

Review, Reflect, and Practice

1 Define development and explain the main processes, periods, and issues in development, as well as links between development and education.

REVIEW

- What is the nature of development?
- What three broad processes interact in a child's development? What general periods do children go through between birth and the end of adolescence?
- What are the main developmental issues? What conclusions can be reached about these issues?
- What implications does the concept of development have for the notion of "appropriate" learning?

REFLECT

- Give an example of how a cognitive process could influence a socioemotional process in the age of children you plan to teach. Then give an example of how a socioemotional process could influence a cognitive process in this age group.

PRAXIS™ PRACTICE

1. Mr. Huxtaby is giving a talk on development to a parent-teacher organization. In his talk, which of the following is he most likely to describe as not being an example of development?
   a. pubertal change
   b. improvement in memory

(continued)

splintered development The circumstances in which development is uneven across domains.

Review, Reflect, and Practice

PRAXIS™ PRACTICE (CONTINUED)

c. change in friendship
d. an inherited tendency to be shy

2. Ms. Halle teaches third grade. Which period of development is likely to be of most interest to her?
   a. infancy
   b. early childhood
   c. middle childhood and late childhood
   d. adolescence
3. Piaget argued that children progress through a series of cognitive development stages. In contrast, Skinner stressed that individuals simply learn more as time goes on. Which developmental issue is highlighted in their disagreement?
   a. continuity and discontinuity
   b. early and later experience
   c. nature and nurture
   d. biological and socioemotional development
4. Alexander's scores on standardized mathematics achievement tests are always very high—among the highest in the nation. In contrast, his scores on reading achievement tests indicate that he is about average. This is an example of
   a. developmentally appropriate teaching
   b. early versus later development
   c. nature versus nurture
   d. splintered development

2 COGNITIVE DEVELOPMENT

The Brain | Piaget's Theory | Vygotsky's Theory

Twentieth-century American poet Marianne Moore said that the mind is "an enchanting thing." How this enchanting thing develops has intrigued many psychologists. First, we explore increasing interest in the development of the brain and then turn to two major cognitive theories—Piaget's and Vygotsky's.

THE BRAIN

Not long ago, scientists thought that our genes primarily determine how our brains are "wired" and that the cells in the brain responsible for processing information just develop on their own with little or no input from environmental experiences. According to that view, whatever brain your genes have provided to you, you are essentially stuck with it. That view of the brain, however, turned out to be wrong. Instead, it is clear that the brain has plasticity and its development depends on contexts and experiences children engage in (de Haan & Johnson, 2016; Goddings & Mills, 2017).

In the increasingly popular **neuroconstructivist view,** (a) biological processes (genes, for example) and environmental experiences (enriched or impoverished, for example) influence the brain's development; (b) the brain has plasticity (the ability to change) and depends on experience; and (c) development of the brain is linked closely with cognitive development. These factors constrain or advance the construction of cognitive skills (Karmiloff-Smith, 2017; Monahan & others, 2016). In other words, what children do can change the development of their brains.

neuroconstructivist view Emphasizes that brain development is influenced by both biological processes and environmental experiences; the brain has plasticity and depends on experience; and brain development is linked closely with cognitive development.

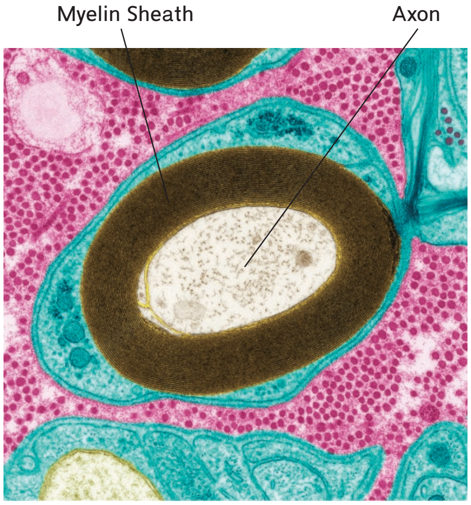


FIGURE 2 MYELINATED NEURON FIBER

The myelin sheath, shown in brown, encases the axon (white). This image was produced by an electron microscope that magnified the nerve fiber 12,000 times. *What role does myelination play in the brain's development?*

DEVELOPMENT

Development of Neurons and Brain Regions The number and size of the brain's nerve endings continue to increase at least into adolescence. Some of the brain's growth in size also is due to **myelination,** the process of encasing many cells in the brain with a myelin sheath (see Figure 2). This increases the speed at which information travels through the nervous system (Fields, 2015). Myelination in brain areas important in focusing attention is not complete until about 10 years of age. The implications for teaching are that children will have difficulty focusing their attention and maintaining it for very long in early childhood, but their attention will improve as they move through the elementary school years. The most extensive increase in myelination, which occurs in the brain's frontal lobes where reasoning and thinking occur, takes place during adolescence (Galvan & Tottenham, 2016).

Another important aspect of the brain's development at the cellular level is the dramatic increase in connections between neurons (nerve cells). *Synapses* are tiny gaps between neurons where connections between neurons are made. Researchers have discovered an interesting aspect of synaptic connections. Nearly twice as many of these connections are made than will ever be used (Huttenlocher & Dabholkar, 1997). The connections that are used become stronger and survive, whereas the unused ones are replaced by other pathways or disappear. In the language of neuroscience, these connections are "pruned." Figure 3 vividly shows the dramatic growth and later pruning of synapses in the visual, auditory, and prefrontal cortex areas of the brain. These areas are critical for higher-order cognitive functioning such as learning, memory, and reasoning. Notice that in the **prefrontal cortex** (where higher-level thinking and self-regulation take place) it is not until middle to late adolescence that the adult density of the synapses is achieved.

Figure 4 shows the location of the brain's four lobes. As just indicated, growth in the prefrontal cortex (the highest region of the frontal lobes) continues through adolescence. Rapid growth in the temporal lobes (language processing) and parietal lobes (spatial location) occurs from age 6 through puberty.

myelination The process of encasing many cells in the brain with a myelin sheath that increases the speed at which information travels through the nervous system.

prefrontal cortex The highest level in the frontal lobes; involved in reasoning, decision making, and self-control.

Brain Development in Middle and Late Childhood Total brain volume stabilizes by the end of middle and late childhood, but significant changes in various structures and regions of the brain continue to occur as brain growth tapers off (Wendelken & others, 2016). In particular, the brain pathways and circuitry involving the

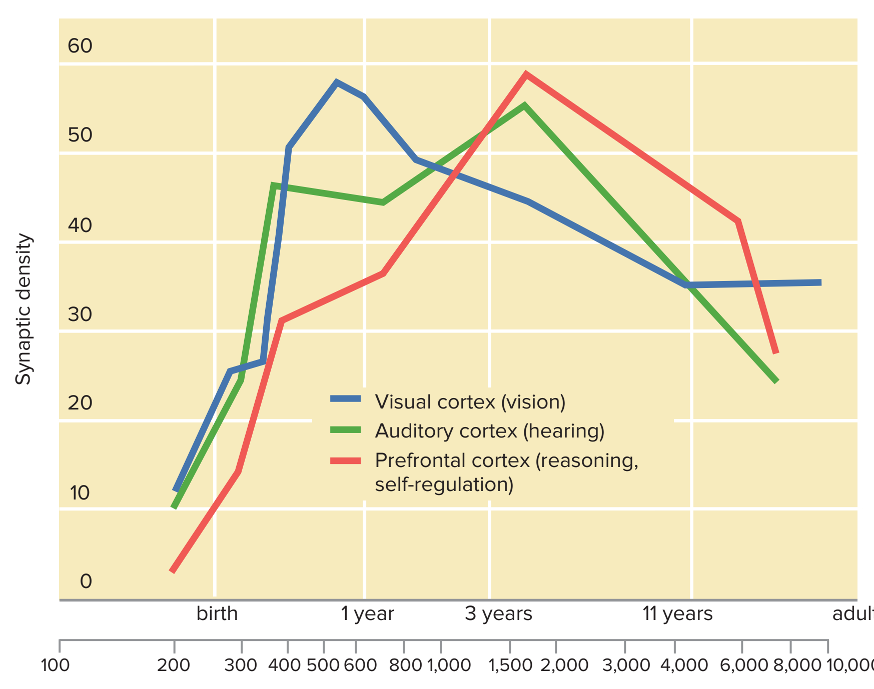


FIGURE 3 SYNAPTIC DENSITY IN THE HUMAN BRAIN FROM INFANCY TO ADULTHOOD

The graph shows the dramatic increase and then pruning of synaptic density for three regions of the brain: visual cortex, auditory cortex, and prefrontal cortex. Synaptic density is believed to be an important indication of the extent of connectivity between neurons.

prefrontal cortex continue to increase in middle and late childhood. These advances in the prefrontal cortex are linked to children's improved attention, reasoning, and cognitive control (Monahan & others, 2016).

Leading researchers in developmental cognitive neuroscience have proposed that the prefrontal cortex likely orchestrates the functions of many other brain regions during development (de Haan & Johnson, 2016). As part of this organizational role, the prefrontal cortex may provide an advantage to neural networks and connections that include the prefrontal cortex. In this view, the prefrontal cortex coordinates which neural connections are the most effective for solving a problem.

Links between the changing brain and children's cognitive development involve activation of some brain areas, with some areas increasing in activation while others decrease (de Haan & Johnson, 2016). One shift in activation that occurs as children develop in middle and late childhood is from diffuse, larger areas to more focal, smaller areas. This shift is characterized by synaptic pruning in which areas of the brain not being used lose synaptic connections and those being used gain additional connections. The increased focal activation is linked to improved cognitive performance, especially in *cognitive control*, which involves flexible and effective control in a number of areas (Durston & others, 2006). These areas include controlling attention, reducing interfering thoughts, inhibiting motor actions, and flexibility in switching between competing choices (Casey, 2015).

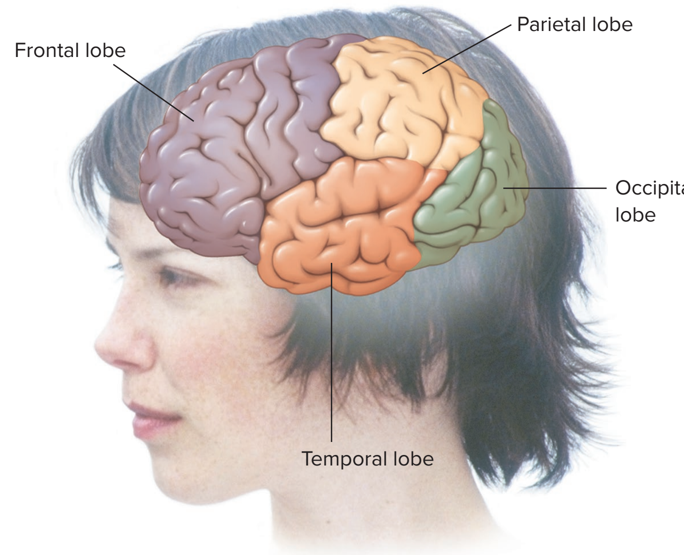


FIGURE 4 THE BRAIN'S FOUR LOBES

Shown here are the locations of the brain's four lobes: frontal, occipital, temporal, and parietal.

Brain Development in Adolescence Along with the rest of the body, the brain is changing in adolescence. Earlier we indicated that connections between neurons are "pruned" as children and adolescents develop. As a result of this pruning, by the end of adolescence individuals have "fewer, more selective, more effective connections between neurons than they did as children" (Kuhn, 2009). And this pruning indicates that the activities adolescents engage in and don't engage in influence which neural connections will be strengthened and which will disappear.

Using fMRI brain scans, scientists have recently discovered that adolescents' brains undergo significant structural changes (Crone, 2017; Monahan & others, 2016). The **corpus callosum,** where fibers connect the brain's left and right hemispheres, thickens in adolescence, and this improves adolescents' ability to process information (Chavarria & others, 2014). Earlier we described advances in the development of the prefrontal cortex in childhood. However, the prefrontal cortex doesn't finish maturing until the emerging adult years, approximately 18 to 25 years of age, or later (Steinberg, 2015a, b).

At a lower, subcortical level, the **limbic system,** which is the seat of emotions and where rewards are experienced, matures much earlier than the prefrontal cortex and is almost completely developed in early adolescence (Monahan & others, 2016). The limbic system structure that is especially involved in emotion is the **amygdala.** Figure 5 shows the locations of the corpus callosum, prefrontal cortex, limbic system, and amygdala.

Leading researcher Charles Nelson (2011) points out that although adolescents are capable of very strong emotions, their prefrontal cortex hasn't adequately developed to the point at which they can control these passions. This means that the brain region for putting the brakes on risky, impulsive behavior is still under construction during adolescence. Or consider this interpretation of the development of emotion and cognition in adolescence: "early activation of strong 'turbo-charged' feelings with a relatively unskilled set of 'driving skills' or cognitive abilities to modulate strong emotions and motivations" (Dahl, 2004, p. 18). This developmental disjunction may account for increased risk taking and other problems in adolescence (Steinberg, 2015a, b).

Thinking Back/Thinking Forward

A surge of interest surrounds identification of the aspects of the brain that are involved in intelligence. Connect to "Individual Variations."

corpus callosum The brain region where fibers connect the left and right hemispheres.

limbic system Brain region that is the seat of emotions and in which rewards are experienced.

amygdala The seat of emotions in the brain.

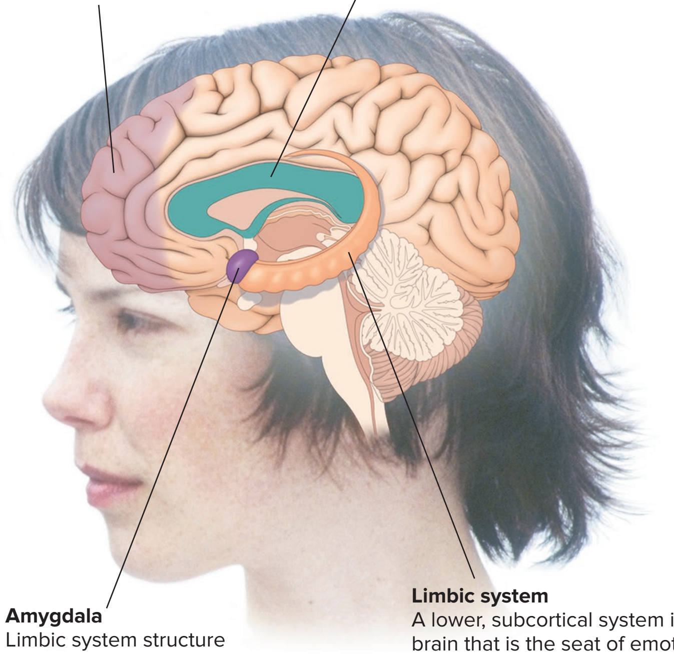


FIGURE 5 THE CHANGING ADOLESCENT BRAIN: PREFRONTAL CORTEX, LIMBIC SYSTEM, AMYGDALA, AND CORPUS CALLOSUM

Lateralization The cerebral cortex (the highest level of the brain) is divided into two halves, or hemispheres (see Figure 6). **Lateralization** is the specialization of functions in each hemisphere of the brain (Francks, 2016). In individuals with an intact brain, there is a specialization of function in some areas.

The most extensive research on the brain's two hemispheres involves language. In most individuals, speech and grammar are localized to the left hemisphere. However, not all language processing is carried out in the brain's left hemisphere (Moore, Brendel, & Fiez, 2014). For example, understanding such aspects of language as appropriate use of language in different contexts, evaluation of the emotional expressiveness of language, and much of humor involves the right hemisphere (Godfrey & Grimshaw, 2016). Also, when individuals lose much of their left hemisphere because of an accident, surgery for epilepsy, or other reasons, the right hemisphere in many cases can reconfigure itself for increased language processing (Xing & others, 2016).

Because of the differences in functioning of the brain's two hemispheres, people commonly use the phrases "left-brained" and "right-brained" to suggest that one hemisphere is dominant. Unfortunately, much of this talk is greatly exaggerated. For example, laypeople and the media commonly exaggerate hemispheric specialization by claiming that the left brain is logical and the right brain is creative. However, most complex functioning—such as logical and creative thinking—in normal people involves communication between both sides of the brain. Scientists who study the brain are typically very cautious when using terms such as *left-brained* and *right-brained* because the brain is more complex than those terms suggest.

lateralization Specialization of functions in each hemisphere of the brain

FIGURE 6 THE HUMAN BRAIN'S TWO HEMISPHERES

The two halves (hemispheres) of the human brain are clearly seen in this photograph.

Plasticity As we have seen, the brain has plasticity (de Haan & Johnson, 2016; Nagel & Scholes, 2017). Children's experiences can affect how their brains develop. By engaging students in optimal learning environments, you can stimulate brain development.

The remarkable case of Michael Rehbein illustrates the brain's plasticity. When Michael was 4½, he began to experience uncontrollable seizures—as many as 400 a day. Doctors said that the only solution was to remove the left hemisphere of his brain, where the seizures were occurring. Michael had his first major surgery at age 7 and another at age 10. Although recovery was slow, his right hemisphere began to reorganize and eventually took over functions, such as speech, that normally occur in the brain's left hemisphere (see Figure 7). Individuals like Michael are living proof of the growing brain's remarkable plasticity and ability to adapt and recover from a loss of brain tissue.

The Brain and Children's Education Unfortunately, too often statements about the implications of brain science for children's education have been speculative at best and often far removed from what neuroscientists know about the brain (Busso & Pollack, 2015; Gleichgerrcht & others, 2015). We don't have to look any further than the hype about "left-brained" individuals being more logical and "right-brained" individuals being more creative to see that links between neuroscience and brain education are incorrectly made (Sousa, 1995).

Another commonly promoted link between neuroscience and brain education is that there is a critical, or sensitive, period—a biological window of opportunity—when learning is easier, more effective, and more easily retained than later in development.

However, some experts on the development of the brain and learning conclude that the critical period view is exaggerated. One leading neuroscientist even told educators that although children's brains acquire a great deal of information during the early years, most learning likely takes place after synaptic formation stabilizes, which is after the age of 10 (Goldman-Rakic, 1996).

A major issue involving the development of the brain is which comes first, biological changes in the brain or experiences that stimulate these changes? (Lerner, Boyd, & Du, 2008). Consider a study in which the prefrontal cortex thickened and more brain connections formed when adolescents resisted peer pressure (Paus & others, 2008). Scientists have yet to determine whether the brain changes come first or whether the brain changes are the result of experiences with peers, parents, and others. Once again, we encounter the nature/nurture issue that is so prominent in examining children's and adolescents' development.

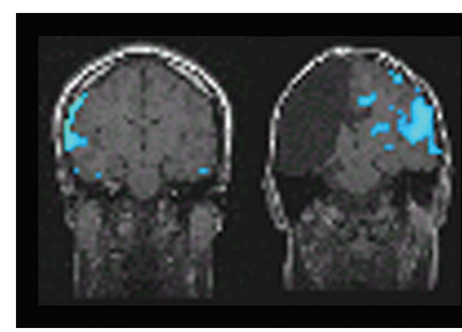
Given all of the hype about brain education in the media, what can we conclude about the current state of knowledge in applying the rapidly increasing research on the brain's development to education? Based on the current state of knowledge:

- *Both early and later experiences, including educational experiences, are very important in the brain's development.* Significant changes continue to occur at the cellular and structural level in the brain through adolescence.
- *Synaptic connections between neurons can change dramatically as a consequence of the learning experiences children and adolescents have*. Connections between neurons that are used when children focus their attention, remember, and think as they are reading, writing, and doing math are strengthened; those that aren't used are replaced by other pathways or disappear.
- *Development at the highest level of the brain—the prefrontal cortex, where such important cognitive processes as thinking, reasoning, and decision making primarily occur—continues at least through the emerging adult years* (Monahan & others, 2016). This development in the prefrontal cortex moves from being more diffuse to more focal and involves increased efficiency of processing information (de Haan & Johnson, 2016). As activation in the prefrontal cortex becomes more focused, cognitive control increases. This is exemplified in children being able to focus their attention more effectively and ignore distractions while they are learning as they become older.
- *Despite the increased focal activation of the prefrontal cortex as children grow older, changes in the brain during adolescence present a challenge to increased cognitive control.* In adolescence, the earlier maturation of the limbic system and the amygdala, which are involved in processing of emotions, and the more drawn-out development of the prefrontal cortex, provide an explanation of the difficulty adolescents have in controlling their emotions and their tendency to engage in risk-taking behavior (Monahan & others, 2016).
- *Brain functioning occurs along specific pathways and involves integration of function.* According to leading experts Kurt Fischer and Mary Helen Immordino-Yang (2008),

> One of the lessons of educational neuroscience, even at this early point in its development, is that children learn along specific pathways, but they do not act or think in compartments. . . . On the one hand, they develop their learning along specific pathways defined by particular content, such as mathematics or history, but on the other hand they make connections between those pathways.

Reading is an excellent example of how brain functioning occurs along specific pathways and is integrated. Consider a child who is asked by a teacher to read aloud to the class. Input from the child's eyes is transmitted to the child's brain, then passed through many brain systems, which translate the patterns of black and white into codes for letters, words, and associations. The output occurs

(a)



(b)

FIGURE 7 PLASTICITY IN THE BRAIN'S HEMISPHERES

(a) Michael Rehbein at 14 years of age. (b) Michael's right hemisphere (*top*) has reorganized to take over the language functions normally carried out by corresponding areas in the left hemisphere of an intact brain (*bottom*). However, the right hemisphere is not as efficient as the left, and more areas of the brain are recruited to process speech.

What are some applications of research on brain development to children's education?
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in the form of messages to the child's lips and tongue. The child's own gift of speech is possible because brain systems are organized in ways that permit language processing.

These conclusions suggest that education throughout the childhood and adolescent years can benefit children's and adolescents' learning and cognitive development (Monahan & others, 2016). Where appropriate throughout the rest of the book, we will describe research involving the development of the brain and children's education.

PIAGET'S THEORY

Poet Noah Perry once asked, "Who knows the thoughts of a child?" More than anyone, the famous Swiss psychologist Jean Piaget (1896–1980) knew.

Cognitive Processes

What processes do children use as they construct their knowledge of the world? Piaget stressed that these processes are especially important in this regard: schemas, assimilation and accommodation, organization, and equilibration.

Schemas

Piaget (1954) said that as the child seeks to construct an understanding of the world, the developing brain creates **schemas.** These are actions or mental representations that organize knowledge. In Piaget's theory, behavioral schemas (physical activities) characterize infancy, and mental schemas (cognitive activities) develop in childhood. A baby's schemas are structured by simple actions that can be performed on objects, such as sucking, looking, and grasping. Older children have schemas that include strategies and plans for solving problems. For example, a 6-year-old might have a schema that involves the strategy of classifying objects by size, shape, or color. By the time we have reached adulthood, we have constructed an enormous number of diverse schemas, ranging from how to drive a car, to how to balance a budget, to the concept of fairness.

Assimilation and Accommodation

To explain how children use and adapt their schemas, Piaget offered two concepts: assimilation and accommodation. **Assimilation** occurs when children incorporate new information into their existing schemas. **Accommodation** occurs when children adjust their schemas to fit new information and experiences.

Consider an 8-year-old girl who is given a hammer and nail to hang a picture on the wall. She has never used a hammer, but from observing others do this she realizes that a hammer is an object to be held, that it is swung by the handle to hit the nail, and that it usually is swung a number of times. Recognizing each of these things, she fits her behavior into this schema she already has (assimilation). But the hammer is heavy, so she holds it near the top. She swings too hard and the nail bends, so she adjusts the pressure of her strikes. These adjustments reflect her ability to slightly alter her conception of the world (accommodation). Just as both assimilation and accommodation are required in this example, so are they required in many of the child's thinking challenges (see Figure 8).

Organization

To make sense out of their world, said Piaget, children cognitively organize their experiences. **Organization** in Piaget's theory is the grouping of isolated behaviors and thoughts into a higher-order system. Continual refinement of this organization is an inherent part of development. A boy with only a vague idea about how to use a hammer also may have a vague idea about how to use other tools. After learning how to use each one, he relates these uses, organizing his knowledge.

What are some applications of research on brain development to children's education?
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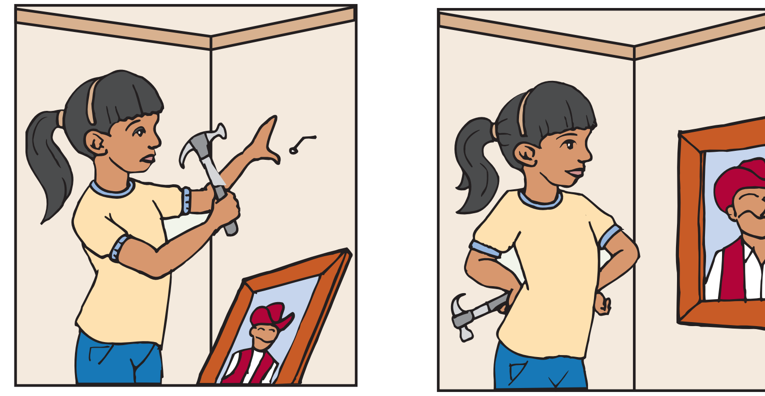
schemas In Piaget's theory, actions or mental representations that organize knowledge.

assimilation Piagetian concept of the incorporation of new information into existing knowledge (schemas).

accommodation Piagetian concept of adjusting schemas to fit new information and experiences.

organization Piaget's concept of grouping isolated behaviors into a higher-order, more smoothly functioning cognitive system; the grouping or arranging of items into categories.

Equilibration and Stages of Development **Equilibration** is a mechanism that Piaget proposed to explain how children shift from one stage of thought to the next. The shift occurs as children experience cognitive conflict, or disequilibrium, in trying to understand the world. Eventually, they resolve the conflict and reach a balance, or equilibrium, of thought. Piaget pointed out that there is considerable movement between states of cognitive equilibrium and disequilibrium as assimilation and accommodation work in concert to produce cognitive change. For example, if a child believes that the amount of a liquid changes simply because the liquid is poured into a container with a different shape—for instance, from a container that is short and wide into a container that is tall and narrow—she might be puzzled by such issues as where the "extra" liquid came from and whether there is actually more liquid to drink. The child will eventually resolve these puzzles as her thinking becomes more advanced. In the everyday world, the child is constantly faced with such counterexamples and inconsistencies.



Assimilation occurs when people incorporate new information into their existing schematic knowledge. *How might this 8-year-old girl first attempt to use the hammer and nail, based on her preexisting schematic knowledge about these objects?*

Accommodation occurs when people adjust their knowledge schemas to new information. *How might the girl adjust her schemas regarding hammers and nails during her successful effort to hang the picture?*

FIGURE **8** ASSIMILATION AND ACCOMMODATION

Assimilation and accommodation always take the child to a higher ground. For Piaget, the motivation for change is an internal search for equilibrium. As old schemas are adjusted and new schemas are developed, the child organizes and reorganizes the old and new schemas. Eventually, the organization is fundamentally different from the old organization; it is a new way of thinking.

Thus, the result of these processes, according to Piaget, is that individuals go through four stages of development. A different way of understanding the world makes one stage more advanced than another. Cognition is *qualitatively* different in one stage compared with another. In other words, the way children reason at one stage is different from the way they reason at another stage.

Piagetian Stages

Each of Piaget's stages is age-related and consists of distinct ways of thinking. Piaget proposed four stages of cognitive development: sensorimotor, preoperational, concrete operational, and formal operational (see Figure 9).

The Sensorimotor Stage The **sensorimotor stage,** which lasts from birth to about 2 years of age, is the first Piagetian stage. In this stage, infants construct an understanding of the world by coordinating their sensory experiences (such as seeing and hearing) with their motor actions (reaching, touching)—hence the term *sensorimotor.* At the beginning of this stage, infants show little more than reflexive patterns to adapt to the world. By the end of the stage, they display far more complex sensorimotor patterns.

The Preoperational Stage The **preoperational stage** is the second Piagetian stage. Lasting approximately from about 2 to 7 years of age, it is more symbolic than sensorimotor thought but does not involve operational thought. However, it is egocentric and intuitive rather than logical.

Preoperational thought can be subdivided into two substages: symbolic function and intuitive thought. The **symbolic function substage** occurs roughly between 2 and 4 years of age. In this substage, the young child gains the ability to represent mentally an object that is not present. This stretches the child's mental world to new dimensions. Expanded use of language and the emergence of pretend play are other examples of an increase in symbolic thought during this early childhood substage. Young children begin to use scribbled designs to represent people, houses, cars, clouds, and many other aspects of the world. Possibly because young children are not very concerned about reality, their drawings are fanciful and inventive (Winner,

DEVELOPMENT

equilibration A mechanism that Piaget proposed to explain how children shift from one stage of thought to the next. The shift occurs as children experience cognitive conflict, or disequilibrium, in trying to understand the world. Eventually, they resolve the conflict and reach a balance, or equilibrium, of thought.

sensorimotor stage The first Piagetian stage, lasting from birth to about 2 years of age, when infants construct an understanding of the world by coordinating sensory experiences with motor actions.

preoperational stage The second Piagetian stage, lasting from about 2 to 7 years of age, when symbolic thought increases and operational thought is not yet present.

symbolic function substage The first substage of preoperational thought, occurring between about 2 and 4 years of age; the ability to represent an object not present develops and symbolic thinking increases; egocentrism is present.

Sensorimotor Stage
The infant constructs an understanding of the world by coordinating sensory experiences with physical actions. An infant progresses from reflexive, instinctual action at birth to the beginning of symbolic thought toward the end of the stage.
Birth to 2 Years of Age

Preoperational Stage
The child begins to represent the world with words and images. These words and images reflect increased symbolic thinking and go beyond the connection of sensory information and physical action.
2 to 7 Years of Age

Concrete Operational Stage
The child can now reason logically about concrete events and classify objects into different sets.
7 to 11 Years of Age

Formal Operational Stage
The adolescent reasons in more abstract, idealistic, and logical ways.
11 Years of Age Through Adulthood

FIGURE 9 THE FOUR PIAGETIAN STAGES OF COGNITIVE DEVELOPMENT

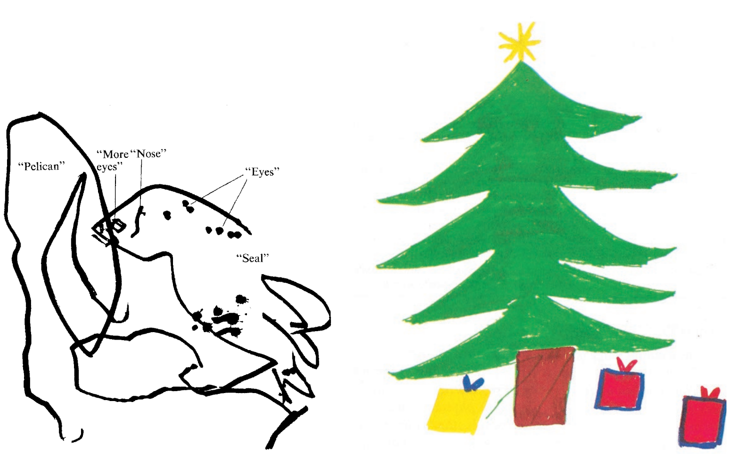
(*Left to Right*) © Stockbyte/Getty Images RF; © BananaStock/PunchStock RF; © image100/Corbis RF; © Purestock/Getty Images RF

intuitive thought substage The second substage of preoperational thought, lasting from about 4 to 7 years of age. Children begin to use primitive reasoning and want to know the answer to all sorts of questions. They seem sure about their knowledge in this substage but are unaware of how they know what they know.

1986). One 3½-year-old looked at the scribble he had just drawn and described it as a pelican kissing a seal (see Figure 10a). In the elementary school years, children's drawings become more realistic, neat, and precise (see Figure 10b).

Even though young children make distinct progress in this substage, their preoperational thought still has an important limitation: egocentrism. *Egocentrism* is the inability to distinguish between one's own perspective and someone else's perspective. Piaget and Barbel Inhelder (1969) initially studied young children's egocentrism by devising the three mountains task (see Figure 11). The child walks around the model of the mountains and becomes familiar with what the mountains look like from different perspectives. The child also can see that there are different objects on the mountains. The child then is seated on one side of the table on which the mountains are placed. The experimenter moves a doll to different locations around the table. At each location, the child is asked to select from a series of photos the one that most accurately reflects the view the doll is seeing. Children in the preoperational stage often pick the view that reflects where they are sitting rather than the doll's view.

What further cognitive changes take place in the preoperational stage? The **intuitive thought substage** is the second substage of preoperational thought, starting at about 4 years of age and lasting until about 7 years of age. At this substage, children begin to use primitive reasoning and want to know the answers to all sorts of questions. Piaget called this substage "intuitive" because children seem so sure about



(a) (b)

FIGURE 10 COGNITIVE DEVELOPMENTAL CHANGES IN CHILDREN'S DRAWINGS

(a) A 3½-year-old's symbolic drawing. Halfway into this drawing, the 3½-year-old artist said it was "a pelican kissing a seal." (b) This 11-year-old's drawing is neater and more realistic but also less inventive.

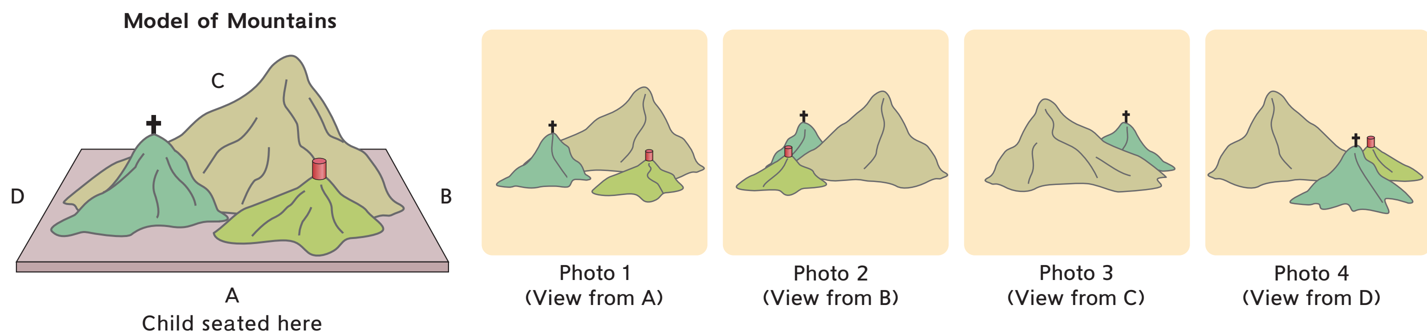


FIGURE 11 PIAGET'S THREE MOUNTAINS TASK

The mountain model on the far left shows the child's perspective from view A, where he or she is sitting. The four squares represent photos showing the mountains from four different viewpoints of the model—A, B, C, and D. The experimenter asks the child to identity the photo in which the mountains look as they would from position B. To identity the photo correctly, the child has to take the perspective of a person sitting at spot B. Invariably, a child who thinks in a preoperational way cannot perform this task. When asked what a view of the mountains looks like from position B, the child selects Photo 1, taken from location A (the child's own view at the time) instead of Photo 2, the correct view.

their knowledge and understanding yet are unaware of how they know what they know. That is, they say they know something but know it without the use of rational thinking.

Many of these preoperational examples show a characteristic of thought called **centration,** which involves focusing (or centering) attention on one characteristic to the exclusion of all others. Centration is most clearly present in preoperational children's lack of **conservation,** the idea that some characteristic of an object stays the same even though the object might change in appearance. For example, to adults it is obvious that a certain amount of liquid stays the same regardless of a container's shape. But this is not obvious at all to young children. Rather, they are struck by the height of the liquid in the container. In this type of conservation task (Piaget's most famous), a child is presented with two identical beakers, each filled to the same level with liquid (see Figure 12). The child is asked if the beakers have the same amount of liquid. The child usually says yes. Then the liquid from one beaker is poured into a third beaker, which is taller and thinner. The child now is asked if the amount of liquid in the tall, thin beaker is equal to the liquid that remains in the second original beaker. Children younger than 7 or 8 usually say no. They justify their answer by referring to the differing height or width of the beakers. Older children usually answer yes. They justify their answers appropriately: If you poured the liquid back, the amount would still be the same.

In Piaget's view, failing the conservation of liquid task indicates that the child is at the preoperational stage of thinking. Passing the test suggests the child is at the concrete operational stage of thinking.

According to Piaget, preoperational children also cannot perform what he called *operations*. In Piaget's theory, operations are mental representations that are reversible.

As in the beaker task, preschool children have difficulty understanding that reversing an action brings about the original conditions from which the action began. These two examples should further help you understand Piaget's concepts of operations. A young child might know that $4 + 2 = 6$ but not understand that the reverse, $6 - 2 = 4$, is true. Or let's say a preschooler walks to his friend's house each day but always gets a ride home. If asked to walk home from his friend's house, he probably would reply that he didn't know the way because he never had walked home before.

Some developmentalists do not believe Piaget was entirely correct in his estimate of when conservation skills emerge. For example, Rochel Gelman (1969) trained preschool children to attend to relevant aspects of the conservation task. This improved their conservation skills.

centration Focusing, or centering, attention on one characteristic to the exclusion of all others; characteristic of preoperational thinking.

conservation The idea that some characteristic of an object stays the same even though the object might change in appearance; a cognitive ability that develops in the concrete operational stage, according to Piaget.

FIGURE 12 PIAGET'S CONSERVATION TASK

The beaker test is a well-known Piagetian test to determine whether a child can think operationally—that is, can mentally reverse actions and show conservation of the substance. (a) Two identical beakers are presented to the child. Then, the experimenter pours the liquid from B into C, which is taller and thinner than A or B. (b) The child is asked if these beakers (A and C) have the same amount of liquid. The preoperational child says "no." When asked to point to the beaker that has more liquid, the preoperational child points to the tall, thin beaker.

Further, children show considerable variation in attaining conservation skills. Researchers have found that 50 percent of children develop conservation of mass at 6 to 9 years of age, 50 percent demonstrate conservation of length at 4 to 9 years of age, 50 percent show conservation of area at 7 to 9 years of age, and 50 percent of children don't attain conservation of weight until 8 to 10 years of age (Horowitz & others, 2005; Sroufe & others, 1992).

Yet another characteristic of preoperational children is that they ask a lot of questions. The barrage begins around age 3. By about 5, they have just about exhausted the adults around them with "Why?" "Why" questions signal the emergence of the child's interest in figuring out why things are the way they are. Following is a sampling of 4- to 6-year-olds' questions (Elkind, 1976):

"What makes you grow up?"

"Who was the mother when everybody was a baby?"

"Why do leaves fall?"

"Why does the sun shine?"

The Concrete Operational Stage The **concrete operational stage,** the third Piagetian stage of cognitive development, lasts from about 7 to about 11 years of age. Concrete operational thought involves using operations. Logical reasoning replaces intuitive reasoning, but only in concrete situations. Classification skills are present, but abstract problems go unsolved.

A concrete operation is a reversible mental action pertaining to real, concrete objects. Concrete operations allow the child to coordinate several characteristics rather than focus on a single property of an object. At the concrete operational level, children can do mentally what they previously could do only physically, and they can reverse concrete operations.

An important concrete operation is classifying or dividing things into different sets or subsets and considering their interrelationships. Reasoning about a family tree of four generations reveals a child's concrete operational skills (Furth & Wachs, 1975).

concrete operational stage Piaget's third cognitive developmental stage, occurring between about 7 and 11 years of age. At this stage, the child thinks operationally, and logical reasoning replaces intuitive thought but only in concrete situations; classification skills are present, but abstract problems present difficulties.

CONNECTING WITH STUDENTS: Best Practices

Strategies for Working with Preoperational Thinkers

As you have just read, young children think on a different plane from older children. Following are some effective strategies for advancing young children's thinking.

1. *Ask children to make comparisons*. These might involve such concepts as bigger, taller, wider, heavier, and longer.
2. *Give children experience in ordering operations*. For example, have children line up in rows from tall to short and vice versa. Bring in various examples of animal and plant life cycles, such as several photographs of butterfly development or the sprouting of beans or kernels of corn.
3. *Have children draw scenes with perspective*. Encourage them to make the objects in their drawings appear to be at the same location as in the scene they are viewing. For example, if they see a horse at the end of a field, they should place the horse in the same location in the drawing.
4. *Construct an inclined plane or a hill*. Let children roll marbles of various sizes down the plane. Ask them to compare how quickly the different-size marbles reach the bottom. This should help them understand the concept of speed.
5. *Ask children to justify their answers when they draw conclusions*. For example, when they say that pouring a liquid from a short, wide container into a tall, thin container makes the liquid change in volume, ask, "Why do you think so?" or "How could you prove this to one of your friends?"

The family tree shown in Figure 13 suggests that the grandfather (A) has three children (B, C, and D), each of whom has two children (E through J), and one of these children (J) has three children (K, L, and M). Concrete operational thinkers understand the classification. For example, they can reason that person J can at the same time be father, brother, and grandson. A preoperational thinker cannot.

Some Piagetian tasks require children to reason about relations between classes. One such task is **seriation,** the concrete operation that involves ordering stimuli along some quantitative dimension (such as length). To see if students can serialize, a teacher might place eight sticks of different lengths in a haphazard way on a table. The teacher then asks the student to order the sticks by length. Many young children end up with two or three small groups of "big" sticks or "little" sticks rather than a correct ordering of all eight sticks. Another mistaken strategy they use is to evenly line up the tops of the sticks but ignore the bottoms. The concrete operational thinker simultaneously understands that each stick must be longer than the one that precedes it and shorter than the one that follows it.

Transitivity involves the ability to reason about and logically combine relationships. If a relation holds between a first object and a second object, and also holds between the second object and a third object, then it also holds between the first and third objects. For example, consider three sticks (A, B, and C) of differing lengths. A is the longest, B is intermediate in length, and C is the shortest. Does the child understand that if A is longer than B, and B is longer than C, then A is longer than C? In Piaget's theory, concrete operational thinkers do; preoperational thinkers do not.

The Formal Operational Stage The **formal operational stage,** which emerges at about 11 to 15 years of age, is Piaget's fourth and final cognitive stage. At this stage, individuals move beyond reasoning only about concrete experiences and think in more abstract, idealistic, and logical ways.

The abstract quality of formal operational thinking is evident in verbal problem solving. The concrete operational thinker needs to see the concrete elements A, B, and C to make the logical inference that if A = B and B = C, then A = C. In contrast, the formal operational thinker can solve this problem when it is verbally presented. Accompanying the abstract nature of formal operational thought are the abilities to idealize and imagine possibilities. At this stage, adolescents engage in extended speculation about the ideal qualities they desire in themselves and others. These

seriation A concrete operation that involves ordering stimuli along some quantitative dimension.

transitivity The ability to reason and logically combine relationships.

formal operational stage Piaget's fourth cognitive developmental stage, which emerges between about 11 and 15 years of age; thought becomes more abstract, idealistic, and logical.

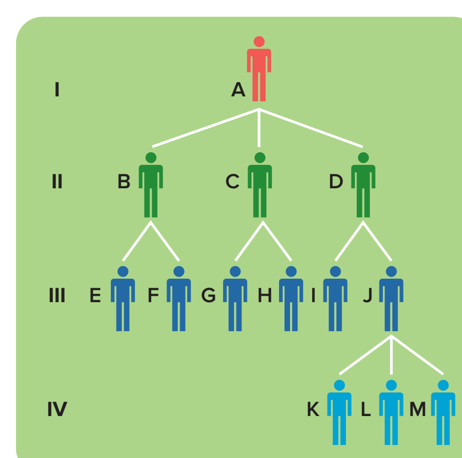


FIGURE 13 CLASSIFICATION

A family tree of four generations (*I to IV*): The preoperational child has trouble classifying the members of the four generations; the concrete operational child can classify the members vertically, horizontally, and obliquely (up and down and across). For example, the concrete operational child understands that a family member can be a son, a brother, and a father, all at the same time.

CONNECTING WITH STUDENTS: Best Practices

Strategies for Working with Concrete Operational Thinkers

As you have just learned, for most of elementary school, children think at a concrete operational level. Their thought process is different from the thinking of young children as well as that of adolescents. Following are some effective strategies for advancing the thinking of children who are at the concrete operational level.

1. *Encourage students to discover concepts and principles.* Ask relevant questions about what is being studied to help them focus on some aspect of their learning. Refrain from telling students the answers to their questions outright. Try to get them to reach the answers through their own thinking.
2. *Involve children in operational tasks.* These include adding, subtracting, multiplying, dividing, ordering, seriating, and reversing. Use concrete materials for these tasks, possibly introducing math symbols later.
3. *Plan activities in which students practice the concept of ascending and descending classification hierarchies.* Have students list the following in order of size (such as largest to smallest): city of Atlanta, state of Georgia, country of United States, Western Hemisphere, and planet Earth.
4. *Include activities that require conservation of area, weight, and displaced volume.* Realize that there is considerable variation in children's attainment of conservation across different domains.
5. *Continue to ask students to justify their answers when they solve problems.* Help them to check the validity and accuracy of their conclusions.

idealistic thoughts may be expressed in fantasy. Many adolescents become impatient with their newfound ideals and the problems of how to live them out.

At the same time that adolescents are thinking more abstractly and idealistically, they also are beginning to think more logically. As formal operational thinkers, they think more like scientists. They devise plans to solve problems and systematically test solutions. Piaget's term **hypothetical-deductive reasoning** embodies the concept that

Might adolescents' ability to reason hypothetically and to evaluate what is ideal versus what is real lead them to engage in demonstrations, such as this protest related to improving education. *What other causes might be attractive to adolescents' newfound cognitive abilities of hypothetical-deductive reasoning and idealistic thinking?*

hypothetical-deductive reasoning Piaget's formal operational concept that adolescents can develop hypotheses to solve problems and systematically reach a conclusion.

adolescents can develop hypotheses (best hunches) about ways to solve problems and systematically reach a conclusion. Formal operational thinkers test their hypotheses with judiciously chosen questions and tests. In contrast, concrete operational thinkers often fail to understand the relation between a hypothesis and a well-chosen test of it, stubbornly clinging to ideas that already have been discounted.

A form of egocentrism also emerges in adolescence (Elkind, 1978). *Adolescent egocentrism* is the heightened self-consciousness reflected in adolescents' beliefs that others are as interested in them as they themselves are. Adolescent egocentrism also includes a sense of personal uniqueness. It involves the desire to be noticed, visible, and "on stage."

Egocentrism is a normal adolescent occurrence, more common in the middle school than in high school years. However, for some individuals, adolescent egocentrism can contribute to reckless behavior, including suicidal thoughts, drug use, and failure to use contraceptives during sexual intercourse. Egocentricity may lead some adolescents to think that they are invulnerable.

What characterizes adolescent egocentrism?

RESEARCH

However, reason to question the accuracy of the invulnerability aspect of the personal fable is provided by research that reveals many adolescents don't consider themselves invulnerable (Fischoff & others, 2010). Some research studies suggest that rather than perceiving themselves to be invulnerable, adolescents tend to portray themselves as vulnerable to experiencing a premature death (Reyna & Rivers, 2008).

Might social media such as Facebook serve as an amplification tool for adolescent egocentrism? A recent study found that Facebook usage does indeed increase self-interest (Chiou, Chen, & Liao, 2014).

I recently asked teachers to describe how they apply Piaget's cognitive stages to their classroom. Following are their comments:

EARLY CHILDHOOD When I teach songs to preschool students who are in the preoperational stage, I use PowerPoint slides projected on the board. The slides have either all the words of the song included, or just key words. I also include corresponding clip art and pictures on the page borders.

—CONNIE CHRISTY, *Aynor Elementary School (Preschool Program)*

ELEMENTARY SCHOOL: GRADES K–5 In my second-grade science class, I use the following method to help students move from concrete thinking to more abstract thinking: Children are given tasks and asked to discuss what happened (for example, the object sank or floated; when something is added to a system, the outcome changes). Then a theory or idea is developed from the actual observations. When children observe an occurrence and explain what was seen, they can more easily move from the concrete to the more abstract. Although these methods and others like it work well with my students, I need to repeat them often.

—JANINE GUIDA POUTRE, *Clinton Elementary School*

MIDDLE SCHOOL: GRADES 6–8 I challenge my seventh-grade students to share examples of how they've applied our classroom lessons to the real world. They can earn extra credit for doing so, but seem to care less about the points than they do about the opportunity to share plishments. For example, after completing a unit on Progressivism, a student shared how he had gone online on his

CONNECTING WITH STUDENTS: Best Practices
Strategies for Working with Formal Operational Thinkers

As you have just learned, adolescents think on a different plane from children. Following are some effective strategies for working with adolescents who are formal operational thinkers.

1. *Realize that many adolescents are not full-fledged formal operational thinkers.* Thus, many of the teaching strategies discussed earlier regarding the education of concrete operational thinkers still apply to many young adolescents. As discussed next in *Through the Eyes of Teachers,* Jerri Hall, a math teacher at Miller Magnet High School in Georgia, emphasizes that when a curriculum is too formal and too abstract, it will go over students' heads.

THROUGH THE EYES OF TEACHERS
Piaget as a Guide

I use Piaget's developmental theory as a guide in helping children learn math. In the sixth, seventh, and eighth grades, children are moving from the concrete to the abstract stage in their cognitive processes; therefore, when I teach, I try to use different methods to aid my students to understand a concept. For example, I use fraction circles to help students understand how to add, subtract, multiply, and divide fractions, and the students are allowed to use these until they become proficient with the algorithms. I try to incorporate hands-on experiences in which students discover the rules themselves, rather than just teaching the methods and having the students practice them with drill. It is extremely important for students to understand the why behind a mathematical rule so they can better understand the concept.

2. *Propose a problem and invite students to form hypotheses about how to solve it.* For example, a teacher might say, "Imagine that a girl has no friends. What should she do?"
3. *Present a problem and suggest several ways it might be approached.* Then ask questions that stimulate students to evaluate the approaches. For example, describe several ways to investigate a robbery, and ask students to evaluate which is best and why.
4. *Develop projects and investigations for students to carry out.* Periodically ask them how they are going about collecting and interpreting the data.
5. *Encourage students to create hierarchical outlines when you ask them to write papers.* Make sure they understand how to organize their writing in terms of general and specific points. The abstractness of formal operational thinking also means that teachers with students at this level can encourage them to use metaphors.

home computer and donated money to help Darfur refugees. He had previously planned to use this money to buy himself a new guitar. This student took the theory of social activism from the Progressive era 100 years ago and applied it to his life today. This student's actions clearly demonstrate Piaget's formal operational stage in action.

—MARK FODNESS, *Bemidji Middle School*

HIGH SCHOOL: GRADES 9–12 My high school art students take part in creativity competitions in which they build, create, explore, problem solve, and perform solutions to challenges presented to them. The competition—"Destination Imagination"—has challenged my students to brainstorm ideas and solutions to seemingly impossible tasks. As a result of their participation in this event, they have won regional and state titles along with the world championship.

—DENNIS PETERSON, *Deer River High School*

TECHNOLOGY

Piaget, Constructivism, and Technology The basic idea of *constructivism* is that students learn best when they are actively constructing information and knowledge. Piaget's theory is a strongly constructivist view. Early in the application of technology to children's learning, Seymour Papert (1980), who studied with Piaget for five years, created the Logo programming language for computers that was based on Piaget's constructivist view. A small robot labeled the "Logo Turtle" guided children in constructing solutions to problems. Today, a wide variety of programs claim constructivism as their foundation and are used in schools worldwide. Examples include robotic kits for students at different grade levels: BeeBots (www.bee-bot.us/) can be programmed for autonomous movement, even by very young children; Dash (www.makewonder.com/dash) and Finch (www.finchrobot.com/) pair with programming apps and languages; Cubelets (www.modrobotics.com/cubelets) are sensor-based blocks that can be programmed to respond to light, sound, motion, and other environmental cues; and Arduino (www.arduino.cc/) is appropriate for older children to create robotics that use sensors.

Children at a Computer Clubhouse, one of 100 Computer Clubhouses worldwide, that provides students from low-income communities opportunities to creatively use technology to explore their ideas and develop their skills.

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Other technologies that support constructive thinking include Scratch (http://scratch.mit.edu/), which is an online programming and communication space for children, and the Computer Clubhouse Network (www.computerclubhouse.org/), which is an international consortium of computer clubs linked over the Internet for 10- to 18-year-olds from low-income communities that provides a creative and safe out-of-school learning environment with adult mentors. An important development in this area is the computational thinking movement, which emphasizes that students need to understand how computers work in order to function in the 21st century. (See https://www.iste.org/explore/articleDetail?articleid=152)

Evaluating Piaget's Theory What were Piaget's main contributions? Has his theory withstood the test of time?

Contributions Piaget is a giant in the field of developmental psychology. We owe to him the present field of children's cognitive development. We owe to him a long list of masterful concepts including assimilation and accommodation, object permanence, egocentrism, conservation, and hypothetical-deductive reasoning. Along with William James and John Dewey, we also owe to Piaget the current vision of children as active, constructive thinkers.

Piaget also was a genius when it came to observing children. His careful observations showed us inventive ways to discover how children act on and adapt to their world. Piaget showed us some important things to look for in cognitive development, such as the shift from preoperational to concrete operational thinking. He also showed us how children need to make their experiences fit their schemas (cognitive frameworks) yet simultaneously adapt their schemas to experience.

Criticisms Piaget's theory has not gone unchallenged. Questions have been raised in the following areas:

- *Estimates of children's competence.* Some cognitive abilities emerge earlier than Piaget thought, others later (Monahan & others, 2016; Quinn & Bhatt, 2016). Conservation of number has been demonstrated as early as age 3, although Piaget did not think it emerged until age 7. Young children are not as uniformly "pre-" this and "pre-" that (precausal, preoperational) as Piaget thought (Flavell, Miller, & Miller, 2002). Other cognitive abilities can emerge later than Piaget thought. Many adolescents still think in concrete operational ways or are just beginning to master formal operations (Kuhn, 2009).

- *Stages.* Cognitive development is not as stage-like as Piaget envisioned (Müller & Kerns, 2015). Piaget conceived of stages as unitary structures of thought. Some concrete operational concepts, however, do not appear at the same time. For example, children do not learn to conserve at the same time as they learn to cross-classify.
- *Training children to reason at a higher level.* Some children who are at one cognitive stage (such as preoperational) can be trained to reason at a higher cognitive stage (such as concrete operational). However, Piaget argued that such training is only superficial and ineffective, unless the child is at a maturational transition point between the stages (Gelman & Opfer, 2004).
- *Culture and education.* Culture and education exert stronger influences on children's development than Piaget envisioned (Gauvain, 2016). For example, the age at which children acquire conservation skills is related to the extent to which their culture provides relevant practice (Cole, 2006). An outstanding teacher can guide students' learning experiences that will help them move to a higher cognitive stage.

Having an outstanding teacher and gaining a good education in the logic of science and mathematics are important cultural experiences that promote the development of operational thought. *Might Piaget have underestimated the roles of culture and schooling in children's cognitive development?*

Still, some developmental psychologists reason we should not throw out Piaget altogether. These **neo-Piagetians** argue that Piaget got some things right but that his theory needs considerable revision. In their revision of Piaget, neo-Piagetians emphasize how children process information through attention, memory, and strategies (Case, 2000). They especially stress that a more accurate vision of children's thinking requires more knowledge of strategies, how quickly and how automatically children process information, the particular cognitive task involved, and the division of cognitive problems into smaller, more precise steps (Fazio, DeWolf, & Siegler, 2016).

Despite such criticism, Piaget's theory is a very important one. As we see next, there are many ways to apply his ideas to educating children.

Thinking Back/Thinking Forward

The information-processing approach emphasizes that children develop a gradually increasing capacity for processing information. Connect to "The Information-Processing Approach."

VYGOTSKY'S THEORY

DEVELOPMENT

In addition to Piaget's theory, another major developmental theory that focuses on children's cognition was developed in Russia by Lev Vygotsky. In Vygtosky's theory children's cognitive development is shaped by the cultural context in which they live (Gauvain, 2016; Holzman, 2017; Yasnitsky & Van der Veer, 2016).

The Zone of Proximal Development Vygotsky's belief in the importance of social influences, especially instruction, on children's cognitive development is reflected in his concept of the zone of proximal development. **Zone of proximal development (ZPD)** is Vygotsky's term for the range of tasks that are too difficult for the child to master alone but that can be learned with guidance and assistance from adults or more-skilled children. Thus, the lower limit of the ZPD is the level of skill reached by the child working independently. The upper limit is the level of additional responsibility the child can accept with the assistance of an able instructor (see Figure 14). The ZPD captures the child's cognitive skills that are in the process of maturing and can be accomplished only with the assistance of a more-skilled person.

Teaching in the zone of proximal development reflects the concept of developmentally appropriate teaching we described earlier in the chapter. It involves being aware of "where students are in the process of their development and

neo-Piagetians Developmental psychologists who believe that Piaget got some things right but that his theory needs considerable revision; they emphasize information processing through attention, memory, and strategies.

zone of proximal development (ZPD) Vygotsky's term for the range of tasks that are too difficult for children to master alone but can be mastered with guidance and assistance from adults or more-skilled children.

CONNECTING WITH STUDENTS: Best Practices

Strategies for Applying Piaget's Theory to Children's Education

Earlier in this chapter, you learned about applying Piaget's theory to teaching children at different stages of cognitive development. Following are five general Piaget-based strategies for educating children.

1. *Take a constructivist approach.* Piaget emphasized that children learn best when they are active and seek solutions for themselves. Piaget opposed teaching methods that treat children as passive receptacles. The educational implication of Piaget's view is that in all subjects students learn best by making discoveries, reflecting on them, and discussing them, rather than blindly imitating the teacher or doing things by rote.
2. *Facilitate rather than direct learning*. Effective teachers design situations that allow students to learn by doing. These situations promote students' thinking and discovery. Teachers listen, watch, and question students to help them gain better understanding. They ask relevant questions to stimulate students' thinking and ask them to explain their answers. As described in *Through the Eyes of Teachers,* Suzanne Ransleben creates imaginative classroom situations to facilitate students' learning.

THROUGH THE EYES OF TEACHERS

Stimulating Students' Thinking and Discovery

Suzanne Ransleben teaches ninth- and tenth-grade English in Corpus Christi, Texas. She designs classroom situations that stimulate students' reflective thinking and discovery. Suzanne created Grammar Football to make diagramming sentences more interesting for students and has students decipher song lyrics to help them better understand how to write poetry. When students first encounter Shakespeare, "they paint interpretations of their favorite line from Romeo and Juliet" (*Source:* Wong Briggs, 2004, p. 7D).

3. *Consider the child's knowledge and level of thinking.* Students do not come to class with empty heads. They have many ideas about the physical and natural world including concepts of space, time, quantity, and causality. These ideas differ from the ideas of adults. Teachers need to interpret what a student is saying and respond with discourse close to the student's level.
4. *Promote the student's intellectual health.* When Piaget came to lecture in the United States, he was asked, "What can I do to get my child to a higher cognitive stage sooner?" He was asked this question so often here compared with other countries that he called it the American question. Piaget believed that maturation in children's learning should occur naturally and that children should not be pushed into achieving too much too early in their development.
5. *Turn the classroom into a setting of exploration and discovery.* What do actual classrooms look like when the teachers adopt Piaget's views? Several first- and second-grade math classrooms provide some good examples (Kamii, 1985, 1989). The teachers emphasize students' own exploration and discovery. The classrooms are less structured than what we think of as a typical classroom. Workbooks and predetermined assignments are not used. Rather, the teachers observe the students' interests and natural participation in activities to determine what the course of learning will be. For example, a math lesson might be constructed around counting the day's lunch money or dividing supplies among students. Often games are prominently used in the classroom to stimulate mathematical thinking.

taking advantage of their readiness. It is also about teaching to enable developmental readiness, not just waiting for students to be ready" (Horowitz & others, 2005, p. 105).

Scaffolding Closely linked to the idea of the ZPD is the concept of scaffolding. **Scaffolding** means changing the level of support. Over the course of a teaching session, a more-skilled person (a teacher or more advanced peer) adjusts the

scaffolding A technique that involves changing the level of support for learning. A teacher or more advanced peer adjusts the amount of guidance to fit the student's current performance.

amount of guidance to fit the child's current performance (Wilkinson & Gaffney, 2016). When the student is learning a new task, the skilled person may use direct instruction. As the student's competence increases, less guidance is given. Scaffolding is often used to help students attain the upper limits of their zone of proximal development.

Asking probing questions is an excellent way to scaffold students' learning and help them to develop more sophisticated thinking skills. A teacher might ask a student such questions as "What would an example of that be?" "Why do you think that is so?" "Now, what's the next thing you need to do?" and "How can you connect those?" Over time, students should begin internalizing these kinds of probes and improve monitoring of their own work (Horowitz & others, 2005).

Many teachers who successfully use scaffolding circulate around the classroom, giving "just-in-time" assistance to individuals or detecting a class-wide misconception and then leading a discussion to correct the problem. They also give children "time to grapple with problems" and guide them when they observe that the child can no longer make progress (Horowitz & others, 2005, pp. 106–107).

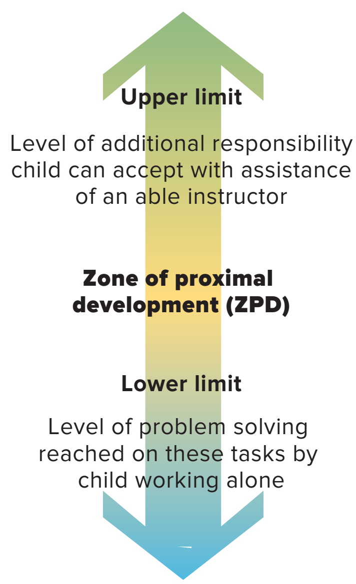

FIGURE 14 VYGOTSKY'S ZONE OF PROXIMAL DEVELOPMENT

Vygotsky's zone of proximal development has a lower limit and an upper limit. Tasks in the ZPD are too difficult for the child to perform alone. They require assistance from an adult or a more-skilled child. As children experience the verbal instruction or demonstration, they organize the information in their existing mental structures so that they can eventually perform the skill or task alone.

Language and Thought In Vygotsky's view, language plays an important role in a child's development. According to Vygotsky, children use speech not only for social communication, but also to help them solve tasks. Vygotsky (1962) further argued that young children use language to plan, guide, and monitor their behavior. This use of language for self-regulation is called *private speech.* For example, young children talk aloud to themselves about such things as their toys and the tasks they are trying to complete. Thus, when working on a puzzle, a child might say, "This piece doesn't fit; maybe I'll try that one." A few minutes later she utters, "This is hard." For Piaget private speech is egocentric and immature, but for Vygotsky it is an important tool of thought during the early childhood years (Alderson-Day & Fernyhough, 2014).

Vygotsky said that language and thought initially develop independently of each other and then merge. He emphasized that all mental functions have external, or social, origins. Children must use language to communicate with others before they can focus inward on their own thoughts. Children also must communicate externally and use language for a long period of time before they can make the transition from external to internal speech. This transition period occurs between 3 and 7 years of age and involves talking to oneself. After a while, the self-talk becomes second nature to children, and they can act without verbalizing. When this occurs, children have internalized their egocentric speech in the form of *inner speech,* which becomes their thoughts.

Vygotsky argued that children who use private speech are more socially competent than those who don't. He argued that private speech represents an early transition in becoming more socially communicative. For Vygotsky, when young children talk to themselves, they are using language to govern their behavior and guide themselves.

Piaget held that self-talk is egocentric and reflects immaturity. However, researchers have found support for Vygotsky's view that private speech plays a positive role in children's development (Winsler, Carlton, & Barry, 2000). Researchers have revealed that children use private speech more when tasks are difficult, after they make mistakes, and when they are not sure how to proceed (Berk, 1994). They also have found that children who use private speech are more attentive and improve their performance more than children who do not use private speech (Berk & Spuhl, 1995).

I recently asked teachers how they apply Vygotsky's theory to their classroom. After reading their responses about Vygotsky, you might want to compare these responses with teachers' descriptions of how they apply Piaget's theory in their classrooms.

EARLY CHILDHOOD In teaching music to preschoolers, I use private speech to help children learn unfamiliar rhythms. When my young students are learning a new rhythm pattern on the African drums, for example, they don't count the eighth and quarter notes, because that is too difficult. Instead, I suggest certain words for them to repeat in rhythmic patterns to learn the beat, or they can come up with their own words to match the new rhythm. My guidance allows children to improve their understanding of musical rhythm.

—CONNIE CHRISTY, *Aynor Elementary School (Preschool Program)*

ELEMENTARY SCHOOL: GRADES K–5 One way to maximize students' zone of proximal development is by flexible grouping. In flexible grouping, groups change often based on need, interest, and so on. I use different group styles—for example, whole class, small group, homogenous groups, and heterogeneous groups. Variance in group members and group styles allows all students to be instructed within their zone of proximal development. This may be on grade level in one area, above grade level in another, and below grade level in still another. The point is that flexible grouping allows me to give students of varying levels the instruction necessary to learn.

—SUSAN FROELICH, *Clinton Elementary School*

MIDDLE SCHOOL: GRADES 6–8 When I teach my students a new skill, it is important that I stay close to them while they are working. This way if they need my assistance, I am there to help them master the new skill with some guidance. This practice works especially well when we are working on multistep projects.

—CASEY MAASS, *Edison Middle School*

HIGH SCHOOL: GRADES 9–12 Advanced art students and independent-study students have always been an active part of my classroom, especially when it comes to helping other students maximize their zone of proximal development (and grow in their own skills as artists as well). In my ceramics class, for example, I have several advanced students—who have especially strong knowledge and skills on the ceramic wheel—help my first-year students, who are attempting to work on the wheel for the first time. This additional assistance from the advanced students allows me to help other students who need further instruction.

—DENNIS PETERSON, *Deer River High School*

We have discussed a number of ideas about both Piaget's and Vygotsky's theories and how the theories can be applied to children's education. To reflect on how you might apply their theories to your own classroom, complete *Self-Assessment 1*.

Thinking Back/Thinking Forward

Collaborative learning and cognitive apprenticeships reflect Vygotsky's social constructivist approach. Connect to "Social Constructivist Approaches."

Evaluating Vygotsky's Theory How does Vygotsky's theory compare with Piaget's? Although both theories are constructivist, Vygotsky's is a **social constructivist approach**, which emphasizes the social contexts of learning and the construction of knowledge through social interaction.

In moving from Piaget to Vygotsky, the conceptual shift is from the individual to collaboration, social interaction, and sociocultural activity (Holzman, 2017; Yasnitsky & Van der Veer, 2016). The endpoint of cognitive development for Piaget is formal operational thought. For Vygotsky, the endpoint can differ, depending on which skills are considered to be the most important in a particular culture. For Piaget, children construct knowledge by transforming, organizing, and reorganizing previous knowledge. For Vygotsky, children construct knowledge through social interaction.

social constructivist approach Emphasizes the social contexts of learning and that knowledge is mutually built and constructed; Vygotsky's theory exemplifies this approach.