Chapter 3

Cognitive Development: Piaget's and Vygotsky's Theories

PIAGET'S THEORY OF COGNITIVE DEVELOPMENT

Key Concepts in Piaget's Theory
Stages of Cognitive Development
Limitations of Piaget's Theory
Educational Implications of Piaget's Theory

VYGOTSKY'S THEORY OF COGNITIVE DEVELOPMENT

Key Concepts in Vygotsky's Theory
Contrasts between Piaget's and Vygotsky's Theories
Limitations of Vygotsky's Theory
Educational Contributions of Vygotsky's Theory

PUTTING PIAGET'S AND VYGOTSKY'S THEORIES TOGETHER

CHAPTER SUMMARY

KEY TERMS

ACTIVITIES

Teacher: *Can someone tell me whether the water today boiled more or less quickly than before?*

Student: *More quickly.*

Teacher: *Why? Who has some ideas?*

Student: *Particles are more separated.*

Teacher: *Okay; let's think about density. Is tap water more or less dense than boiled water? What happens to water when it boils?*

Student: *There are bubbles.*

Student: *It evaporates.*

Teacher: *Is the water turning into gas?*

Student: *Yes.*

Teacher: *Would that make the water more or less dense?*

Student: *Less dense.*

Teacher: *Okay; think about two pots of beans. If you have one pot with just a little bit of beans and a pot with a lot of beans, which pot would take longer to boil?*

Student: *The pot with a lot of beans.*

Teacher: *Why?*

Student: *It's more dense.*

Teacher: *Okay; let's talk about temperature. At what temperature did the tap water boil? What about the already boiled* *water? What did you see? Maybe we first need to come to some consensus about boiling. Who can give me a definition?*

Student: *When the water starts to bubble.*

Student: *When there is steam.*

Teacher: *Okay; if we get steam, what is the boiling water doing? Is it changing states?*

Student: *It's changing into gas.*

Teacher: *Okay; now did the boiling occur at a higher or lower temperature with the already boiled water?*

Student: *Higher.*

Teacher: *Who can tell me why?*

Student: *It's less dense.*

Teacher: *Why?*

Student: *It's got less stuff in it.*

Teacher: *Okay; can anyone give us a general rule about the relationship between density and boiling?*

Student: *The less dense the solution, the longer it takes to boil.*

Teacher: *Good. Now let's think about some other solutions. What about salt water?*

Student: *It's more dense.*

Teacher: *What about alcohol?*

Student: *It's less dense.*

Teacher: *Which would take longer to boil—alcohol or salt water?*

Student: *Alcohol, because it's less dense.*

Teacher: *Good. We'll talk about the experiment some more tomorrow. It's time to change classes.*

This conversation is from a sixth-grade science class. The students have just completed an experiment in which they observed and recorded the temperature of and the time it took to boil a solution of previously boiled water. The teacher expected the students to compare these data with the information they collected from a similar experiment with tap water. At the end of an activity, the teacher and students discuss the results together.

Do you think the students demonstrate a good understanding of the experiment at the beginning of discussion? Not really. Although the students make some very good observations about the experiment, few are able to give a scientific explanation for what they observed. The teacher and students *construct* this understanding jointly. The teacher does not give the students the answers but helps the students think through the experiment by posing questions, linking new information to familiar experiences, giving feedback, and so forth. We will learn that this teacher is providing a *scaffold* to guide the students' thinking. By the end of the discussion, the teacher and students have come to a shared understanding of the experiment, and the students are able to apply this learning to new problems (e.g., What about alcohol and salt water?).

This science teacher is using what is known as a **constructivist approach.** The simple proposition underlying this approach is that children must construct their own understandings of the world in which they live. Knowledge is not something teachers can directly transmit to learners. The information must be mentally acted on, manipulated, and transformed in order to have meaning for the learner. However, as the example illustrates, the teacher helps guide this knowledge construction process through focusing attention, posing questions, and stretching children's thinking. The teacher's role is to help students rethink their ideas by asking questions they would not generally think about on their own. According to a constructivist point of view, learning involves structural changes in the way children think about their world.

Following the constructivist view of learning, children build their own knowledge of the world from interactions with their environment, and teachers help guide this knowledge construction process by focusing attention, posing questions, and stretching children's thinking.

Constructivism is the basis for many current reforms in education. Both the National Council for Teachers of Mathematics and the National Science Teachers Association have called for classrooms where problem-solving, "hands-on" experimentation, concept development, logical reasoning, and authentic learning are emphasized. Similarly, advocates of whole language approaches to reading and language arts also stress the importance of authentic learning in which students are immersed in a language-rich environment in meaningful and productive ways.

In this chapter, we examine the developmental theories that provide the psychological foundations for a constructivist approach to learning. Constructivism is theoretically grounded in the developmental research of Piaget and Vygotsky. Piaget's theory can help teachers understand how children reason or think about their world at different ages. Vygotsky's theory can help teachers understand the social processes that influence the development of children's intellectual abilities. Both theories have important implications for teaching.

Piaget's Theory of Cognitive Development

Jean Piaget had a major impact on the way we think about children's development. Before Piaget's theory was introduced, children were generally thought of as passive organisms who were shaped and molded by their environment. Piaget taught us that children act as "little scientists," trying to make sense of their world. They have their own logic and ways of knowing, which follow predictable patterns of development as children biologically mature and interact with the world. By forming mental representations of their world, children are able to act on and influence their environment as much as their environment influences them.

Piaget taught us that children actively seek knowledge through their interactions with the environment and that they have their own logic and ways of knowing that evolve over time.

Piaget was born in Switzerland in 1896. As a child, he was extremely bright and inquisitive. By the age of 10, he published his first scientific paper; he received his first job as a curator of the mollusk collection at the Geneva museum by the age of 15. He received his Ph.D. in natural sciences 6 years later. Piaget continued to develop his scholarship in many areas, including sociology, religion, and philosophy. While studying philosophy, he became intrigued with epistemology, or how knowledge is obtained. This question led him to study philosophy and psychology at the Sorbonne, where he met Theodore Simon, who, at the time, was developing the first intelligence test for children. Simon persuaded Piaget to assist him in collecting age norms for his test items. It was through this work that Piaget began to explore children's reasoning processes. He became intrigued with the fact that individual children often had very different reasons for the answers they chose. For example, two children might say a tree is alive but explain their answers differently. One child may say it is alive because it moves, while another may say it's alive because it makes seeds. Through a set of procedures, which became known as the *clinical interview method* (see Chapter 1, pp. 00–00), Piaget explored the reasoning processes underlying children's correct and incorrect answers. His fascination with children's knowledge acquisition processes helped sustain a 60-year career in child development research. By the end of his career, Piaget had published more than 40 books and 200 articles on child psychology.

Piaget was an early constructivist theorist in psychology. He believed that children actively construct their own knowledge of the environment using what they already know to interpret new events and objects. Piaget's research focused primarily on how children acquire knowledge as they develop. That is, he was not so interested in *what* children know as he was in *how* they thought about problems and solutions. He believed cognitive development involved changes in a child's ability to reason about his or her world.

Key Concepts in Piaget's Theory

Cognitive Stages

Piaget divided cognitive development into four major stages, each stage representing a transformation into a more complex and abstract way of knowing.

Piaget was a stage theorist who divided cognitive development into four major stages: sensorimotor, preoperations, concrete operations, and formal operations. At each stage of development, children's thinking is assumed to be *qualitatively* different from their thinking at other stages. According to Piaget, cognitive development involved not simply quantitative changes in facts and skills but rather major transformations in the way children organize knowledge. Once children have entered a new cognitive stage they do not revert to an earlier form of reasoning or functioning.

Piaget proposed that cognitive development occurs in an invariant sequence. That is, all children proceed through the four stages of cognitive development in the same sequence. It is not possible to skip or miss a stage. Piaget's stages are generally related to specific age ranges, but there is a great deal of individual and cultural variation in the amount of time children may spend in a particular stage. We will examine the cognitive characteristics of each stage in a later section.

Development as Changes in Knowledge Structures

Schemes are sets of physical actions, mental operations, concepts, or theories people use to acquire information about their world.

Piaget believed that everyone, even infants, begin to organize their knowledge of the world into what he called *schemata* or *schemes.* **Schemes** are sets of physical actions, mental operations, concepts, or theories people use to organize and to acquire information about their world. Young children primarily know their world through physical actions they can perform, whereas older children and adults can perform mental operations and use symbol systems (e.g., language) to acquire knowledge about their world. As children progress through Piaget's stages, they become increasingly able to use complex and abstract schemes for organizing knowledge. Cognitive development involves not just the construction of new schemes, but the reorganization and differentiation of existing schemes.

Piaget distinguished between three types of knowledge. **Physical knowledge** is knowing the attributes of objects such as their number, color, size, and shape. Other examples of physical knowledge may include the observations that some objects roll and other do not, that some objects float and others do not, or that length of string can effect how fast objects on a pendulum move back and forth. Physical knowledge is acquired by acting on objects, experimenting, and observing reactions.

Logico-mathematical knowledge involves the mental construction of relationships. For example, logico-mathematical knowledge involves the understanding that a certain number of objects (which can be observed and counted) also represent a more abstract concept such as number. The number "eight" is an abstract concept that cannot be derived from experience. Also, groups of 10 objects can make up larger numbers such as 50 or 100. Logico-mathematical knowledge is also evident in the understanding that a mathematical problem such as 4 + 4 can also be represented by 2 + 2 + 2 + 2. Whereas physical knowledge is derived from observing and experimenting, logico-mathematical knowledge involves mental constructions or a **reflective abstractions.** Figure 3.1 shows children's representation of the number "eight" in Piaget's theory. In this example, the eight apples, tallies, and circles are concrete and observable (physical knowledge), but the number "eight" is a form of logico-mathematical knowledge because it is a construction that needs to constructed by the child from social knowledge. Unlike tallies and pictures that children can use to express their understanding of eight, the spoken word or sign for eight is taught (Kamii, 2000).

Physical knowledge is derived from observing and experimenting, but logico-mathematical knowledge involves mental constructions or abstractions.

In this way, Piaget's theory also recognized the importance of **social knowledge** that is derived in part through interactions with others. Examples of this form of knowledge are mathematical words and signs (e.g., "+" for addition), languages, musical notations, as well as social and moral conventions, such as turn taking in conversations, ways of initiating interactions, how to play a game, or how to respond to another person in distress.

Principles of Development

Organization and Adaptation In Piaget's theory two basic principles guide children's intellectual development. The first of these principles is **organization,** which Piaget believed is an innate predisposition in all species. As children mature, they integrate simple physical patterns or mental schemes into more complex systems. The second guiding principle is **adaptation.** According to Piaget, all organisms are born with the ability to adapt their mental structures or behavior to fit environmental demands.

Assimilation and Accommodation Piaget used the terms *assimilation* and *accommodation* to describe how children adapt to their environment. Through the process of **assimilation**

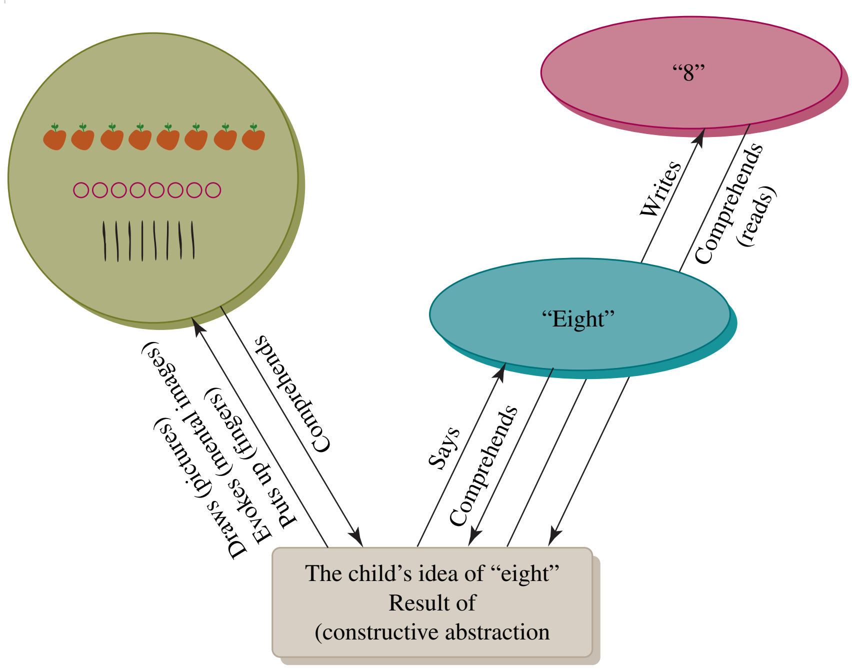


FIGURE 3.1
A Child's Representation of "Eight" in Piaget's Theory
SOURCE: After Kamii (2000)

children mold new information to fit their existing schemes. For example, a young child who has never seen a donkey may refer to it as a pony with long ears. Assimilation is not a passive process; it often involves actively modifying or transforming new information to make it fit prior knowledge. When this new information is consistent with what the child already knows, a state of equilibrium or balance is achieved. All the pieces of information fit together. When new information does not fit into an existing scheme, the child may alter his or her old way of thinking or acting to fit the new information. The process of changing existing schemata is called **accommodation.** In the example given here, the child may form a new scheme when he or she learns that the animal was not a pony but a donkey. Accommodation is most likely to occur when the information is only slightly discrepant with the child's existing schemes. If the information is too discrepant, accommodation may not be possible, because the child does not have any mental structures for interpreting this information. According to Piaget, the processes of assimilation and accommodation are closely intertwined and explain changes in cognition throughout the life span.

Assimilation is the process of actively molding new information to fit existing schemes; accommodation is the process of changing existing schemes to fit new, discrepant information.

Can you think of an example of assimilation and accommodation from your own learning experiences? As you are reading this material, you should be using what you already know about children's development to make sense of the new information. However, you may need to adjust some of your ideas as you acquire new information. For example, you may have learned elsewhere that infants are incapable of symbolic thought. As you will see, Piaget's theory teaches us that a form of symbolic thought begins to emerge during the second year. Therefore, in order to develop a more sophisticated understanding of infancy, you would need to change your existing knowledge of infant development to incorporate (accommodate) this new information.

Development Processes

If cognitive development represents changes in children's cognitive structures or schemata, what causes those developmental changes? As an interactional theorist, Piaget viewed development as a complex interaction of innate and environmental factors. According to Piaget, the following four factors contribute to children's cognitive development:

- Maturation of inherited physical structures
- Physical experiences with the environment
- Social transmission of information and knowledge
- Equilibration

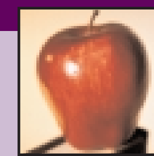
Equilibration is a unique concept in Piaget's theory that refers to our innate tendency to keep our cognitive structures in balance. Piaget maintained that states of disequilibrium or imbalance are so intrinsically dissatisfying that people are compelled to alter their cognitive structures in order to restore balance. Equilibration is thus a form of self-regulation in Piaget's theory. By altering and adjusting our cognitive structures we maintain organization and stability in our environment. We also reach a higher level of cognitive functioning as a result of this equilibration process.

Equilibration is the innate tendency to keep one's cognitive structures in balance using the processes of assimilation and accommodation.

Stages of Cognitive Development

Piaget proposed that cognitive development followed an invariant sequence from infancy through adolescence. The four stages of development are: (1) sensorimotor stage (birth to 2 years); preoperational stage (2 to 7 years); (3) concrete operational stage (7 to 11 years); and (4) formal operational stage (11 years through adulthood). The Focus on Development summarizes characteristics of each stage. As we will discuss later, child development

Focus on Development



Stages in Piaget's Theory of Cognitive Development

Stage	Age	Characteristics
Sensorimotor		
The Active Child	Birth to 2 Years	Infants develop goal-directed behavior, means-ends thinking, and object permanence.
Preoperations		
The Intuitive Child	2 to 7 Years	Children can use symbols and words to think. Intuitive problem solving, but thinking limited by rigidity, centration, and egocentrism.
Concrete Operations		
The Practical Child	7 to 11 Years	Children develop logical operations for seriation, classification, and conservation. Thinking tied to real events and objects.
Formal Operations		
The Reflective Child	11 to 12 Years and Onward	Children develop abstract systems of thought that allow them to use propositional logic, scientific reasoning, and proportional reasoning.

researchers today question several aspects of Piaget's theory. For instance, questions have been raised about the ages associated with each stage. We will learn that children may be able to perform some cognitive operations earlier or later than Piaget originally proposed. Theorists have also raised questions about the stagelike nature of children's thinking. When children are making a transition into a new stage, they often exhibit characteristics of the new and old stage at the same time. We will first discuss the four stages, then consider the limitations of Piaget's theory.

According to Piaget, children acquire the competencies of goal-related behavior and object permanence during the sensorimotor period.

Sensorimotor Stage (Birth to 2 Years)

During the **sensorimotor stage,** children acquire schemes for two basic competencies: (1) goal-directed behavior and (2) object permanence. Piaget regarded these schemes as the building blocks of symbolic thinking and human intelligence.

Development of Goal-Directed Behavior One defining characteristic of the sensorimotor period is an infant's clear progression toward goal-directed actions. At birth, a child's behavior is largely controlled by reflexes. Babies are born with the ability to suck, grasp, cry, and move their bodies, which allows them to assimilate physical experiences. For example, a young child learns to differentiate hard from soft objects by sucking on them.

Six-Month Old Infant
SOURCE: Mike Malyszko/Stock Market.

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Within the first few months, new behaviors are added. Thumb-sucking, for instance, is a chance occurrence that, once discovered, is repeated over and over, because it is a pleasant sensation for the baby. It is initiated by the child with a specific goal in mind. Piaget referred to this set of intentional or goal-directed actions as **circular reactions.**

By the end of the first year, a child begins to anticipate events and combines previously acquired behaviors to achieve those goals. At this point, infants are no longer repeating accidental events but are initiating and selecting a sequence of actions to obtain a specific goal. Piaget first observed this sequence of behavior when he placed his 10-month-old son's favorite toy under a pillow. His son paused, batted the pillow away, and grabbed the toy. He combined several actions to get what he wanted.

At the end of the sensorimotor period, children begin to experiment with new ways of accomplishing their goals when a problem cannot be solved with existing schemata (such as looking, reaching, and grasping). If, for example, a child's toy is out of reach under the sofa, the child may crawl around to the back of the sofa to retrieve it. Rather than continuing to apply existing schemata, the child is now able to mentally construct new solutions to problems. For Piaget, the invention of new problem-solving methods marked the beginning of truly intelligent behavior. Although children continue to solve problems through trial and error for many more years, some of this experimentation can now be carried out internally through mental representation of action sequences and goals.

Development of Object Permanence

Another important development that occurs in the sensorimotor period is object permanence. **Object permanence** involves the knowledge that objects continue to exist even when they can no longer be seen or acted on. As adults, we know a missing shoe continues to exist even though we cannot see it. We search the closet, check under the bed, and finally find it under the sofa in the living room. Young infants act differently when objects disappear from their sight. They act as though the object no longer exists.

A child's concept of object permanence can be studied in a number of different ways. As described here, one way is to hide a child's favorite toy under a pillow or blanket while the child watches. Young infants (1 to 4 months) may visually track the object to the spot where it disappears but show no awareness of the object once it is no longer visible. Piaget explained that at this age, objects have no reality or existence for children unless directly perceived. Because the child's only way of knowing objects is through their reflexive actions, an object no longer exists if it cannot be sucked, grasped, or seen. In other words, the child is not yet able to form a mental representation of this object.

Object permanence involves the knowledge that objects continue to exist even when they are out of sight.

The first glimmer of object permanence emerges around 4 to 8 months. The child will now search for an object if it is partially visible but needs some perceptual cue to remember the object continues to exist. Between 8 and 12 months, a child's behavior indicates that he or she understands an object continues to exist even though it cannot be seen. Children will now actively search for hidden objects by combining several sensorimotor schemes, such as looking, crawling, and reaching, into goal-directed actions.

Some researchers have questioned Piaget's findings on object permanence (Baillargeon, Spelke, & Wasserman, 1985; Flavell, 1985). Recent evidence suggests that a mental representation of objects may appear as early as 3 and 4 months. Other researchers claim that babies may understand that objects are permanent, but may lack the memory skills to remember the location of the object or the motor skills to carry out the actions needed to find the object. Nevertheless, most theorists agree that the ability to construct mental images of objects within the first year of development is a significant achievement. From this point on, children's intellectual development is influenced more by mental representations than by sensorimotor activities.

Preschool Child Playing Dress-UP
SOURCE: LWA/Dann Tardif/The Stock Market.

Preoperational Stage (2 to 7 Years)

The ability to think about objects, events, or people in their absence marks the beginning of the preoperational stage. From 2 to 7 years old, children demonstrate an increased ability to use symbols—gestures, words, numbers, and images—to represent real objects in their environment. They can now think and behave in ways that were not possible before. They can use words to communicate, use numbers to count objects, engage in make-believe play, and express their ideas about the world through drawings.

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Although the ability to represent objects and events symbolically is a significant advance, preoperational thinking is limited in a number of ways. Piaget used the term **preoperational stage** because preschool children lack the ability to do some of the logical operations he observed in older children. Before examining the limitations of preoperational thinking, let's consider the important cognitive advances of this stage.

Semiotic or representational thinking is the ability to use words to stand for (symbolize) an object that is not present or events not directly experienced.

Representational Thinking During the preoperational stage, children can use symbols as a tool to think about their environment. The ability to use a word (e.g., *cookies, milk*) to stand for a real object that is not present is called **symbolic** or **representational thinking.** Piaget suggested that one of the earliest forms of representational thinking was deferred imitation, which first appears toward the end of the sensorimotor period. **Deferred imitation** refers to the ability to repeat a simple sequence of actions or sounds several hours or days after they were originally produced. Piaget (1962) observed the following example of deferred imitation with his daughter:

> Jacqueline (1 year, 4 months) has a visit from a 1.5-year-old boy whom she used to see from time to time, and who, in the course of the afternoon, got into a terrible temper. He screamed as he tried to get out of the playpen and pushed it backward, stamping his feet. Jacqueline stood watching him in amazement, never having witnessed such a scene before. The next day, she herself screamed in her playpen and tried to move it, stamping her feet lightly several times in succession. (p. 62)

The ability to repeat a sequence of actions or sounds several hours or days after they were originally made is called deferred imitation.

Several new examples of representational thinking appear during the preoperational stage. The preschool years are often considered the "golden age" of symbolic play (Singer & Singer, 1976). Symbolic play begins with simple sequences of behavior using real objects, such as pretending to drink from a cup or to eat with a spoonlike object. By 4 years of age, children can invent their own props, make up a story line, and assume various social roles. Consider how these 4-year-olds are learning to negotiate social relationships in the following example of pretend play from Vivian Gussin Paley's (1988) *Bad Guys Don't Have Birthdays:*

Barney: Keep makin' gold. You're the walkout guards and the goldmakers. Don't forget, I'm the guard that controls the guns.

Frederick: But we control the guns when you sleep.

Barney: No. You make the gold and I control the guns. Anyway, I'm not sleeping, because there's bad guys coming. Calling all guards! Stuart get on. You wanna be a guard? Bad guys! They see the ship because it's already in the sun.

Mollie: No bad guys, Barney, the baby is sleeping.

Barney: There hasta be bad guys, Mollie. We gots the cannons.

Mollie: You can't shoot when the baby is sleeping.

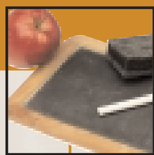
Barney: Who's the baby? We didn't say a baby.

Mollie: It's Christopher. Come on, baby Starlite. Lie down over here.

Barney: Say no, Christopher. You can be the Boy Scout brother. Say no, say no.

Christopher: I gotta shoot bad guys for awhile, okay, Mollie? (p. 19)

Focus on Teaching



Should Superheros Be Banned from the Classroom?

Children's involvement in superhero play is a growing concern of teachers and parents. Many believe that permitting children to play Ninja Turtles, Power Rangers, and Buzz Light Year can increase young children's aggressive tendencies. In Chapter 7, we will discuss the influence of television violence on the development of aggression in children. For the most part, this research suggests that the effects of television violence are not straightforward. Research also suggests that superhero play makes up less than 5 percent of play time in early childhood settings, and generally only a few children, mostly boys, engage in this type of play. (Boyd, 1997). Studies further suggest that teachers and children often have differing perspectives on superhero play. Teachers tend to see these behaviors as "aggressive," whereas children see them as playful. Interviews with preschool teachers reveal that superhero play is often equated with adolescent violence and gang activity. However, there is no evidence connecting superhero play to violent behavior in later development. Furthermore, researchers argue that fantasy play may help children to work through issues related to power and control (Carlsson-Paige & Levin, 1991). Banning superhero play from the classroom or playground can send the message to children that they need to hide their interests from adults, and teachers may lose an opportunity to help children express concerns about power and control. This is not to say that educators should not help children learn from their superhero friends. There are resources available to help teachers support and use superhero play effectively in their classroom (see Greenberg, 1995; Gronlund, 1992; Levin, 1994).

For the most part, children's pretend play reflects real events in their lives (e.g., playing house, going to the store, going on a trip), but pretend play involving fantasy and superhero characters is very appealing to young children as well. As discussed in the Focus on Teaching box, many parents and educators have become vocal opponents of superhero play in the classroom. However, many experts believe that pretend play is important for the development of children's language, cognitive, and social skills. It also helps to foster their creativity and imagination.

Piaget believed that the development of representational thinking enables children to acquire language. The preschool years are a period of rapid language development, with most children saying their first words around their second birthday and increasing their vocabulary to approximately 2,000 words by the age of 4. We will discuss language development in detail in Chapter 5; for now, it is important to understand its connection to representational thinking. When babies first begin to talk, they use words that refer to ongoing activities and events and immediately present desires. During the preoperational period, children begin to use words in a truly representational way. Rather than focusing exclusively on ongoing activities or immediate desires, children begin to use words to stand for absent objects and past events (Ginsburg & Opper, 1988). In other words, children use words to refer to events they are not experiencing directly. Piaget believed that representational thinking facilitates the rapid development of language in the preoperational period. That is, thinking precedes language development in Piaget's view.

In Piaget's view, the development of representational thinking allows children to acquire language.

During the preoperational period, children also begin to represent their world through pictures and images, leading some experts to refer to children's art as the "silent language." By studying children's art, we can learn much about their thinking and feelings. For example, 2- and 3-year-old children, when asked what they are drawing or painting, are likely to respond, "I'm just drawing." By age 3 or 4, however, children begin to combine marks to make squares, crosses, circles, and other geometric shapes. Children enter the representational stage of drawing around the age of 4 or 5. They draw houses, animals, people, cartoon characters, and other objects. Their figures may represent real objects in their environment or fantasy characters they have heard about or seen. The Focus on Development box shows this developmental progression in children's drawings. As they develop, children add more and more detail to their drawings, including words that tell the story line. By the time they enter kindergarten, some children can write their own names. Now, printed words as well as pictures can stand for a real object in a child's environment.

Number Concepts Along with an increased ability to use words and images as symbols, children begin to use numbers as a tool for thinking during the preschool years. Piaget argued that children do not acquire a true concept of numbers until the concrete operational stage when they begin to understand serial and hierarchical relations. However, recent research has indicated that some basic number principles begin to appear during preoperations. Research by Rochel Gelman and her associates (Gelman & Gallistel, 1978; Gelman & Meck, 1983) suggests that some 4-year-olds can understand the following basic principles of counting: (a) any array of items can be counted; (b) each item should be counted only once; (c) numbers should be assigned in the same order; (d) the order in which objects are counted is irrelevant; and (e) the last spoken number word is the number of items in that set. Preschool children also have some basic understanding of number relationships. Most 3- and 4-year-olds, for example, know that 3 is more than 2. In addition, preschool children seem to have an intuitive understanding of addition and subtraction.

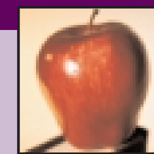
Although preschoolers are beginning to understand basic number concepts, it is important to keep in mind that they will make plenty of counting errors. They may skip numbers (e.g., 1, 2, 3, 5), miss items while counting, and so on. In addition, most preschool and early elementary children have difficulty counting large groups of disorganized items (Baroody, 1987). It is also difficult for preschool children to count beyond 10 in English, because the teen-number words do not follow their 1 to 10 counterparts. Learning to count beyond 10 is easier for children who speak Japanese, Chinese, or Korean (see Focus on Research).

Preoperational children have an animistic conception of the world; they do not distinguish between animate and inanimate objects.

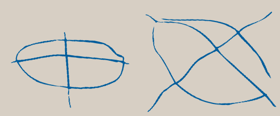
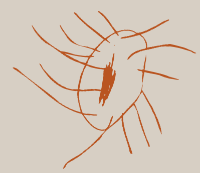
Intuitive Theories Young children are known for their curiosity and inquisitiveness. During the preschool years, children begin to form **intuitive theories** about natural phenomena. Piaget (1951) interviewed young children to find out how they explained events, such as the origins of trees, the movement of clouds, the beginning of the sun and moon, and the concept of life. He found that young children's conceptions of the world are characterized by **animism;** that is, they do not distinguish between animate (living) and inanimate (mechanical) objects, and they attribute intentional states and human characteristics to inanimate objects. For example, a 3-year-old may say that the sun is hot because it wants to keep people warm or that trees lose their leaves because they want to change the way they look. Rocks, trees, fires, rivers, cars, and bicycles are all judged to have lifelike characteristics because they move. The following example illustrates this animistic thinking, according to Piaget:

> Zimm (7 years, 9 months; child's responses in italics). Is a cat alive? *Yes.* A snail? *Yes.* A table? *No.* Why not? *It can't move.* Is a bicycle alive? *Yes.* Why? *It can go.* Is a cloud alive? *Yes.* Why? *It sometimes moves.* Is water alive? *Yes, it moves.* Is it alive when it does not

Focus on Development



Developmental Progression of Children's Drawings

Placement stage	Age 32 months	 (scribbles)
Basic shapes	Age 42 months	 (circle)
Design stage	Age 40 and 47 months	 (combination design)
Pictoral stage	Age 45 months	 (sun)
Pictoral stage	Age 48 to 60 months	 (humans)

SOURCE: After Kellogg (1970)

> move? *Yes.* Is a bicycle alive when it isn't moving? *Yes, it's alive, even when it doesn't move.* Is a lamp alive? *Yes, it shines.* Is the moon alive? *Yes, sometimes it hides behind the mountains.* (Piaget 1951, p. 199)

In constructing their beliefs, children draw on their own personal experiences and observations. The term *intuitive* is often applied to the preoperational stage, because the child's reasoning is based on immediate experiences.

Basic number concepts begin to emerge during the preschool years.

Focus on Research

Learning Place Value: Does Language Make a Difference?

International comparisons of mathematics achievement consistently show large differences in favor of Asian students. Research studies have shown that the superior performance of Asian students in abstract counting and in understanding place value may already be apparent by the first grade. Differences in children's understanding of number concepts may be due to differences in the number words. In most languages, the numbers 1 to 10 are arbitrary, and the numbers after 20 have a regular pattern (twenty-one, thirty-two, etc). English, French, and Swedish children have a difficult time learning the number words from 11 to 20, because the teen-numbers do not match their 1 to 10 counterparts. In Japanese, the numbers from 11 to 20 follow a regular pattern, and they are composed of "ten" plus the single number. For example, in Japanese the number 10 is *juu* and the number 2 is *ni.* The word for twelve is *juu-ni* ("ten-two"). The number words for 11 to 20 also follow this pattern in Chinese and Korean.

Do the number words for 11 to 20 give Asian children an advantage in learning to count? Studies show no differences in children's counting performance through the age of 3 when learning is focused on acquiring the first 10 number words. However, around the time children begin to learn the teen words large differences appear. Learning to count beyond 10 is considerably easier for children who speak some Chinese, Japanese, or Korean because the number words for 11 to 20 follow a regular pattern (e.g., "ten-one," "ten-two," etc.). In addition, studies reveal that Asian children have less difficulty than U.S. children in understanding place value because the number names in their languages explicitly state each number's composition ("ten-five"). By the time Asian children are 6 years old, they have little difficulty making models of multidigits using 10 blocks and units. For example, they can represent the number 54 with 5 ten blocks and 4 unit blocks. In contrast, U.S. children showed a preference for representing whole numbers in terms of individual units rather than units of 10. Asian number words may help children in those countries to learn place value at a younger age than U.S. children who, even by the third grade, have difficulty identifying correctly the value of numerals in different positions (e.g., in the one place, tens place, and hundreds place).

This research has important implications for education. To help children acquire a sense of number and place value, teachers might use counting words that resemble Asian languages, such "ten-one," "ten-two," "ten-three" as a different way of saying *eleven, twelve,* and *thirteen.* Children also need opportunities to work with math manipulatives that provide opportunities to organize large numbers of items into units of 10s.

SOURCE: Adapted from Miura, Okamoto, Kim, Steere, & Fayol (1993).

However, recent studies reveal that children's intuitive understandings of their physical and biological concepts are a little more sophisticated than Piaget believed. In the area of physics, research suggests that young children have a naive understanding of atomic theory of matter—objects are composed of tiny bits of matter (Carey, 1991). Four-year-olds understand that you cannot pour water into a box that is already filled with a steel block.

- Sugar ceases to exist when placed in water.
- Clouds or the earth's shadow causes the phases of the moon.
- Plants get their food from the soil.
- Light travels farther at night than in the day.
- Shadows are made out of matter.
- Heavier objects fall faster.
- Electric current is used in a light bulb.
- The world is flat.
- Coldness causes rust.
- If you add warm water to an equal amount of warm water, you get water that is twice as warm.

FIGURE 3.2
Elementary School Students' Naive Conceptions in Science

SOURCES: After Driver, Guesne, & Tiberghien (1985) and Hyde & Bizar (1989).

Preschoolers can also attribute the snuffing out of a candle to a fan that was turned on rather than one turned off. Other research suggests that preschool children have also developed concepts about the earth's shape, the movement of the planets, and so on. Along these same lines, toddlers and preschoolers have acquired some rudimentary biological conceptions as well. Preschool children can distinguish inanimate from living objects, contrary to Piaget's suggestion, and they are beginning to develop an understanding of biological properties. Recent research suggests that preschool children recognize that plants, like people, can grow, heal, and decompose (Wellman & Gelman, 1998). Preschool children also have a rudimentary understanding of inheritance. They expect, for example, that animals of the same family share certain physical properties. Additionally, they understand that an infant calf that comes from a cow will grow up "to moo" and "to have a straight tail," even if it is raised among pigs.

However, young children have many misconceptions of their intuitive physical and biological worlds that can have a lasting influence on their learning. When children are presented factual information in school this information is often assimilated into the naive or commonsense theories they have already formed about the world. For example, Eaton, Anderson, and Smith (1984) found that after 6 weeks of science lessons on light and vision, most of the fifth-graders in their study held onto their naive conceptions: We see things because light shines on them and brightens them. According to these researchers, the teachers seemed to do everything right in presenting scientific explanations, but they did not directly confront their students' naive conceptions of light. Figure 3.2 lists other examples of children's naive theories in science. These schemes for explaining natural events may persist, unless children's naive conceptions are confronted directly.

Just as children begin to develop theories of the external world during the preoperational period, they also begin to develop theories about the internal world of the mind. Piaget (1963) proposed that children confuse mental and real events. This confusion was most evident when children were asked to explain the origins of dreams (e.g., Where do dreams come from?). For preoperational thinkers, dreams are external events that can be seen by

Preschool children understand that the mind can think, remember, and dream.

other people. Piaget used the term **realism** to describe the young child's tendency to confuse physical and psychological events.

Current research indicates that preschoolers' knowledge of the mind is more sophisticated than Piaget originally suggested (Wellman & Gelman, 1998). According to Henry Wellman (1990), most 3-year-olds understand that internal wishes and desires can cause a person to act a certain way. Most 3- to 5-year-olds also know it's not possible to touch or eat cookies that are in a person's dreams, and they know dreams can be about impossible events, such as a dog flying (Wellman & Estes, 1986). When asked to name things the mind can do, 4- and 5-year-olds say that the mind can think, remember, and dream. By this age, children can also distinguish between their own knowledge and that of others (Wellman, 1990).

Although children are beginning to develop a theory of mind in the preoperational stage, they have a very limited understanding of thinking processes and memory. Preschool children, for example, believe they can remember everything they see and hear. Between the ages of 8 and 10, children begin to acquire what is known as *metacognitive knowledge.* **Metacognition** is "thinking about thinking," and it plays a very important role in children's cognitive development during the middle childhood years. We will discuss how metacognition influences children's cognitive development when we explore information processing theories.

Preoperational thinking is limited because it is egocentric, rigid, and centered on only one aspect of a stimulus.

Limitations of Preoperational Thinking So far we have discussed the important advances in children's thinking during the preoperational period. Let's turn to some of the limitations of preoperational thinking. The three main cognitive limitations of this stage are egocentrism, centration, and rigidity of thinking.

Egocentrism refers to the tendency to "perceive, understand, and interpret the world in terms of the self" (Miller, 1993, p. 53). This egocentrism is particularly evident in the conversations of preschoolers. Because young children are unable to take the perspective of others, they make little effort to modify their speech for the listener. Three-year-olds seem to have what are called **collective monologues,** in which their remarks to each other are unrelated. By 4 and 5 years of age, children begin to show some ability to adjust their communication to the perspective of their listeners.

Piaget and Inhelder (1956) used the famous mountain task to study the egocentrism of young children. A model of a landscape containing three mountains was placed on top of a table with four chairs arranged around the table. For the study, a child sat in one chair and was asked to choose from a group of drawings the one that best described how the mountains might look to a person sitting in another chair. This study found that most children under the age of 7 or 8 picked the drawing that showed how the mountains looked to them, not how the mountain might look to someone sitting in another chair.

Some researchers have claimed that the mountain task is not a fair test of children's perspective-taking abilities. To do this task, children must be able to rotate objects in a spatial arrangement. When a simplified form of this task is used, preschoolers seem to be less egocentric than Piaget claimed. For example, most 3-year-olds understand that if a picture of an object is held vertically facing them, they can see the depicted object, but someone sitting opposite them cannot, as Figure 3.3 shows. This later research suggests that an understanding that two people can have different perspectives of the same object develops between the ages of 3 and 4 (Flavell, 1985).

Another limitation of preoperational thinking is *centration.* **Centration** means that young children tend to focus or center their attention on only one aspect of a stimulus. Other features of the stimulus are ignored. As will be discussed later, centration explains why children have difficulty performing conservation tasks. Suppose you show a 4-year-old two identical glasses containing the same amount of water and then pour the contents

Which child can see the cat?

FIGURE 3.3
Perspective-Taking Task

of one glass into a tall, thin glass. When asked, "Which glass has more?" the child will focus on the height of the water and choose the taller glass. Other dimensions of the glass, such as its width, will be ignored.

This example illustrates another limitation of preoperational thought. Young children's thinking tends to be very rigid. In the previous example, the child is focusing on "before" and "after" states rather than the transformation process. With development, children's thinking becomes less rigid, and they begin to consider how transformations (pouring the contents of one glass into another glass) can be reversed. The ability to mentally reverse operations is a characteristic of the next stage of cognitive development known as *concrete operations.*

Until children have developed some mental operations, such as reversibility, they tend to base their judgments of quantity on perceptual appearances rather than reality. If a glass looks like it has more water, young children assume it has more. Flavell and his associates (Flavell, Green, & Flavell, 1986) studied children's understanding of appearances and reality. They found that the ability to distinguish appearance from reality develops between the ages of 3 and 5. When 3-year-olds are shown a sponge that looks like a rock, they believe it really is a rock. If a cloth smells like an orange, then it is an orange. This tendency to confuse reality and appearances is what makes Halloween a scary event for most 3-year-olds and some 4-year-olds. If a person looks like a monster, then that person must be a monster! By age 5, most children begin to distinguish between appearances and reality.

Concrete Operational Stage (7 to 11 Years)

In the elementary years, children begin to use mental operations and logic to think about events and objects in their environment. For example, if asked to arrange a set of five sticks according to size, concrete operational thinkers can mentally compare the objects and then draw logical inferences about the correct order without physically performing the actions. This ability to use logic and mental operations allows concrete operational children to approach problems more systematically than a preoperational child.

The ability to think logically and perform mental operations allows concrete operational children to approach problems more systematically than preoperational children.

According to Piaget, there are several advances in children's thinking during the **concrete operational** stage. First, their thinking appears to be less rigid and more flexible. The child understands that operations can be mentally reversed or negated. That is, you can

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SOURCE: Mary Kate Denny/Photo Edit.

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change a stimulus, such as the water poured into the thin beaker, back to its original state by reversing the action. Along these same lines, the child's thinking appears to be less centrated and egocentric. The grade schoolchild can attend to several characteristics of a stimulus at the same time. Rather than focusing exclusively on static states, the child is now able to make inferences about the nature of transformations. Finally, concrete operational thinkers no longer base their judgments on the appearances of things.

Let's take a closer look at the three types of mental operations or schemes children use to organize and make sense of their world during concrete operations: seriation, classification, and conservation.

Seriation, a mental operation that appears in the concrete operations stage, involves the ability to order objects in a logical progression.

Seriation Seriation involves the ability to order objects in a logical progression, such as from shortest to tallest. **Seriation** is important for understanding the concepts of numbers, time, and measurement. For example, most preschoolers have a limited concept of time. In their minds, 2 minutes is the same as 20 minutes or 200 minutes. In contrast, elementary schoolchildren can order concepts of time in terms of increasing or decreasing quantity. For them, 20 minutes is fewer than 200 minutes, but more than 2 minutes.

In one of his experiments, Piaget asked children to order a series of sticks like the ones shown in Figure 3.4. At ages 3 and 4, children can find the longest and shortest sticks. They seem to understand the **logical rule of progressive change**—that is, items can be ordered in terms of increasing and decreasing size—but they have difficulty constructing an ordered sequence of three or more sticks. To succeed at this task, the children must perform two mental operations simultaneously. They must select the appropriate stick by thinking about how long or short it is in relation to the sticks already used as well as to those that remain. Preschool children are unable to perform this task because they focus on one dimension at a time (i.e., their thinking is centrated). The ability to coordinate two pieces of

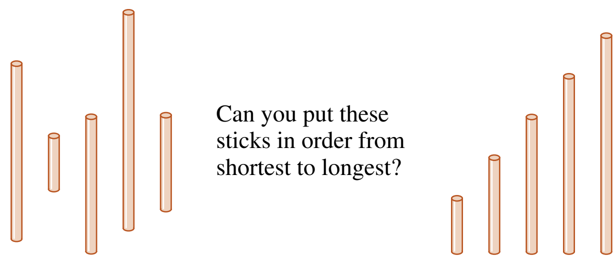


FIGURE 3.4
Seriation Task

information simultaneously develops gradually during the early elementary years, when children's thinking begins to be characterized less by centration.

In order to solve seriation problems, children must also apply the **logical rule of transitivity.** Part of the problem for young elementary children is that they do not understand that objects in the middle of a series are both shorter and longer than others. Older children can mentally construct relations among objects. They can infer the relationship between two objects by knowing its relationship to a third. For example, if they know stick A is shorter than stick B, and stick B is shorter than stick C, then A must be shorter than C. This answer is a logical deduction based on the rule of transitivity ($A > B$ and $B > C$, thus $A > C$). According to Piaget's theory, an understanding of transitivity is acquired between the ages of 7 and 11.

Classification In addition to seriation, Piaget believed that classification skills are central to the development of concrete operations. **Classification** is another way children can impose order on their environment by grouping things and ideas according to common elements. Classification is a skill that begins to emerge in early childhood. Toddlers and preschoolers can generally group objects according to a single dimension, such as size or color. However, it is not until the concrete operational period that children classify objects according to multiple dimensions or understand relations between classes of objects. Piaget described two different types of classification systems that develop during middle childhood as matrix and hierarchical classification.

Piaget believed classification skills are central to the development of concrete operations.

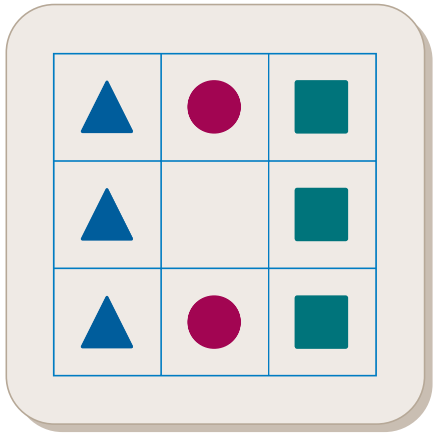
Matrix classification involves classifying items by two or more attributes, as shown in Figure 3.5. We already know that preschool children can group objects according to single dimensions. What would happen, however, if you gave a group of children objects of different shapes *and* colors to sort? Piaget found that young preschool children sort things correctly along one dimension, either shape or size. A slightly more advanced preschool child might then subdivide each of the color groups along the second dimension. This behavior suggests that children are in a transition stage. They *notice* more than one dimension but are unable to coordinate this information. By age 8 or 9, children will demonstrate the ability to sort objects using two dimensions simultaneously.

Matrix classification involves sorting items by two or more attributes; hierarchical classification involves understanding the ways in which parts are related to the whole.

Piaget believed that centration places a greater constraint on younger than on older children's classification skills. Young children tend to group things based on their similarities; differences between objects are typically ignored. Older children are able to consider how objects may be similar and different at the same time. The ability to classify objects according to two dimensions also requires *reversibility* in thinking. This ability to mentally reverse an operation allows a child to first classify an object by one dimension (color) and then reclassify it by a second attribute (shape or size). Older elementary school children are able to handle this problem, because they are becoming more flexible in their thinking.

During the later elementary school years, children also begin to use **hierarchical classification** systems for imposing order on their environment. Such classification systems are

FIGURE 3.5
Matrix Classification Task



What is the color and what is the shape of the missing object?

used to organize information about geology, biology, astronomy, history, physics, music, and so forth. By sixth grade, for instance, children are expected to know that all matter is composed of molecules, and each molecule is made up of atoms, which carry different units of protons, electrons, and neutrons. The child must also be able to reason about hierarchical relations in order to understand number concepts. For example, the number 5 is part of a set that also includes the numbers preceding it (1, 2, 3, and 4). The number 1 can be divided into several different parts (halves, quarters, tenths, etc.), and the number 100 is made up of 10 groups of tens. During the concrete operational stage, children begin to understand hierarchical relations.

The standard test for assessing children's understanding of hierarchies is the *class inclusion* task. A child is shown pictures of two different animals, say three dogs and seven cats, and then asked, "Are there more cats or more animals?" (see Figure 3.6). Most 5- and 6-year-olds say there are more cats. They typically compare the subclasses (dogs and cats) and do not grasp that they make up a larger class (animals). To answer correctly, children have to think about the subsets in relation to the whole. Around the age of 8 or 9, children begin to base their responses on the **logical rule of class inclusion.** They now understand that a total collection of items must be larger than any one of its subparts and use this logical operation to organize information in class inclusion problems. Before children have acquired an understanding of class inclusion, they may have difficulty understanding part-whole relations in math, science, reading, and many other subjects.

Conservation involves the understanding that an entity remains the same despite superficial changes in its form or physical appearance.

Conservation According to Piaget's theory, the ability to reason about conservation problems was the major hallmark of the concrete operational stage. **Conservation** involves the understanding that an entity remains the same despite superficial changes in its form or physical appearance. During the concrete operational stage, children no longer base their reasoning on the physical appearance of objects. They recognize that a transformed object may seem to have more or less of the quantity in question, but it may not. In other words, appearances can be misleading.

Piaget examined children's understanding of five types of conservation: number, liquid, substance (mass), length, and volume. Examples of these conservation tasks are shown in the Focus on Development box. Although these tasks differ with respect to the dimension that is to be conserved, the basic paradigm is the same. In general, a child is shown two

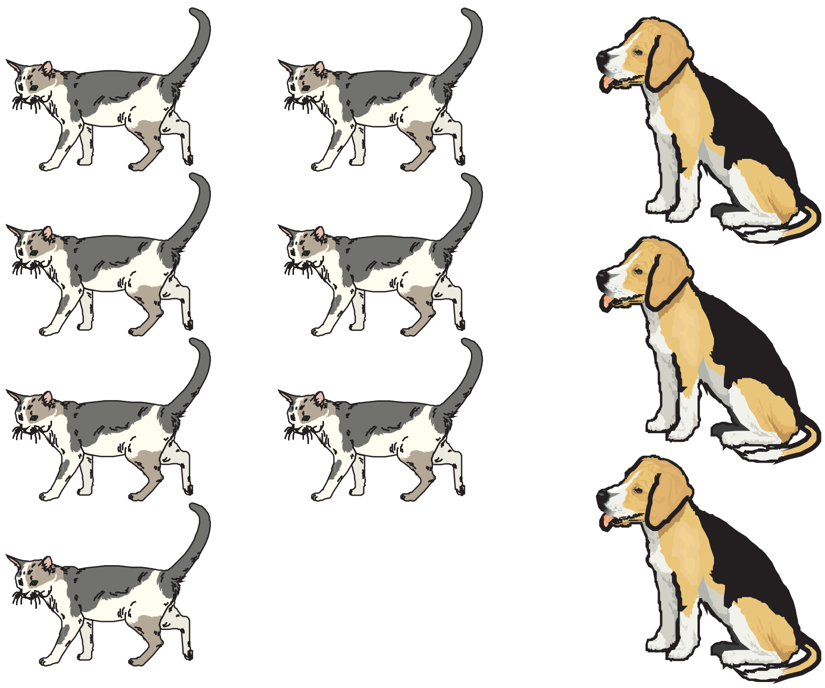


FIGURE 3.6
Are There More Dogs or Animals?

Preschool children respond that there are more cats, because they compare the two groups. They do not understand that each group also belongs to a larger class (animals).

identical sets of objects, such as identical rows of coins, identical amounts of clay, or identical glasses of water. After the child agrees that the objects are the same, one object is transformed in a way that changes its appearance but not the basic dimension of interest. For example, in the conservation-of-number task, one row of coins is shortened or lengthened. The child is allowed to observe this transformation. The child is then asked to state whether the dimension of interest (quantity, mass, area, etc.) is still the same.

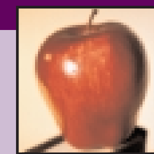
Children who have entered the concrete operational stage will reply that the set of objects is still the same. One object may look bigger, longer, or heavier, but the two objects are really the same. According to Piaget, children use three basic mental operations to perform conservation tasks: **negation, compensation,** and **identity.** These mental operations are reflected in the ways an 8-year-old might explain why the amount of water in two different glasses remained the same:

> "You could pour it back and it will be the same." *(negation)*
>
> "The water goes up higher, but the glass is skinnier." *(compensation)*
>
> "You just poured it, nothing was added or taken away." *(identity)* (Miller, 1993, p. 57)

Between the ages of 7 and 11, children acquire the mental operations needed to think about the transformations represented in conservation problems. When children can reason logically about number, mass, and volume without being confused by physical appearances, they are capable of *reflective abstraction.* They can separate the invariant characteristics of stimuli (e.g., weight, number, volume) from how the object may appear to them.

The acquisition of the mental operations used to perform conservation tasks does not take place at the same time in all areas. Children's understanding of conservation problems

Focus on Development



Development of Conservation Concepts

Children's Understanding of Conservation Problems

CONSERVATION SKILL	BASIC PRINCIPLE	TEST FOR CONSERVATION SKILLS: Step 1	TEST FOR CONSERVATION SKILLS: Step 2
Number (Ages 5 to 7)	The number of units in a collection remains unchanged even though the units are rearranged in space.	Two rows of pennies arranged in one-to-one correspondence	One of the rows elongated or contracted
Substances (Ages 7 to 8)	The amount of a malleable, plastic-like material remains unchanged regardless of the shape it assumes.	Modeling clay in two balls of the same size	One of the balls rolled into a long, narrow shape
Length (Ages 7 to 8)	The length of a line or an object from one end to the other end remains unchanged regardless of how it is rearranged in space or changed in shape.	Strips of cloth placed in a straight line	Strips of cloth placed in altered shapes
Area (Ages 8 to 9)	The total amount of surface covered by a set of plane figures remains unchanged regardless of the position of the figures.	Square units placed on top of each other	Square unit rearranged
Weight (Ages 9 to 10)	The heaviness of an object remains unchanged regardless of the shape that it assumes.	Units placed on top of each other	Units placed side by side
Volume (Ages 12 to 14)	The space occupied by an object remains unchanged regardless of a change in its shape.	Displacement of water by object placed vertically in the water	Displacement of water by object placed horizontally in the water

SOURCE: After Vander Zanden (1993).

follows a developmental sequence (see Focus on Development). Children generally acquire the ability to conserve numbers between the ages of 5 and 7. The ability to conserve area and weight develops between the ages of 8 and 10. Most children are unable to perform conservation of volume tasks until 10 or 11 years. Piaget referred to this inconsistency of children's thinking within a stage as **horizontal decalage.**

Formal Operational Stage (11 to 12 Years and Onward)

Having the ability to handle problems like seriation, classification, and conservation, children from about 11- or 12-years-old begin to develop a coherent system of formal logic. By the end of the concrete operational period, they have the cognitive tools for solving many types of logical problems, for understanding conceptual relations among mathematical operations (e.g., 15 + 8 = 10 + 13), and for ordering and classifying bodies of knowledge. During adolescence, the mental operations that emerged in previous stages are organized into a more elaborate system of logic and abstract ideas.

As children enter the formal operations stage, their thinking begins to differentiate between the real (concrete) and the possible (abstract).

The most important change that occurs during the formal operations stage is that children's thinking shifts from the *real* to the *possible* (Flavell, 1985). Older elementary schoolchildren can reason logically but only about people, places, and things that are tangible and concrete. In contrast, adolescents can think about things they have never experienced (e.g., When you read this story, try to imagine what it might have been like to be a slave in the 1850s.); they can generate ideas about events that never happened (e.g., What would Europe be like today if Germany had won World War II?); and they can make predictions about hypothetical or future events (e.g., Suppose the federal government passed a bill to ban the death penalty. What would happen to the crime rate?). Older adolescents can discuss complex social and political issues involving abstract ideas such as human rights, equality, and justice. They can also reason about proportional relations and analogies, solve algebraic equations and geometric proofs, and analyze the inherent validity of an argument.

The ability to think abstractly and reflectively is called formal operations.

The ability to think abstractly and reflectively occurs during the **formal operational** stage. In the following sections, we look at four key characteristics of formal operational thinking: propositional logic, scientific reasoning, combinatorial reasoning, and reasoning about probabilities and proportions.

Propositional Logic Adult mental operations correspond to a certain type of logical operation called *propositional logic,* which Piaget believed was central to formal operational thinking. **Propositional logic** involves the ability to draw a logical inference based on the relationship between two statements or premises. In everyday language, propositional logic can be expressed in a series of if/then statements. Consider the following example:

> If babies are older than adults;
> And babies are older than children;
> Then adults are older than children.

The *conclusion* is factually correct but invalid, because it *does not follow* from the information that preceded it. David Moshman and Bridget Franks (1986) found that elementary schoolchildren tend to evaluate the above conclusion on the basis of its factual truth rather than the validity of the argument. As children enter formal operations, however, they begin to consider the inherent validity of the argument, regardless of its factual truth. The conclusion may be factually correct, but some adolescents would question the validity of the argument.

Propositional logic is more concerned with the logical relationship between two statements or premises than with their accuracy or truth.

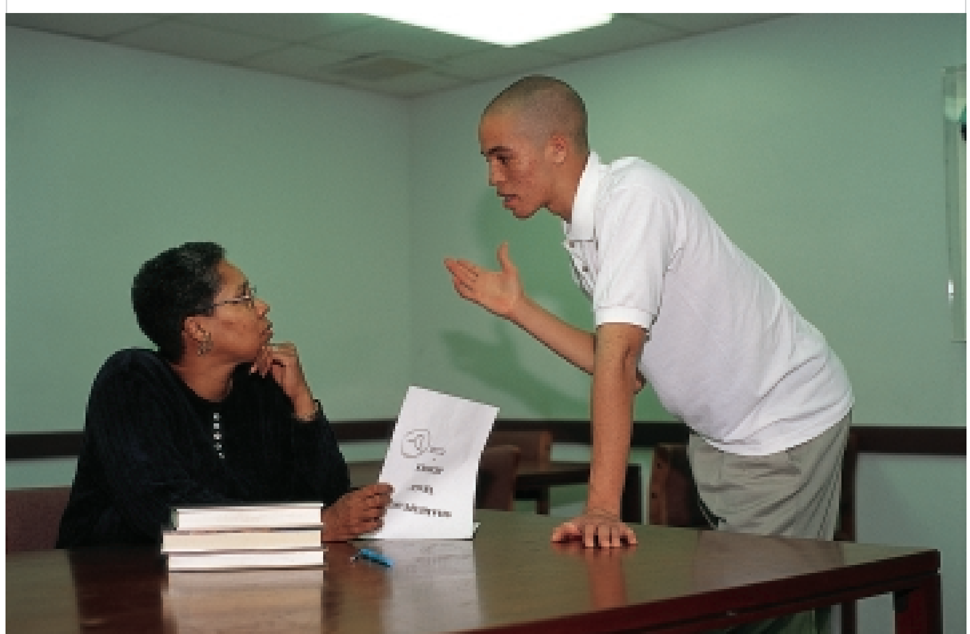
For formal operational thinkers, the validity of the argument has to do more with the way the statements are related than with the truthfulness of the content. According to Piaget, formal operational reasoning involves thinking about the logical relationships among propositions. Formal operational thinkers seem to understand that logical arguments have a "disembodied, passionless life of their own, at least in principle" (Flavell, 1985, p. 101).

Many types of problem-solving situations involve the use of propositional logic. Solving algebra problems, for example, involves the ability to think about propositional statements (e.g., $x + 2y = 11$; if $y = 1$, then $x =$ _____?). Propositional logic is also essential for reasoning about scientific problems, such as determining how to classify an animal or plant (e.g., If all mammals nurse their young and this animal nurses its young, then it must be a mammal.).

Good writers, lawyers, politicians, and teachers use propositional logic when they want to argue a point. When adolescents acquire this ability, be prepared. They not only become more argumentative, but also better arguers. They can find the fallacies in your logic and come back with the appropriate counterargument.

Scientific Reasoning As adolescents develop their use of propositional logic, they approach problems in a more systematic manner. They can form hypotheses, determine how to test each one against the facts, and rule out those that prove to be wrong. Piaget called the ability to generate and test hypotheses in a logical and systematic manner **hypothetico-deductive thinking.**

To study the development of this type of thinking, Piaget used the pendulum task shown in Figure 3.7. In this experiment, a child is given a rod from which strings of different lengths are suspended. Different size weights can be easily attached to each string. The child is shown how the pendulum works, and then asked which of four factors—length of string, weight of object, force of push, or height of drop—is responsible for the speed at which the pendulum swings. They are allowed to experiment with the apparatus before stating their answer.



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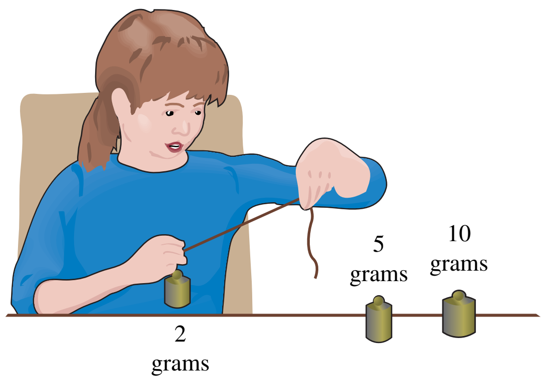
SOURCE: Cleve Bryant/Photo Edit.



What makes the pendulum swing faster? The four factors involved are the length of the string, the weight of the pendulum, the height from which the pendulum is released, and the force with which the pendulum is pushed.

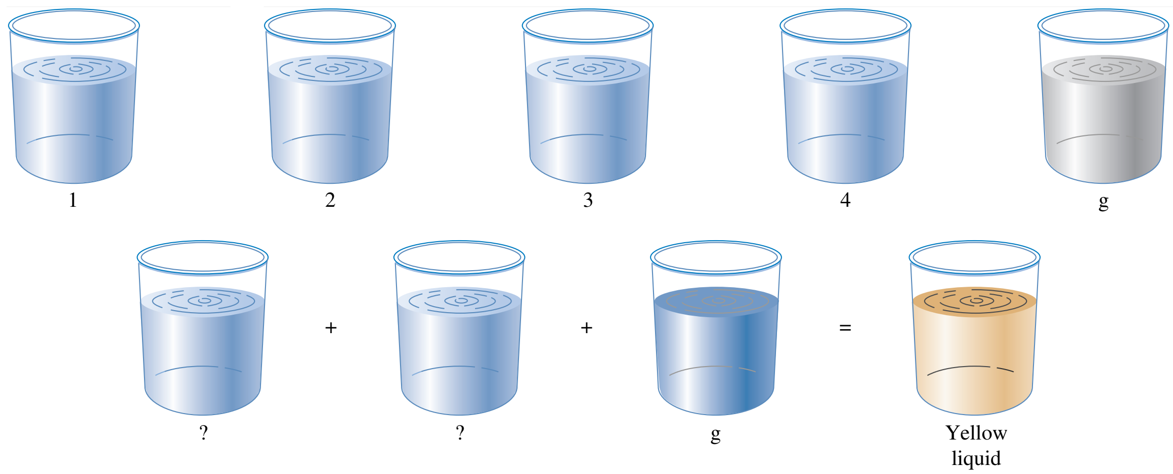
FIGURE 3.7
Pendulum Task

What do you think the correct answer is? How would you approach this problem? The first step is to generate a hypothesis or make a prediction. Concrete operational thinkers are able to use this problem-solving strategy. The next step involves testing the hypothesis. This step generally separates the concrete from the formal operational thinker. The trick is to change one of the problem's factors or variables while holding all others constant. Concrete operational thinkers often get off to a good start but fail to test all possible combinations. They may also change more than one variable at the same time (e.g., the string and the weight). Because they do not approach the problem systematically, concrete operational thinkers often draw the wrong conclusion when there are multiple variables to consider. In contrast, the formal operational thinker typically thinks about all possible combinations of variables. In this example, there are 16 different combinations that should be considered to draw the correct conclusion. The correct answer, of course, is the length of string. *A short string makes the pendulum go faster, regardless of all other factors.*

Hypothetico-deductive thinking is the ability to generate and test hypotheses in a logical and systematic manner.

Combinatorial Reasoning Another characteristic of formal operations is the ability to think about multiple causes. Suppose you give elementary and secondary students four plastic chips of different colors and ask them to put the chips together in as many different ways as possible. Children are likely to combine only two chips at the same time. Few will be able to do this task in any systematic way. Adolescents, on the other hand, may develop a way of representing all the possible combinations, including combinations of three and four chips. They are also more likely than children to produce these combinations systematically. This process is known as **combinatorial reasoning.**

Piaget and Inhelder (1956) used a chemistry experiment to study children's and adolescents' ability to use combinatorial logic. Figure 3.8 shows this experiment, in which children must combine liquids from different bottles to create a yellow solution. When the liquids from two bottles are combined with the g liquid, the solution turns yellow. Liquid from one of the bottles has no effect, and liquid from a fourth bottle can turn the solution clear. Concrete operational children generally take a drop of liquid from each of the four bottles and combine it with the g liquid one by one. If nothing happens, they think they have exhausted all possibilities. If they are told to combine liquids, they may do so but not in a systematic way. Formal operational thinkers go beyond testing each liquid one at a



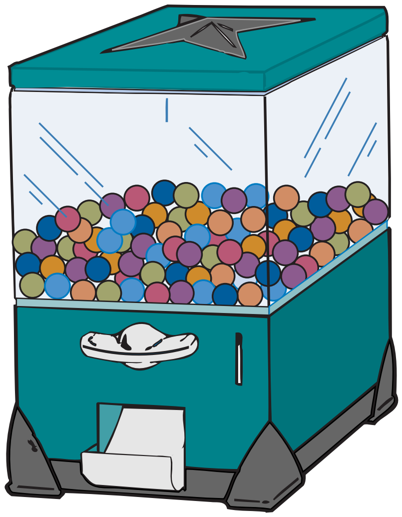
Two of the clear liquids in the four beakers when combined with liquid g produce a yellow solution. How would you solve this problem?

FIGURE 3.8 *Chemistry Task*

time. They combine the liquids systematically (1 + 2 + g, 1 + 3 + g, 1 + 4 + g, etc.), until they find the combination that turns the solution yellow when g is added. Some adolescents may even go on to speculate about which liquids would combine to turn the solution clear again.

Reasoning about Probabilities and Proportions Elementary-aged children generally have a limited understanding of probability. Piaget's theory helps to explain why. Figure 3.9 shows a bubble gum machine with 30 red balls and 50 yellow balls. If a child inserts a coin into the machine, which color gumball is most likely to come out? A concrete operational thinker is likely to say "yellow," because there are more yellow than red balls. This child focuses on the absolute difference between the two quantities. Formal operational thinkers will mentally represent the problem differently. They will think about the problem in terms of the ratio of red to yellow balls. Adolescents are more likely to say that the child has a higher likelihood of getting a yellow ball, because there is a higher proportion of yellows to reds. A ratio is not something a person can see; it is an inferred relationship between two quantities. This example illustrates how concrete and formal thinkers may answer a question the same way, but they use a qualitatively different system of logic.

Some theorists contend that Piaget's research may have overestimated the ability of adolescents to reason about proportions. There is some evidence to suggest that even adults may not use a proportional reasoning strategy when solving practical problems. In one study, researchers asked 50 women in a supermarket to judge which of two sizes of the same product was a better buy (Capon & Kuhn, 1979). One bottle of garlic powder contained 1.25 ounces and sold for 41 cents, whereas the second bottle contained 2.37 ounces and sold for 77 cents. The women were given pencil and paper and told to justify their responses. The most direct way to do this problem is to compute the price of garlic powder per ounce for each bottle, and then compare the amounts. This strategy involves reasoning about proportions, which, according to Piaget's theory, is a characteristic of formal operations. Capon and Kuhn's supermarket study reported that fewer than 30 percent of the women used a proportional reasoning strategy when comparing products. Most used a



If you insert a coin, which color gumball is most likely to come out?

FIGURE 3.9
Ratio Task

subtraction strategy, and justified their response by saying, "With the bigger one you get 32 more ounces for 36 more cents." Others just relied on previous experience and justified their choices by simply saying, "The bigger one is always better or cheaper." This study concluded that many adults may be unable to use formal operations when solving real world problems.

This finding will not surprise most high school teachers. Most know that their students have difficulty with tasks involving more abstract forms of reasoning. It is estimated that only 30 percent to 40 percent of high school students in American schools can solve formal operational tasks (Keating, 1990). The development of formal operations is greatly influenced by cultural expectations and experiences. Formal operational thinking is more prevalent in societies that emphasize mathematical and technical skills. Even within scientifically oriented countries like the United States, some groups of students have greater experience with mathematical and scientific thinking than others.

Limitations of Piaget's Theory

Piaget's theory is one of the most widely cited and discussed theories of cognitive development. Piaget helped to alter the course of research on children's development. Once researchers viewed development through Piaget's eyes, they could no longer see a child as a passive organism molded and shaped by the environment (Miller, 1993). Although Piagetian research continues to influence the way we think about children, in recent years his theory has generated substantial controversy and criticism. Questions have been raised about (a) his research methods; (b) the stagelike nature of children's thinking; (c) the adequacy of the equilibration models for explaining developmental changes; and (d) the universality of Piaget's stages (Flavell, 1985; Miller, 1993).

Concerns about Research Methods Many contemporary theorists believe that Piaget underestimated younger children's abilities due to the research methods he used. As stated earlier, the tasks he used were highly complex and cognitively demanding, many requiring sophisticated verbal skills. Critics have argued that children may have the ability to perform

Focus on Research

Magic Mice Experiment

Rochel Gelman (1972) designed a simple task to study young children's ability to conserve number. In Gelman's experiment, 3-year-olds were shown two different plates. One plate contained three toy mice and the other plate contained two mice. The children were told to pick the "winner" plate and the "loser" plate. Children consistently identified the plate with three mice as the "winner." After children demonstrated they could correctly identify the winner and loser plates, the experimenter "magically" changed the winner plate by taking away the middle mouse or by pushing the mice closer together. When the children viewed the plates again, they acted surprised. Some asked where the missing mouse had gone. More important, they defined the winner plate by the number of mice on it rather than by the length of the row. When the three mice in the row were pushed together, they still called it the winner. Gelman's magic mice study showed that children can conserve number much earlier than Piaget claimed.

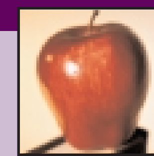
Piaget's theories are not without criticism: some question his theory of invariant stages, others point out his lack of attention to the cultural context in which thinking skills develop, and others feel his equilibration view of developmental change is inadequate.

problems at higher cognitive levels but may lack the verbal skills to demonstrate their competence. Thus, when nonverbal measures are used to test for the presence or absence of key concepts, the results differ from those reported by Piaget. In the infancy section, for example, we discussed recent research suggesting that object permanence may appear earlier than Piaget claimed. We also reviewed research suggesting that 3- and 4-year-old children can perform simple visual perspective-taking tasks (see section on egocentrism). In another experiment, Rochel Gelman (1972) found that 3-year-olds were able to understand number conservation tasks when more familiar language and a small number of objects were used. A description of this experiment appears in the Focus on Research box. This study supports contemporary theorists' suggestions that children's cognitive abilities in both infancy and childhood were underestimated by Piaget (Gelman & Baillargeon, 1983).

Concerns about the Nature of Development Piaget has received the most criticism for his ideas about the qualitative nature of cognitive development. Some theorists have questioned that changes in children's cognitive systems are as "fundamental, momentous, qualitative, and stagelike as Piaget suggested" (Flavell, 1985, p. 82). Researchers have also argued that the equilibration model is inadequate for explaining advances in cognitive development. There are no precise statements as to what cognitive activities actually take place during the process of assimilation, accommodation, and equilibration (Flavell, 1985; Miller, 1993; Siegler, 1991).

Considerable research now suggests that stagelike changes in children's thinking appears to be causally linked to more gradual and quantitative sorts of changes in children's attentional and memory capacities. This research suggests that young children may be unable to perform some Piagetian tasks because they fail to attend to the relevant dimensions, to encode the appropriate information, to relate information to existing knowledge, to retrieve the appropriate solution from memory, and so forth (Siegler, 1991). When young children are trained to use these cognitive processes more effectively, age differences in children's performances on Piagetian tasks begin to disappear. For example, nonconservers as young as 4-years-old can perform conservation tasks when they are trained to attend to the relevant dimensions (Gelman, 1969). Other research suggests that concrete

Focus on Development



Stages in Case's Theory of Cognitive Development

Stage	Age Range (approx.)	Characteristics
Sensory motor control structures	Birth to $1^{1}/_{2}$ years	Mental representations are linked to physical movements.
Relational control structures	11/2 to 5 years	Children can detect and coordinate relations along one dimension among objects, events, or people. For example, weight is viewed as bipolar—heavy and light.
Dimensional control structures	5 to 11 years	Children can extract the dimensions of significance in the physical and social world. They can compare two dimensions (e.g., height and width) in a quantitative way.
Abstract control structures	11 to $18^{1}/_{2}$ years	Children acquire abstract systems of thought that allow them to use proportional reasoning, solve verbal analogy problems, and infer psychological traits in other people.

SOURCE: After Miller (1993).

operational children can be trained to solve formal operational problems (Siegler, Robinson, Liebert, & Liebert, 1973). However, this learning may not transfer to other types of formal operational tasks.

Although training studies call into question the qualitative nature of developmental changes, the issue of stages in children's cognitive development remains controversial (Flavell, 1985). Some theorists contend that a stage theory of cognitive development may still be viable (Case, 1985). **Neo-Piagetian theories** have attempted to add greater specificity to developmental changes, while maintaining the basic assumptions of Piaget's theory (e.g., knowledge is actively constructed, cognitive changes are stagelike, etc.). These theories have begun to look at the role of children's information processing capabilities in explaining structural changes in children's thinking. The Focus on Development box presents Robbie Case's cognitive development model. This model links structural changes (movement from stage to stage) to the development of cognitive strategies and memory processes. Case's theory is just one of many that attempt to integrate Piagetian and information processing theories (see also Fisher, 1980).

Concerns about the Universality of Piaget's Stages An additional issue of concern for contemporary theorists is the universality of Piaget's stages. As stated earlier, it is estimated that only a small minority of adolescents reach Piaget's formal operational stage. The

Focus on Research

Learning Arithmetic in Context

A group of British and Brazilian researchers studied the computational skills of 9- to 15-year-old street vendors in Brazil. In many Brazilian towns, it is common for younger sons and daughters of street vendors to help their parents at the market. Adolescents may develop their own businesses to sell roasted peanuts, popcorn, coconut milk, or corn on the cob. These researchers found that children and adolescents develop sophisticated arithmetic skills in the context of buying and selling, but they are unable to perform the same mathematical operations when they were presented out of context. For example, a typical interview with a 12-year-old street vendor in the market might go like this (Carraher, Carraher, & Schlieman, 1985):

Customer: How much is one coconut?

Child: 35 cruzerios.

Customer: I would like ten. How much is that?

Child: (pause) Three will be 105, with three more, that will be 210. (pause) I need four more. That is…(pause) 315. I think it is 350.

After the interviewers posed a number of such questions, the children were given a paper and pencil and asked to solve identical problems. For example, they were asked: $35 \times 10 =$ ____? The math operation that was performed on the street was also represented in a word problem: Each banana costs 12 cruzerios. Mary bought 10 bananas. How much did she pay altogether?

The results of this interesting study showed that when mathematical problems were embedded in real life contexts (e.g., buying and selling), they were solved at a much higher rate than the same problem presented out of context. Children correctly answered the context-specific question 98 percent of the time. When the same operation was embedded in a word problem, children correctly solved the problem 73 percent of the time. In contrast, children correctly solved the mathematical operation with no context 37 percent of the time.

The results of this study show that context can have an important influence on whether or not children are able to use their existing mathematical knowledge. The children in this study were unable to use the computational strategies they used while selling on the streets for solving problems in school-type situations. This study raises questions about teaching mathematics as a set of conventions and routines that are divorced from children's daily problem-solving activities.

development of formal operations seems to be influenced by cultural expectations and experiences. Some theorists claim that Piaget's research did not adequately consider the role of culture in the development of thinking skills. Compare Capon and Kuhn's supermarket study with the study described in the Focus on Research box. In this study, 10- to

12-year-old vendors in Brazil had very little difficulty making large number computations when selling on the street but were unable to perform similar operations when asked to read multidigit numerals in written form. The results of cross-cultural studies underscore the importance of considering the cultural context in which thinking skills develop (Rogoff, 1990).

Conclusions about Piaget's Theory Despite the criticisms discussed here, most theorists believe that Piaget captured many of the major trends in children's thinking (Flavell, 1985). Most preschool children are unable to consider more than one dimension of a stimulus object, to think about relations, or to take the perspective of another person. Older elementary school children can think logically about relations, perform mental operations, and reflect on their own thinking processes, but they are unable to solve hypothetical problems in their heads or to approach problems in a systematic way, especially when multiple steps are involved. Adolescents are better able to use complex symbol systems, to analyze the inherent logic of an argument, and to draw inferences from multiple pieces of evidence, even when there is some conflicting information. Simply put, Piaget taught us that children do not see and think about the world as adults do.

Piaget taught us that children do not see and think about the world as adults do.

Educational Implications of Piaget's Theory

Much of Piaget's research focused on children's development of logical, scientific, and mathematical concepts. Although Piaget reflected on the general educational implications of his research, he refrained from making specific educational recommendations. Nevertheless, Piaget's research on children's intellectual development inspired major curriculum reforms during the 1960s and 1970s. Piaget's theory of cognitive development had a major impact on preschool education (DeVries, 1990). The National Association of Young Children (NAEYC) developed and published teaching guidelines that incorporated Piaget's ideas about children's development (Bredekamp & Copple, 1997). Piaget's theory also serves as the theoretical rationale for constructivist, discovery, inquiry, and problem-oriented teaching approaches in today's classrooms. The Focus on Research box describes a constructivist approach to teaching and learning mathematics that incorporates learning principles from Piaget's theory. In this section, we discuss the implications of this theory for teaching.

Piaget believed "learning how to learn" should be the major focus of education and also that children must construct their own knowledge from interactions with their environment.

Focus on Cognitive Processes

One of the most important contributions of Piaget's work concerns the purposes and goals of education. Piaget was critical of educational approaches that emphasized the transmission and memorization of ready-made information. Such approaches, he argued, discourage children from learning to think for themselves and from developing confidence in their own thinking processes. In Piaget's view, "learning how to learn" should serve as the major focus of education, so that children can become creative, inventive, and independent thinkers. Education should "form not furnish" children's minds (Piaget, 1969, pp. 69–70).

Focus on Exploration

The second most important contribution of Piaget's research is the idea that knowledge is constructed from the child's own physical and mental activities. Piaget (1964) taught us that knowledge is not something that can simply be given to children.

Focus on Research

Box Learning and Teaching Mathematics: A Constructivist Approach

Piaget was very critical of the teaching of mathematics. In his view, mathematics was being taught as a set of ready-made rules and formulas. When math is taught this way, children acquire very little understanding of mathematical concepts and rules. As a result, they are unable to explain problem solutions. When asked, for example, to explain why they do the steps of a long-division problem, most fourth-graders reply, "I don't know, my teacher told me to do it this way."

Terry Wood, Paul Cobb, and Erna Yackel (1992) developed a set of mathematical activities for second-grade children that were based on constructivist principles of teaching and learning. These activities were subsequently used in ten second-grade classrooms for a full year. The mathematical activities could be solved in a variety of ways. The children worked on the problem in pairs so that they could share ideas, justify answers, and resolve conflicting points of view. As children worked on problems collaboratively, the teacher observed and listened. When appropriate, the teacher intervened to offer suggestions to challenge ideas and to probe the children's thinking. Small-group work was then followed by a whole-class discussion. In this setting, children explained and shared their problem solutions. The goal of this whole-class discussion was to construct some shared meaning of the mathematical problem and its solution. The following excerpt illustrates how the class developed a "shared" understanding of commutativity:

Teacher: Okay. Can we stop a minute boys? I think we have all agreed on something that I want to get clear. We all agree that 3 times 6 is 18?

Children: Yes.

Teacher: And we agree 6 times 3 is 18?

Children: No. No. Yes. (Children begin to talk.)

> Knowledge is not a copy of reality. To know an object, to know an event, is not simply to look at it and make a mental copy or image of it. To know an object is to act on it. To know is to modify, to transform the object, and to understand the process of this transformation, and as a consequence to understand the way the object is constructed. (p. 8)

Piaget's theory of intellectual development has also greatly influenced mathematics and science education. Current reform efforts in these areas are guided by constructivist views of teaching and learning that are based in part on Piaget's theory. Consistent with Piaget's views, the new curriculum standards in mathematics and science education emphasize that knowledge is not simply transmitted. Students must have opportunities to experiment, to question, and to create their own meaning through their own physical and mental activities. The curriculum standards also emphasize the important role of peer interactions in children's cognitive development. Students need opportunities to share, discuss, and argue different points of view. Moreover, reform efforts in mathematics and science emphasize the role of teachers in choosing appropriate learning activities, guiding learning, and

Matt: But I will count on my fingers. (He goes to front.) Watch. 6 plus 6 is 12.

Teacher: Let's listen.

Matt: So that's two (holds up two fingers for the two 6s) and then adds 6 more on. Six (putting his thumb up then pausing to think) 12–13, 14, 15, 16, 17, 18 (counts on, using his other hand).

Teacher: Okay we have agreed on that, haven't we?

Children: Yeah.

Teacher: We've agreed that 3 times 6 is 18 and that 6 times 3 is 18, so is it possible to switch them around and still come up with the same answer?

Children: Yes.

Teacher: I think we have pretty much agreed on that, haven't we?

Children: Yes.

At the end of the school year, researchers assessed how well children in the problem-oriented mathematics curriculum performed on a standardized achievement test (Wood, Cobb, & Yackel, 1992). When compared with children who had traditional textbook instruction in mathematics, children in the problem-oriented classes did just as well on computational tests, but they scored higher on tests that measured mathematical concepts and applications. In addition, children in the problem-oriented classes were more likely to report that understanding and collaboration leads to success in mathematics, whereas children in the traditionally taught mathematics classes reported that success depended on conforming to the ideas of others, being neat, and working quietly.

stimulating children's reasoning processes. The Focus on Teaching box presents a high school biology lesson that incorporates Piaget's principles of learning.

Focus on Social Interactions

Another important contribution of Piaget's research to education concerns the role of social interactions in children's cognitive development. Piaget (1976) emphasized, "No real intellectual activity can be carried out in the form of experimental actions and spontaneous investigations without free collaboration among individuals, that is to say, among students" (pp. 107–108). For younger children, social interactions play an important role in the reduction of egocentrism. For older children, especially adolescents, interactions with peers and adults are a natural source of cognitive conflict. Through interacting with others, children clarify their views, obtain conflicting opinions, and reconcile their ideas with those of others. The equilibration processes described previously are often set into motion when children do not agree with one another.

Focus on Teaching

Learning Genetics Through Inquiry

Mrs. Johnson is planning a semester unit on how traits are inherited from one generation to the next. She believes that many important learning goals of her school's science program can be met in this unit. Mrs. Johnson wants to provide student with opportunities to understand basic principles of transmission genetics. She also wants them to appreciate how using a *mental model* is useful for understanding. She wants her students to engage in and learn the processes of inquiry as they develop their mental models, and she also wants them to understand the effect of transmission genetics on their lives and on society.

Selecting an appropriate computer program to simulate genetic events is important, because simulation will be key. In reviewing several programs, she noted several common features. Each simulation allows students to select parental phenotypes and make crosses. Offspring are produced quickly by all programs. The student will be able to simulate many generations of crosses in a single class period.

All the programs are open-ended—no answer books are provided to check answers. All the programs allow students to begin with data and to construct a model of elements and processes of an inheritance program. Students will work in teams to develop their inheritance models. Mrs. Johnson also plans to obtain reprints of Mendel's original article for students to read early in the unit. In addition to using the simulations and reading, Mrs. Johnson wants her students to be working with living organisms. She has ordered yeast strains, fruit flies, and Fast Plants. She has prepared units in genetics using each of these organisms and has adapted the units to meet the needs of the students. As the unit progresses, a genetics counselor from a local hospital will talk to the class about common genetic disorders and how such disorders are diagnosed and treated.

For the final project, each student will become an "expert" in one inherited disorder and prepare a report that discusses its inheritance pattern, symptoms, frequency, and effects. Students will present their findings as a poster, presentation, or report to be shared with their classmates and parents. Mrs. Johnson has also actively gathered information from organizations, such as March of Dimes, so students, if they choose, can become involved in service organizations focused on a particular genetic disorder.

SOURCE: National Research Council (1996).

Social interactions can also help children develop an awareness and understanding of others. Teachers and parents can facilitate perspective-taking skills by asking children to explain how they feel when they are hurt or injured by another child. When negotiating conflict, adults can help children generate and evaluate different solutions to problems. Role taking and simulation activities are also helpful for helping children understand the perspective of others. Children's literature may be helpful as well. Adults can ask children how different characters feel about different events or to act out how a character may be feeling. Discussion and reading groups for adolescents can help them to understand that others may have feelings like them.

The Importance of Play

Piaget's theory also emphasizes the important role of play in children's development. Play is a natural way for children to learn. It is through play that children learn about the world and how to master the environment. Play is also an important window into children's cognitive and social development. Researchers indicate that forms of children's play follow Piaget's stages of cognitive development. Infants play by exploring and manipulating objects, such as shaking a rattle or kicking a mobile in their crib. Preschoolers engage in pretend, sociodramatic or fantasy play, such a pretending to be a firefighter or going on a trip. Children in the primary grades engage in a good deal of fantasy play, but as they cognitively mature they begin to prefer organized games with rules. By late childhood, children have moved away from dramatic play to games that are group oriented. Play may involve organized sports, board games, or simply hanging out with friends and listening to music.

Although children's play is often not taken seriously by adults, it has many important benefits. In infancy, play can stimulate brain development and provide the foundation for understanding causality. Through symbolic play, children express and represent their ideas, thoughts, and feelings. Play also helps to develop abstract thinking, problem solving, perspective taking, and persistence. In addition to supporting cognitive development, play has many important benefits for children's language, social, emotional, and physical development. As Maria Montessori so wisely observed, "Play is the child's work."

The Role of Learning

Although Piaget's ideas about development have influenced educational theory, there is one dimension of his theory that remains controversial. Piaget (1964) argued that "learning is subordinated to development and not vice-versa" (p. 17). Piaget's theory represents a fundamental departure from the view that learning can stimulate development. Behaviorists such as Edward Thorndike and B. F. Skinner, for example, assert that learning new information or skills can result in higher levels of cognitive functioning. As will be discussed presently, Vygotsky (1978) also proposed that "properly organized learning results in mental development and sets in motion a variety of developmental processes that would be impossible apart from learning" (p. 90). For Piaget, the stage of development limits what children can learn and how they learn. It is not possible to accelerate development through learning experiences. The following statement (Duckworth, 1964) makes this point very clear.

Unlike most of his contemporaries, Piaget believed that development controls learning more than learning controls development.

> The goal in education is not to increase the amount of knowledge, but to create the possibilities for the child to invent and to discover. When we teach too fast, we keep the child from inventing and discovering himself.... Teaching means creating the situations where [mental] structures can be discovered; it does not mean transmitting structures which may be assimilated at nothing other than the verbal level (p. 3).

Unfortunately, Piaget's view on the relationship of development to learning is often interpreted to mean that the teaching of certain skills and subjects should be delayed until the child is "mentally ready." It is important to keep in mind that Piaget recognized social interactions as a factor that stimulated children's development. Piaget's point was that external stimulation of thinking can only succeed if it provokes the child to engage in assimilation and accommodation processes. It is the child's own efforts to resolve a conflict that takes him or her to a new level of cognitive functioning. Children can certainly memorize that $2 + 18 = 20$, but do they really understand that the 1 in 18 stands for ten? The Focus on Research box describes how teaching simple algorithms like "carrying" and

Focus on Research

How Teaching Algorithms "Unteaches" Place Value

For 20 years, Constance Kamii has observed children doing math lessons in the early primary grades. Her book *Young Children Reinvent Arithmetic* (Kamii, 2000) uses Piaget's theory to explain how children acquire number concepts. Consistent with a constructivist approach, Kamii believes that mathematical knowledge is *"constructed (created) by each child from within, in interaction with the environment"* (Kamii, 2000, p. 3). Kamii's research has shown that teaching children algorithms can "unteach" place value. This conclusion is based on interviews with three classes of second graders. One of the teachers taught algorithms (i.e., carrying and borrowing), but two did not. At the end of the school year, children were asked to solve the following problem without paper or pencil: 7 + 52 + 186 = _____. Children in the no-algorithm classes produced the highest number of correct answers (45 percent), and the algorithm classes produced the lowest number (12 percent). By analyzing children's *incorrect* answers, Kamii began to see the harmful effects of algorithms. Children in the algorithm classes gave answers that were not reasonable (e.g., 29, 30, 198, 938, 989, etc.) in relation to the addends given. Kamii explained that answers in the 900s were obtained by adding 7 to the 1 of 186, and carrying one from another column. Answers smaller than 186 were obtained by adding all the digits as one: 7 + 5 + 2 + 1 + 8 + 6. In contrast, incorrect answers in the no-algorithm classes were reasonable. The children in these classes began by adding 50 to 180, then adding the 1s. They appeared to be using good number sense (i.e., the answer could not be smaller than one of the addends).

Kamii argues that encouraging young children to use algorithms to solve arithmetic problems can prevent them from developing number sense. It encourages them to give up their thinking about numbers. Adults understand that the 5 in 52 stands for 50, but children who are still acquiring a sense of place value think that the 5 means five. In this way, algorithms can "unteach" place value. Kamii has developed a series of videotapes for teaching numerical concepts using Piaget's theory:

Kamii, C. (1989). *Double-column addition: A teacher uses Piaget's theory.* [videotape]. New York: Teachers College Press.

Kamii, C. (1990). *Multidigit division. Two teachers using Piaget's theory.* [videotape]. New York: Teachers College Press.

Kamii, C. & Clark, F. B. (2000). *First graders dividing 62 by 5.* [videotape]. New York: Teachers College Press.

SOURCE: After Kamii (2000).

"borrowing" while children are acquiring an understanding of place value can undermine the development of their numerical reasoning.

According to Piaget, a better approach would be to ensure that students have numerous opportunities to group and count objects before problems are presented in a symbolic or abstract form. The task for teachers is to probe their students' current level of understanding and to determine the prerequisite experiences students need to move to a higher level of understanding. This interpretation implies that teachers should not simply wait until children are "mentally ready" to learn. They should adjust their instructional tactics to meet the levels of cognitive development they encounter.

Vygotsky's Theory of Cognitive Development

Lev Vygotsky (1896–1934) was a major figure in Russian psychology. Vygotsky provided a theory of children's development that was greatly influenced by the historical events of his time. Following the Russian Revolution in 1917, leaders of the new Soviet society emphasized the role of each person in transforming society through labor and education. Vygotsky constructed a psychological theory of development that fit the view of this new Soviet state.

Vygotsky's theory stresses relations between the individual and society. He asserted that it is not possible to understand a child's development without some understanding of the culture in which the child is raised. Vygotsky believed that an individual's thinking patterns are not due to innate factors but are products of cultural institutions and social activities. Adult society has a responsibility to share its collective knowledge with younger and less advanced members in order to promote intellectual development. Through social activities, children learn to incorporate cultural tools such as language, counting systems, writing, art, and other social inventions into their thinking. Cognitive development occurs as children internalize the products of their social interactions. According to Vygotsky's theory, both the history of the child's culture and the history of the child's own experiences are important for understanding cognitive development. This tenet in Vygotsky's theory represents a cultural-historical view of children's development.

Vygotsky's career as a psychologist was brief, due to his premature death at age 38 from tuberculosis. During his 10-year career, however, Vygotsky wrote more than 100 books and articles. His most influential book, *Thought and Language,* was not published until the year of his death. From 1936 to 1956, Vygotsky's work was banned in the Soviet Union, because it contained references to Western psychologists. Consequently, Vygotsky's work did not become widely available to researchers until the 1960s, almost 30 years after his death.

In the last two decades, Vygotsky's influence on developmental psychology has steadily grown. His views regarding the social context of learning also have a major impact on educational practices today. In the next sections, we consider the major contributions of Vygotsky's theory for understanding children's cognitive development and learning in the classroom.

Key Concepts in Vygotsky's Theory

Social Origins of Thought

Vygotsky is considered one of the earliest critics of Piaget's theory of cognitive development. In Vygotsky's view, knowledge is not individually constructed, as Piaget proposed, but socially *co-constructed* between people as they interact. Social interactions with more knowledgeable peers and adults provide the main vehicles for intellectual development. For Vygotsky, knowledge is not located in the environment nor in the child. Rather, it is situated in a particular social or cultural context. In other words, Vygotsky believed that

Vygotsky did not believe that knowledge is individually constructed, as Piaget proposed, but that it is coconstructed between people as they interact.

individual mental processes, such as remembering, problem solving, or planning, have a social origin (Wertsch & Tulviste, 1992).

Internalization refers to the process of forming a mental representation of external physical actions or mental operations.

According to Vygotsky, children are born with elementary mental abilities such as perception, attention, and memory. By interacting with more knowledgeable peers and adults, these "innate" abilities are transformed into higher mental functions. More specifically, Vygotsky believed that cognitive development involves the internalization of functions that first occur on what he called a *social plane.* **Internalization** refers to the process of constructing an internal representation of external physical actions or mental operations. James Wertsch (1985) described Vygotsky's ideas about the social origins of cognition in this way:

> An important point to note about Vygotsky's ideas on the social origins of cognition is that it is at this point that he uses the notion of *internalization.* He is not simply claiming that social interaction leads to the development of the child's abilities in problem solving, memory, etc.; rather, he is saying that the *very means* (especially speech) used in social interactions are taken over by the individual child and internalized. Thus, Vygotsky is making a very strong statement here about internalization and the social foundations of cognition. (p. 146; italics added)

A good example of this internalization process may be observed when an adult reads to a young child. For instance, a parent may point to objects on a page and count off "one," "two," "three," and so forth. The next time this parent and child read the book together, the child may point to the pictures and try to count the objects on his or her own. A very young child will have difficulty remembering the order of number tags, so the parent is likely to say the number words too. In the Vygotskian sense, the child is internalizing a way of using numbers to give meaning to a set of objects. When children begin to count off objects in the absence of a parent's prompts or assistance, then they have truly made this external operation their own. The counting operation has become a part of the children's own internal organization, and it is carried out without the support of others.

Tools for Thought

Technical tools are used to change objects or to gain mastery over the environment; psychological tools are used to organize or to control thought and behavior.

Similar to Piaget's way of thinking, Vygotsky defined cognitive development in terms of qualitative changes in children's thinking processes. However, he described these developmental changes in terms of the technical and psychological tools children use to make sense of their world. Technical tools are generally used to change objects or to gain mastery over the environment, whereas psychological tools are used to organize or control thought and behavior.

In the example described previously, the child is learning to use a counting system as a way of ordering objects. Numbers, words, and other symbol systems are different examples of psychological tools. Other examples include systems of logic, social norms and conventions, theoretical concepts, maps, literary forms, or drawings. Some examples of technical tools include pencil and paper, protractors, machines, scales, hammers, and so on. According to Vygotsky, every culture has its own set of technical and psychological tools that are passed on to children through social interactions. These cultural tools in turn shape the mind.

What are some ways children's thinking is molded by society? In the early 1900s, for instance, mothers taught their daughters to churn butter and to weave cloth by the time they reached puberty. Few young women today learn these skills. Before the availability of inexpensive calculators, students of all ages were required to memorize arithmetic facts, including square roots of numbers. Most schools today allow students to use calculators in mathematics and science classes. Currently, another technological tool, the computer, is becoming more and more common in classroom and home environments. It is interesting to consider how computers are influencing the way children and adolescents think.

Language and Development

For Vygotsky, language is the most important psychological tool influencing children's cognitive development. In Vygotsky's (1962) words, "The child's intellectual development is contingent on mastering the social means of thought, that is, language" (p. 24). He identified three different stages in children's use of language: social, egocentric, and inner speech.

Vygotsky identified three stages—social, egocentric, and inner speech—in a child's use of language.

In the first stage, **social speech,** language is used primarily for communicative functions. Thought and language have separate functions. Children enter the next stage of development, **egocentric speech,** when they begin to use speech to regulate their behavior and thinking. For example, many 5- and 6-year-old children talk aloud to themselves as they work on various tasks. Because children are not trying to communicate with others, these self-verbalizations are viewed as private rather than social speech. At this point in development, speech begins to serve an intellectual as well as communicative function. Berk and Garvin (1984) observed the following examples of *private speech* in an Appalachian mission school for low-income children aged 5 to 10 years old.

> [Student] O. Sits down at the art table and says to himself, "I want to draw something. Let's see. I need a big piece of paper. I want to draw my cat."
>
> [Student] C., working in her arithmetic workbook says out loud to no one in particular, "Six." Then counting on her fingers she continues, "Seven, eight, nine, ten. It's ten, it's ten. The answer's ten." (p. 277)

In Vygotsky's last stage of speech development, **inner speech,** children internalize egocentric speech. They use language internally to guide their thinking and behavior. At this stage, children can think about problem solutions and action sequences by manipulating language "in their heads."

Zone of Proximal Development

One of the most important contributions of Vygotsky's theory to psychology and education is the *zone of proximal development.* Vygotsky (1978) was interested in children's *potential* for intellectual growth rather than their *actual* level of development. The **zone of proximal development** includes those functions that are in the process of developing but not yet fully developed.

Vygotsky's zone of proximal development is the gap between cognitive activities children can do on their own and what they can do with the assistance of others.

> The zone of proximal development defines those functions that have not yet matured but are in the process of maturation, functions that will mature tomorrow but are currently in an embryonic state. These functions could be termed the "buds" or "flowers" of development rather than the "fruits" of development. The actual development level characterizes mental development retrospectively, while the zone of proximal development characterizes mental development prospectively. (pp. 86–87)

In practice, the zone of proximal development represents the gap between what children can do on their own and what they can do with the assistance of others, as illustrated in Figure 3.10. For example, a 6-year-old might have difficulty assembling a model airplane alone, but with the assistance and guidance of an older, more experienced sibling, the child can successfully complete the task.

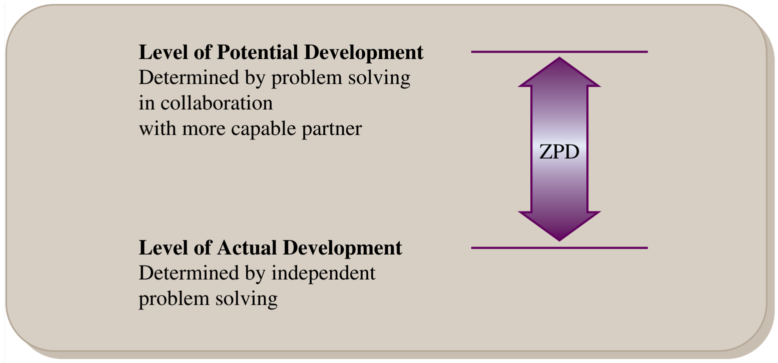


FIGURE 3.10
Zone of Proximal Development
SOURCE: After Hamilton & Ghatala (1994).

In the example presented at the beginning of the chapter about boiling tap water, the students are acquiring a more sophisticated understanding of their science experiment with the teacher's guidance. Note that the teacher is not telling students what they should learn from the experiment. He is guiding their thinking through the use of questions (What happens when the water is boiled?) and prompts (Think about density.). At the end of the discussion, the students can use what they learned from the experiment to make hypotheses about other liquids. As a result, the students are thinking about the experiment at a level that was not evident when they were carrying out the experiment on their own.

Vygotsky assumed that interactions with adults and peers in the zone of proximal development helps children to move to a higher level of functioning. We will examine how adults can help "build scaffolds" for children when we consider the educational implications of Vygotsky's theory.

Contrasts Between Piaget's and Vygotsky's Theories

There are several important differences in the basic assumptions of Vygotsky's and Piaget's theories. Both theorists agree that knowledge must be mentally constructed by the child, but Vygotsky placed a much stronger emphasis on the role of social interactions in this construction process. To Vygotsky, the construction of knowledge is not an individual process. Rather, it is primarily a social process in which higher mental functions are products of socially mediated activity. Collaborative learning and problem solving are the main vehicles of cognitive change.

Compared with Piaget, Vygotsky also placed a stronger emphasis on culture in shaping children's cognitive development. As children develop, they learn to use tools for thought that are valued by their culture. There are no universal patterns of development because cultures emphasize different kind of tools, intellectual skills, and social conventions. The intellectual skills needed for survival in a highly technical society differ from those needed for survival in a largely agrarian society.

Another important difference between Piaget's and Vygotsky's views concerns the importance placed on learning. As we know, Piaget believed that cognitive development limits what children are capable of learning from social experiences. It is not possible to accelerate development through learning experiences. Although Vygotsky (1978) agreed that learning is not the same as development, he argued that "learning is a necessary and universal aspect of the process of developing culturally organized, specifically human, psychological functions" (p. 90). Vygotsky believed instruction (both formal and informal) by more knowledgeable peers or adults is at the heart of cognitive development. Vygotsky believed that learning precedes development.

In addition, Vygotsky's zone of proximal development offers a very different view of readiness than the one provided by Piaget's theory. According to Piaget, children's readiness for learning is defined by their existing level of competence and knowledge. If a teacher attempts to teach a concept or operation before a child is mentally ready, it can result in what Piaget called "empty learning." In contrast, Vygotsky (1978) argued that instruction should be directed toward children's potential level of development, the level of competence they can demonstrate with the assistance and guidance of others. In his words, "The only 'good learning' is that which is in advance of the child's development" (p. 89).

Vygotsky believed that learning precedes development and is the product of social interactions shaped by one's cultural tools.

Finally, Vygotsky and Piaget had very different opinions about the role of language in development. In Piaget's view, the egocentric speech of young children reflects the child's inability to take the perspective of others. It plays no useful role in their development. Thinking processes develop from children's actions on objects, not from talking. Vygotsky, on the other hand, thought that egocentric speech is an extremely important developmental phenomenon. He believed that egocentric speech helps children organize and regulate their thinking. When children talk to themselves, they are trying to solve problems and think on their own. According to Vygotsky, egocentric speech, or private speech, is the means by which children move from being regulated by others (other-regulated) to being regulated by their own thinking processes (self-regulated). Egocentric speech has both an intellectual and self-regulatory function for young children.

Limitations of Vygotsky's Theory

Vygotsky's theory helps to understand the how cognition and learning is a social collaborative process with others (Rogoff, 1998). This theory represents a radical departure from Piaget's view that cognition is an individual activity, and, as described below, it has important implications for education. Nevertheless, Vygotsky's theory has some important limitations that need to be considered. First, Vygotsky's theory places much less emphasis on physical maturation or innate biological processes than most other developmental theories. We have learned that development involves a complex interaction of genetic and environment influences. Additionally, little attention was given to what is meant by learning and development in this perspective. In Vvgotsky's view, development involves changes in the child's participation in social activities; however, the cognitive processes that enable this transformation to occur have not been clearly specified. For example, what cognitive changes enable the child to move from an assisted reader to an independent reader? As discussed in Chapter 5, this transformation involves attention and memory processes, as well as social interactions that support reading efforts. For this reason, some theorists regard Vygotsky more as educational than developmental theorist (Flavell, 1994).

Educational Contributions of Vygotsky's Theory

Vygotsky regarded education as central to the development of children (Moll, 1990). In the introduction to Vygotsky's *Thought and Language* (1962), Jerome Bruner wrote, "Vygotsky's conception of development is at the same time a theory of education" (p. v). Although seven of Vygotsky's first eight writings in psychology (written between 1922 and 1926) addressed educational issues, his work is only beginning to have a significant impact on education in the United States (Moll, 1990; Newman, Griffin, & Cole, 1989; Tharp & Gallimore, 1989). This section examines the educational implications and applications of Vygotsky's theory.

The Role of Private Speech

In Vygotsky's theory, egocentric speech is the means by which children move from being regulated by others to being self-regulated by their own thinking.

In Vygotsky's theory, **private speech** serves an important self-regulatory function. It is the means by which children guide their own thinking and behavior. Children engage in overt self-regulatory speech before they use covert, inner speech. As children make this transition in the early grades, they need learning activities that permit them to talk aloud as they are solving problems and completing tasks.

Observations of children in classroom settings provide clear support for Vygotsky's claim that private speech plays an important role in learning. For example, Berk and Garvin (1984) observed the frequency and variety of private speech among 5- to 10-year-olds in a school setting. They observed an average of 30 private utterances per hour. Interestingly, there were no age differences in the quantity of private speech observed, and, for all age groups, private speech increased when students completed cognitively demanding tasks without an adult present. In another study, Berk (1986) observed the frequency of private speech in first- and third-grade mathematics classes. She reported that nearly 98 percent of the children talked aloud to themselves as they worked on math problems. Furthermore, this task-related private speech was positively related to mathematics achievement in the early grades.

As children mature, task-related vocalizations are gradually transformed into quiet whispers until they are internalized as inner speech. Private speech in the form of self-guiding statements or reading aloud declines by the age of 10. However, some studies suggest that older students can continue to benefit from the use of self-instructional strategies, especially if they lack an ability to regulate their behavior or thinking.

Donald Meichenbaum's (1977) program of **cognitive behavior modification** uses self-regulatory speech to help children control and regulate their behavior. Children are taught self-regulatory strategies that can be used as a verbal tool to inhibit impulses, control frustration, and promote reflection. The training program generally begins with an adult performing a task while talking aloud *(cognitive modeling).* Next, a child performs the same task under the guidance of an adult who encourages the child to talk aloud as he or she works on the task *(overt guidance)* and reinforces the child for using the modeled strategies. When children in this program become proficient in the use of cognitive strategies and overt self-instructions, they are encouraged to perform the task while guiding their behavior by way of whispering the instructions to themselves *(faded self-guidance)* or by internal speech *(covert self-instruction).* Following is an example of a training protocol for a line drawing task that was first modeled by an adult and eventually used by a child (Meichenbaum & Goodman, 1971):

> Okay, what is it that I have to do? You want me to copy the picture with the different lines. I have to go carefully and slowly. Okay, draw the line down, down, good; then to the right, that's it; now down some more and to the left. Good. I'm doing fine so far. Remember, go slowly. Now back up again. No, I was supposed to go down. That's okay. Just erase the line carefully. . . . Good. Even if I make an error I can go on slowly and carefully. I have to go down now. Finished. I did it! (p. 117)

Self-instructional training has been used successfully to improve self-management skills and self-control in impulsive and aggressive children (Manning, 1988; Camp, Blom, Hebert, & van Doornick, 1977; Neilens & Israel, 1981). These techniques also show promise for improving children's writing skills, reading comprehension, and mathematics achievement (Harris & Graham, 1985; Meichenbaum & Asarno, 1978; Schunk & Cox, 1986). In sum, considerable research suggests that private speech is a valuable tool for learning. Because private speech is important for the development of self-regulatory processes, teachers need to model self-instructional strategies and to encourage students' use of task-related verbalizations when they are having difficulty in the classroom.

The Importance of Adult Guidance and Scaffolding

Vygotsky's theory emphasized the critical role of adults in guiding and supporting children's intellectual development. Through the social guidance provided by others, children can function at a higher level of development, their zone of proximal development. Several researchers have studied the processes by which adults guide children's participation in the zone of proximal development. We will examine two different but closely related conceptions of this social process—guided participation and scaffolding.

Barbara Rogoff (1990) used the term **guided participation** to describe the mutual involvement between children and their social partners in collective activities. Guided participation has three phases: choosing and structuring activities to fit the skills and interests of children; supporting and monitoring children's participation in activities; and adjusting the level of support provided as children begin to perform the activity independently. The goal of guided participation is to transfer responsibility for the task from the skilled partner to the child.

Rogoff and her colleagues (1984) observed many examples of guided participation in a study of mothers assisting 6- and 9-year-old children to perform two different classification tasks in the laboratory. The tasks resembled either a home activity (i.e., sorting food items onto shelves) or a school activity (i.e., sorting photographs of objects into abstract categories). The mothers used a variety of techniques to guide their child's participation in these activities. For example, some mothers connected the food sorting task to putting groceries away at home. Other mothers used subtle gestures (pointing, looking, etc.) and verbal cues to guide their child's participation.

Guided participation and scaffolding both involve adults' helping children perform some task they could not perform without help and then gradually withdrawing help as the children become more proficient.

Most significantly, Rogoff and her colleagues found that mothers adjusted their level of support according to their perceptions of the child's ability to handle the task. For example, mothers of 6-year-olds provided more formal instruction in the school task than mothers of 8-year-olds. Age differences in the level of support provided by mothers were less evident in the more familiar home task. In addition, as the children showed they could handle more of the task on their own, the mothers provided less instruction, but when the children began to make errors, this instructional support reappeared. This sensitive adjustment of support is perhaps the most significant aspect of guided participation, because it enables the child to gradually assume more responsibility for managing the activity.

Rogoff's notion of guided participation is closely related to the concept of *scaffolding*. Jerome Bruner and his associates (Wood, Bruner, & Ross, 1976) introduced this term before Vygotsky's work was widely known in the United States. Similar to guided participation, **scaffolding** refers to the process by which adults provide support to a child who is learning to master a task or problem. When adults scaffold a task or problem, they perform or direct those elements of the task that are beyond the child's ability.

Scaffolding can take the form of verbal or physical assistance. For example, a father who is building a birdhouse with his 7-year-old daughter might help guide her hands while she saws and nails the pieces of wood. The daughter is not yet able to perform these activities on her own, but with her father's assistance, she can participate meaningfully in the activity. At a later point, the father may assist his daughter in another woodworking task by providing verbal reminders ("Remember how I taught you to hold the hammer.") or by providing feedback ("This piece of wood needs to be sanded some more before you paint it."). With practice and time, the daughter will learn to perform woodworking activities more and more independently.

XXX

XXX
XXX
SOURCE: David Young-Wolff/Photo Edit.

In a classic study, Wood, Bruner, and Ross (1976) studied an adult's role in helping a child move from joint to independent problem solving. Female tutors, who were given no special training, were asked to build a pyramid from interlocking wooden blocks with 3-, 4-, and 5-year-old children. By observing this joint problem-solving activity, the researchers identified six important elements of the scaffolding process. These are shown in Figure 3.11.

In summary, the concepts of guided participation and scaffolding were both inspired by Vygotsky's theory of development. Both processes are powerful teaching tools at home and school. In the classroom, these processes can take the form of demonstrating skills; leading students through the steps of a complicated problem; breaking a complex task into subtasks; doing part of the problem as a group; asking questions to help students diagnose errors; and providing detailed feedback (Rosenshine & Meister, 1992). Keep in mind, however, that teachers need to gradually pass more and more control of the activity to the child. By relinquishing control, the teacher enables the child to engage in independent and self-regulated learning.

Reciprocal Teaching

One of the best applications of Vygotsky's theory is the **reciprocal teaching** model developed by Annemarie Palincsar and Ann Brown (1984). The model was originally designed to help poor readers acquire comprehension skills. In this program, teachers and students take turns being the discussion leader. Through collaborative learning dialogues, children learn how to regulate their own reading comprehension. The reciprocal teaching procedure has been used successfully with both elementary and secondary school students.

The program starts out with adults or teachers serving as the leaders and modeling how to lead the discussion. The leader is responsible for asking questions that require students to summarize material, detect inconsistencies, and make predictions about what will

1. **Recruitment.** The adult elicits the child's interest in accomplishing the intended goal of the activity. This function is particularly important for learners who are not able to keep the goal in mind.
2. **Demonstrating solutions.** The adult demonstrates or models a more appropriate form of a solution than was originally performed by the child. Children are much more likely to perform those acts they can already do.
3. **Simplifying the task.** The adult breaks the task into a set of subroutines that the child can successfully complete on his or her own.
4. **Maintaining participation.** The adult provides encouragement and keeps the student oriented toward the goal of the activity.
5. **Providing feedback.** The adult provides feedback that identifies discrepancies between what the student is doing and what is required to successfully complete the task.
6. **Controlling frustration.** The adult helps control frustration and risk in finding problem solutions.

FIGURE 3.11
Elements of the Scaffolding Process

happen next. Students carry out simpler aspects of the task while observing and learning from the adult. As the students develop their comprehension skills, the teacher increases his or her demands, requiring students to participate at slightly more challenging levels. Eventually, students assume the leader's position, and the teacher acts more as a coach than as a model. During the course of training, student questions become more and more sophisticated. The Focus on Research box compares the quality of reciprocal teaching dialogue on day 3 and day 13 of the program.

Palincsar and Brown's instructional program incorporates several features of Vygotsky's theory. First, group discussions allow less competent students to perform at levels slightly above their current level of competence or at their zone of proximal development. Second, the learning situation is carefully scaffolded by the adult. The teacher continues to push for deeper understanding and to provide instructional support for less able students but then "fades into the background when students demonstrate they can take over" (Brown & Campione, 1990, p. 119). Finally, the meaning of the text is socially negotiated and constructed in the context of group discussions.

Studies reported by Palincsar and Brown (1984) indicate that the reciprocal teaching procedure leads to substantial improvements in seventh-grade students' comprehension skills. Additionally, the students maintained the effects of the program for at least 8 weeks. Even more important, the training generalized to other subject areas. The students who participated in the program showed a better understanding of science and social studies materials they read in their classroom. Thus, the internalization of strategies learned in the reciprocal teaching program allowed students to better monitor and regulate their comprehension in other learning situations as well.

The Role of Peer Interactions

Both Piaget and Vygotsky emphasized the importance of peers in children's cognitive development. Following Piaget's theory, children can influence each other's cognitive development when they say or do something that is in conflict with the other child's thinking. Cognitive conflict leads children to restructure their thinking *(accommodate)* in order to restore a balance *(equilibration).* By comparison, researchers examining peer interactions from a Vygotskian perspective have argued that children influence each other's development

Focus on Research

Examples of Reciprocal Teaching Dialogue: Day 3 and Day 13 of Training

Day 3

TEXT (read silently):

Can Snakes Sting with their Tongues? No—snakes' tongues are completely harmless. They're used for feeling things and for sharpening the snakes' sense of smell. Although snakes can smell in the usual way, the tongue flickering in the air picks up tiny particles of matter. These particles are deposited in two tiny cavities at the base of the nostrils to increase the snake's ability to smell.

1. A: Do snakes' tongues sting?

2. K: Sometimes.

3. A: Correct. This paragraph is about do snakes sting with their tongue, and different ways that the tongue is used for and the senses of smell.

4. T: Are there any questions?

5. C: Snakes' tongues don't sting.

6. T: Beautiful! I thought, boy, I must have been doing some fast reading there because I missed that point. A, could you ask your question again?

7. A: Do snakes' tongues really sting?

8. T: Now, A, since you have asked the question, can you find in that paragraph where the question is answered?

9. A: No, snakes' tongues are completely harmless.

10. T: So we'll try again. Can you generate another question that you think a teacher might ask?

11. A: What are the tongues used for?

12. T: Good!

through the process of collaboration (Tudge & Rogoff, 1989). The following example illustrates how one student can help guide the thinking of another student while working on a lever task in fifth-grade science.

Hank: Ready? Do you want to hold the lever?

Lester: Yeah.

Day 13

TEXT (read silently):

The second oldest form of salt production is mining. Unlike early methods that made the work extremely dangerous and difficult, today's methods use special machinery, and salt mining is easier and safer. The old expression "back to the salt mine" no longer applies.

1. L: Name two words that often describe mining salt in the old days.

2. K: Back to the salt mines?

3. L: No. Angela?

4. A: Dangerous and difficult.

5. L: Correct. This paragraph is about comparing the old mining of salt and today's mining of salt.

6. T: Beautiful.

7. L: I have a prediction to make.

8. T: Good.

9. L: I think it might tell when salt was first discovered, well, it might tell what salt is made of and how it's made.

10. T: O.K. Can we have another leader?

L = Indicates discussion leader

T = Indicates adult teacher

A, B, C, K, and L are seventh-grade students with reading comprehension skills 2 years below grade level.

SOURCE: After Palincsar & Brown (1984).

Hank: Now, let's wait a sec. Let's make sure that we're setting everything up right. Now, that [spring scale] goes on the 4 and the block goes on 5. [Lester begins adjusting the scale.]

Hank: I'll tell you when it's level. You just have to pull. You have to pull real hard. OK. A little bit more, pull a little bit more. OK, stop. You got it. Great. (Jones & Carter, 1994, pp. 613–614)

XXX
XXX
SOURCE: Bill Whitman.

XXXX

Piaget believed peer interaction stimulates thinking by creating cognitive conflict situations; Vygotsky believed peer interaction stimulates thinking through cognitive cooperation.

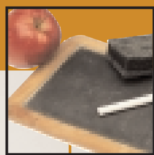
From a Vygotskian perspective, collaborative problem solving among peers offers some of the same experiences for children as adult-child interactions. When children work jointly on problems, they must come to some mutual understanding of the problem, procedures, and solution. Children use speech to guide each other's activities, and these social interactions are gradually internalized as tools for regulating independent problem-solving efforts in the future.

To study the processes by which peers influence learning and development, Jonathan Tudge (1993) paired nonconservers with conservers on a mathematical balance beam problem. The results showed that the less competent partner improved significantly on the balance beam task when paired with a peer who could reason about the problem at a more advanced level. This study also suggested that the less competent partner needed to adopt the reasoning of the more competent partner while performing the task. That is, mere exposure to a higher level of thinking did not lead to improvements in the less competent partner's use of problem-solving rules. Of even greater importance was the finding that there were some circumstances under which children's thinking may be adversely affected by a peer. This decline is most likely to occur when children are not provided any feedback after working on a problem or when they are not confident about their reasoning. Under these conditions, children's thinking may be negatively influenced by social interactions that are slightly behind their current level of thinking (Tudge, 1993).

Although Tudge's study provides support for Vygotsky's ideas about the cognitive benefits of peer interactions, it also suggests that teachers need to carefully structure the conditions under which children work together. In a review of Vygotskian research related to the effects of peer interactions on development, Tudge and Rogoff (1989) conclude:

1. Young children may show limited cognitive benefits from peer interactions, because they are unable to provide each other the type of scaffolded assistance or guidance that older children and adults can provide.

Focus on Teaching



Applications of Piaget's Theory

- Provide opportunities for students to communicate through symbols—art, writing, drama, mathematical formulas, and so on.
- Provide a range of "real world" experiences to serve as foundations for building new concepts, and provide opportunities for children to choose activities of interest to them.
- For young learners, use concrete objects, visual aids, and other teaching tools (videotapes, geoboards, Unifix cubes) for teaching abstract and unfamiliar concepts.
- Provide opportunities for students to explore, experiment, apply knowledge, and to engage in "hands on" learning.
- Ask students to explain their reasoning and help them to find inconsistencies. Suggest alternative explanations to consider.
- Provide opportunities for students to express opinions, discuss, debate, and receive feedback from peers.

Applications of Vygotsky's Theory

- Use guided participation in which students can be apprentices in learning. Use modeling and verbal cues to guide students learning, gradually giving the students more responsibility for carrying out the learning activity on their own.
- Model "thinking aloud" when problem solving with students, and encourage students to "talk themselves" through challenging problems.
- Provide opportunities for students to collaborate on learning activities together. Peers are important role models for problem solving, and learning is facilitated when have opportunities to explain ideas and resolve controversies with other students. Interactions with equal or more skilled peers have the most positive benefits.
- Direct learning and assessment toward students' *zone of proximal development* By providing sufficient instructional supports (cues, suggestions, assistance), help students perform challenging tasks. Gradually withdraw the support when they are able to perform the task on their own.

2. Adult-child interactions may be more beneficial than peer interactions when children are first learning new skills or concepts.

3. Peer interactions are most effective when partners must achieve a shared understanding of a topic or problem and work toward a shared goal.

Putting Piaget's and Vygotsky's Theories Together

We have examined important distinctions between Piaget's and Vygotsky's theories, now it time to consider some common themes in this last section. As we have discussed, both theories serve as the foundation for constructivist approaches in education. Piaget and Vygotsky both believed that cognitive development involved changes in children's abilities to represent knowledge in terms of more abstract forms such as symbols, logical rules, principles, concepts, and so forth. Both theorists also emphasize that children are not passive recipients of knowledge. Piaget focused on how children constructed knowledge by ordering, transforming, and reorganizing existing knowledge, whereas Vygotsky described how children constructed internal representations of mental operations learned through social interactions with adults and peers. Finally, both theories maintain that teachers serve as important organizers, stimulators, guides, and supporters of learning. The Teaching Focus box summarizes some ways the two theories can be applied in the classroom.

Chapter Summary

Constructive Approaches to Education

- Piaget's and Vygotsky's theories of cognitive development provide the psychological foundations for constructivist approaches to teaching and learning. Constructivists believe that children must form their own understanding of the world in which they live. Adults help guide this knowledge construction process by providing structure and support.
- Both Piaget's and Vygotsky's theories of cognitive development are concerned with qualitative changes in children's thinking. Piaget argued that cognitive development involved major transformations in the way knowledge is organized. Vygotsky believed that cognitive development represented changes in the cultural tools children use to make sense of their world.

Piaget's Theory of Development

- Piaget proposed that two basic principles guide children's intellectual development: organization and adaptation. As children mature, their knowledge schemes are integrated and reorganized into more complex systems that are better adapted to their environment. Adaptation of knowledge schemes occurs through the process of assimilation and accommodation. Through the process of assimilation, children mold information to fit existing knowledge structures. Through the process of accommodation, children change their schemes to restore a state of equilibrium. The process of assimilation and accommodation explains changes in cognition at all ages.
- Piaget proposed that development follows an invariant sequence. The early childhood years are characterized by two stages. During the sensorimotor period (birth to 2 years), children acquire schemes for goal-directed behavior and object permanence. In the preoperational stage (2 to 7 years), children begin to use words, numbers, gestures, and images to represent objects in their environment. Children also begin to form intuitive theories to explain events in their environment that can have a lasting influence on learning. The major limitations of preoperational thinking are egocentricism, centration, and rigidity of thinking.

- The elementary and secondary school years are characterized by two additional stages. During the concrete operational stage (7 to 11 years), children begin to use mental operations to think about events and objects in their environment. The mental operations that appear in this stage are classification, seriation, and conservation. These mental operations can only be applied to concrete stimuli that are present in the child's environment. In the last stage of cognitive development, formal operations (11 years to adult), adolescents and adults can think about abstract objects, events, and concepts. They develop the ability to use propositional logic, inductive and deductive logic, and combinatorial reasoning. Formal operational thinkers are also able to reflect on their own thinking processes.
- Piaget's theory has generated a lot of controversy and criticism. Concerns have been raised about Piaget's research methods, the adequacy of the equilibration model for explaining developmental changes, and the universality of Piaget's stages. Nevertheless, Piaget's research provides a rich description of children's thinking at different ages.
- Neo-Piagetian theories have attempted to add greater specificity to Piaget's theory, while maintaining its basic assumptions that cognitive development is qualitative and stagelike. Neo-Piagetian theorists examine the role of children's information processing capabilities in explaining developmental changes.
- Piaget's theory has inspired major curriculum reforms, and it continues to have an important influence on education practice today. Among Piaget's major contributions to education are the ideas that (a) knowledge must be actively constructed by the child; (b) educators should help children learn how to learn; (c) learning activities should be matched to the child's level of conceptual development; and (d) peer interactions play an important role in the child's cognitive development. Piaget's theory also emphasizes the role of teachers in the learning process as organizers, collaborators, stimulators, and guides.

Vygotsky's Theory of Cognitive Development

- When compared with Piaget, Vygotsky places a stronger emphasis on social interactions. Knowledge is not individually constructed, but coconstructed between two people. Remembering, problem solving, planning, and abstract thinking have a social origin.
- In Vygotsky's theory, elementary cognitive functions are transformed into higher mental functions through interactions with more knowledgeable adults and peers. Internalization refers to the process of constructing an internal (cognitive) representation of physical actions or mental operations that first occur in social interactions. Through internalizing elements of social interactions, children develop ways of regulating their own behavior and thinking.
- Vygotsky described developmental changes in children's thinking in terms of the cultural tools they use to make sense of their world. Technical tools are generally used to change objects or to gain mastery over the environment, whereas psychological tools are used to organize behavior or thought. In Vygotsky's view, society shapes the child's mind through the transmission of tools that are appropriate for functioning in that culture. The history of both the culture and the child's experiences are important for understanding cognitive development.
- Vygotsky believed that language was the most important psychological tool that influences children's cognitive development. He identified three different stages in children's use of language. At first, language is primarily used for communication (social speech). Next, children begin to use egocentric or private speech to regulate

their own thinking. Talking aloud or whispering while performing a task are forms of private speech. In the last stage of language development, children use inner speech (verbal thoughts) to guide their thinking and actions.

- Vygotsky used the term zone of proximal development to refer to the difference between what children can do on their own and with the assistance of others. If an adult or peer carefully provides an appropriate level of support and guidance, children are generally able to perform at a higher level than they can perform on their own. Vygotsky assumed that interactions with adults and peers in the zone of proximal development helps children move to higher levels of mental functioning.

Comparisons between Piaget's and Vygotsky's Theory

- There are several important distinctions between Piaget's and Vygotsky's theories. The most important ones for educators concern the role of language and learning in development. Whereas Piaget believed that egocentric speech plays no useful function in young children's development, Vygotsky argued that egocentric speech is the means by which children organize and regulate their thoughts and actions. With regard to learning, Piaget claimed that development limits what children are capable of learning from social experiences. For Vygotsky, instruction by more knowledgeable peers or adults is at the heart of cognitive development.
- Vygotsky's writings are beginning to have a major impact on education in the United States. Among the major educational contributions of Vygotsky's theory are the role of private speech in cognitive development, the importance of guided participation and scaffolding, and the role of peer interactions in cognitive development. Palincsar and Brown developed the reciprocal teaching procedure that incorporates several features of Vygotsky's theory. This procedure has been used successfully with elementary and secondary students.

Key Terms

Accommodation
Adaptation
Animism
Assimilation
Circular reactions
Centration
Cognitive behavior modification
Collective monologues
Combinatorial reasoning
Concrete operation
Conservation
Constructivist approach
Egocentricism
Egocentric speech
Equilibration
Formal operations
Guided Participation
Hierarchical classification
Horizontal decalage
Hypo-deductive thinking
Internalization
Logico-mathematical knowledge
Matrix classification
Metacognition
Object permanence
Physical knowledge
Preoperational stage
Propositional logic
Realism
Reflective Abstraction
Representational thinking
Schemes
Sensorimotor stage
Seriation
Social knowledge
Social speech
Zone of proximal development

Activities

1. Piaget used many different tasks to study children's logic while performing operations such as seriation, classification, and conservation. The purpose of this activity is to examine how elementary school children of different ages perform Piagetian tasks. Three simple tasks are described below. Using these tasks, individually test two kindergarteners and two third-graders, and then compare their responses. Be sure to ask children to explain their responses, to get at their logic and reasoning. If you do these activities at school, you will need the teacher's permission. After collecting your data, answer the following questions: (a) Which tasks were the kindergarten and third-grade children able to solve correctly? (b) How do the kindergarten children's responses reflect the limitations of preoperational thinking? (c) What types of cognitive operations did the third-grade students use in solving the problems? (d) How did your observations help you understand Piaget's theory of cognitive development?

Task 1: Seriation

Use 5 to 10 sticks or strips of paper that vary in length from 1 to 10 inches. Begin by asking students to place 3 sticks in order, then 5 sticks, and add 2 more sticks until the student is unable to perform the task. Be sure to mix up the sticks each time, and record the students' responses.

Task 2: Conservation of Number

Use 12 coins of the same denomination (all pennies or dimes). Place 6 coins in one row about a half inch apart, and place the other 6 coins below the first row. Ask the student if the number of coins in each row is the same or different and then ask, "How do you know?" Next, spread out the coins in the first row, so that each coin is several inches from the others. Ask the student again if the number of coins in each row is the same or different. Again ask, "How do know?" and record the students' responses.

Task 3: Multiple Classification

Cut out geometric shapes (triangles, squares, and circles) from red, blue, and yellow construction paper (3 colors per shape). Ask the student to sort the cutouts that go together into different piles. Record how the student sorts the cutouts. Now, ask the student if there is another way the cutouts can be sorted and record how they do the second sort.

2. Observe two or three small groups of children working on a common task. Record the way in which the children help one another to perform the task. After completing your observations, answer the following questions.
   a. Did you see evidence of the students directing, monitoring, or assisting one another?
   b. How did the children negotiate roles? Did one student assume responsibility for leading the activity?
   c. Did you see evidence of scaffolding by the children or teacher? If so, describe some examples of this scaffolding.
   d. How did this activity help you understand Vygotsky's concept of the zone of proximal development?
3. Obtain permission to observe an elementary or secondary classroom (any subject) in a local school. Observe three to four lessons in each classroom, and identify the questions or problems that pose difficulty for the students. Describe the problems in your observational notes. After collecting your observations, use Piaget's theory of

cognitive development to analyze the problems students encountered in their lessons. Use the following questions to analyze your notes.

a. How are the problems related to limitations in the students' concrete or formal operational thinking?

b. What type of instructional support or scaffolding was available to help students when they were having difficulty?

c. How did this observation help you understand different aspects of concrete or formal operational thinking?

4. To assess students' formal operational thinking, individually test two middle school students and two high school students using the Piagetian tasks described below. Be sure to use mixed-gender groups at each level. Ask students to think aloud as they do the problems, and record their responses. If you do these tasks in a local school, you will need the teacher's permission. After collecting your data, answer the following questions:

a. How did the students approach each task? Did they have a systematic plan that considered all possible solutions or combinations. In task 1, did they systematically manipulate each variable and test its effect?

b. What differences did you observe between the responses of the younger and older adolescents? Did you see evidence of formal operational reasoning in either, both, or neither groups of adolescents? Do your observations support Piaget's theory?

c. Did you find evidence of gender differences in students' responses? How would you account for these findings?

Task 1: Pendulum Problem

For this task, you will need three different lengths of string and four different weights that can be attached to the string. Instruct your students to experiment with the string and weights in order to determine which variable(s) makes the pendulum go faster or slower. They should consider four variables: the length of the string, the different weights, the force of the initial push, and the height at which they let go of the pendulum.

Task 2: Sandwich Combinations

For this task, you need to write on a piece of paper four different breads (white, rye, sourdough, and wheat), four different meats (ham, beef, turkey, and salami), and four different spreads (mayonnaise, mustard, butter, and ketchup). For each sandwich, they can only use one bread, one meat, and one spread. Ask your students to figure out how many different sandwich combinations they can make. The students may want to use pencil and paper for this task.