



Science and Cognitive Development

Science for young children is all about gaining new knowledge of the world around them; what they can see, hear, smell and touch. Science for young children is also about learning how to learn. It's about being curious and following a process to make new discoveries. In order for children to gain new knowledge and be able to use this knowledge, it's helpful to take a close look at cognitive development. There are two different perspectives on cognitive development that provide us with useful information about how children's mental abilities develop. Jean Piaget's theory of cognitive development and Lev Vygotsky's sociocultural theory of cognitive development help us to have appropriate expectations about; how children think, what they can think about logically; and how you can provide direct support to each child's growing ability to think.

Jean Piaget: mental processes and appropriate expectations

Who was Jean Piaget?

Jean Piaget was a Swiss psychologist who observed children and asked them questions to find out how knowledge develops (Thomas 1992). Before Piaget became known as a psychologist, he was a very serious biologist. He was also an expert in using the scientific method. Piaget used the scientific method to study how mollusks adapt to their environment. Maybe you're wondering what being a biologist who uses the scientific method have to do with cognitive development in children. The answer. A lot!

Piaget believed that people's thinking changed as a way to adapt to their environment, (an important biological concept) and that the goal of thinking or the highest level of thinking people could develop is abstract thought. Abstract thought is the kind of thinking scientists who have - logical-mathematical intelligence use.

Logical mathematical intelligence is one of the eight theories of multiple intelligences identified by Howard Gardner, a psychologist at Harvard University. In 1983, Howard Gardner wrote and published a book called *Frames of Mind* that explained his theory of multiple intelligences. Howard Gardner shared that there is not just one kind of intelligence. In 1983 he identified 7 different kinds of knowing (logical-mathematical, linguistic, musical, bodily-kinesthetic, linguistic, and interpersonal, and intrapersonal). Later he added naturalistic intelligence.

Logical-mathematical intelligence is the process of looking for and discovering patterns and problem solving. Logical-mathematical thinkers use tools such as calculation, thinking skills, numbers, scientific reasoning, logic, abstract symbols, and pattern recognition. It's also the type of intelligence that children who are very successful in school use frequently.

What Piaget believed about cognitive development

Piaget believed that we construct knowledge. Cognitive development happens as children's concrete, hands-on experiences and knowledge of the physical world become mental actions. This happens so that children can adapt to their environment. (Thomas 1992) Here's an example: Let's start with the word c-h-a-i-r. When you read or hear the word chair a picture



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most likely comes into your heads. You may see a kitchen chair or the recliner in your living room. Maybe you see a chair like the one you sat on at school. Did you think about the chairs the children sit on in your day care program? In order to have that image in your head, it's likely that sometime when you were very young you saw a real chair and touched it or sat on it. Maybe you climbed upon a chair, crawled under it, moved it or tipped it over. Perhaps someone helped you climb into a chair or gave you a smaller chair to sit in because they were afraid that you would fall out of a bigger chair. Perhaps you used the chair to help you stand up and take your first steps. Maybe one of your favorite storybooks to look at by yourself was *Goldilocks and the Three Bears* because you liked the picture that showed the three chairs with the smallest one broken into pieces. Your actual physical experiences with a chair becomes mental pictures or symbols you can "see" in your head so that whenever anyone mentions the word chair or you read the word c-h-a-i-r you know exactly what the person is talking about. Your brain takes something concrete and turns it into a picture or a symbol that you can use it over and over again without having to sit on the chair or move the chair or even touch the chair in order to remember it.

How knowledge is constructed: The building blocks of children's thought

Children use schemas to make to make sense of the world. Schemas are actions that organize and give structure to our thoughts. They can be simple or complex. Babies' schemas are very simple. One example is their grasping movement. They use this action to grasp a bottle, a rattle, a finger or the edge of a crib. Schemas can also be more complex. Think about what actions you take to drive a car down the street or what you do to prepare appropriate activities for each of the children in your care everyday. Each of these multiple step processes are schemas.

Schemas change

The number of schemas or actions increases as children grow older. They also become more complex. For example, learning letter sounds becomes learning words, and words connect to become sentences that children can read. Change like this happens automatically. It happens in two different ways; through the processes of assimilation and accommodation. Change happens because the information that a child encounters is different from what he or she already knows. This creates disequilibrium or a sense of being out of balance for the child. Mentally, he or she needs to take an action in order to get back into balance. One way to think about this process is to think about a child's teeter-totter. When the teeter-totter is tipped to one side, representing new information, a child experiencing cognitive change will do something to bring the teeter-totter back to the center.

When a child comes across new information, this new information is automatically compared to what already exists. If the new information is like what's already there, it's added and the child ends up with more schemas; more actions he or she can use to adapt to his or her environment. This process is called assimilation. When a child comes across new information that doesn't fit with what's already there, the information is ignored or the child's brain tries to make a match for it. This process is called accommodation. The child's existing schema or actions have to change to make room for this new information.



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Although assimilation and accommodation happen automatically, it takes four ingredients to set them in motion:

Heredity

Heredity provides the time table and the equipment for cognitive growth.

Physical experience

Physical experience happens when a child “directly manipulates, observes, or listens to, objects to see what occurs when they are acted upon.”

Social transmission

This is knowledge that is passed on to the child from parents, schools, their community and the world at large.

Equilibrium.

Equilibrium is the balance that is created between the forces of heredity, physical experience and social transmission. (Thomas, 1992)

Piaget’s idea that knowledge is constructed takes place in four different periods, the sensorimotor period, the preoperational period, the concrete operational period and the formal operational period. Children move from one stage to the next as their schemas become more complex. Each stage has unique qualities that help us to have appropriate expectations about children’s thinking.

The sensorimotor period (Birth to Age 2)

Infants and toddlers begin constructing knowledge and learning about their world by using their senses (sight, hearing, feeling, taste, and smell) and their motor abilities. It starts with each baby’s automatic reflexes. These automatic reflexes can include the rooting, sucking and startle reflexes. Babies one to four months old grasp and let go of objects over and over again. If you watch them, it seems like a kind of unplanned practice. After a while, the baby begins to get a hint that there is a connection between what he or she is doing with the rattle and what happens when he lets go. There are two very important characteristics of the sensorimotor period; object and person permanence and egocentric thinking.

Object and person permanence

During the sensorimotor period infants and toddlers develop object permanence. Object permanence is the idea that even if something is out of sight, it still exists. You probably know it as, out of sight, **not** out of mind. You see it when a baby between 8 and 12 months-old searches for an object that they have seen move out of sight. When a favorite cloth ball rolls under a blanket and the child looks for it under the blanket, you know that he or she has object permanence. You can also recognize it when the 8 to 18 month-olds in your care get upset when Mom or Dad leave after dropping off their child at the beginning of the day. This is a classic



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case of separation anxiety. It's normal! You should expect to see some distress, but also be able to distract the child and calm her down within a short period of time.

Egocentric Thinking

During the sensorimotor period and preoperational period that follows, children are unable to stand in someone else's shoes and see things from a different perspective. Children in these stages of development literally believe that what they see, everyone sees, what they think, everyone thinks, and what they feel, everyone feels. They haven't developed the mental ability to understand that their behavior can set off someone else's reactions and responses. When a young 3-year-old playing hide and seek covers up only his head and face with a blanket and considers himself hidden he is demonstrating egocentric thinking. Another example of egocentric thinking is a child who believes that if his favorite cartoon character is Elmo, then Elmo must be everyone's favorite character. It can't be Ernie, Bert, Dora or Barney.

You should expect infants and toddlers in the sensorimotor period of cognitive development to:

- Begin to get anxious when mom or dad moves out of sight at around 8 months. This distress will most likely become more intense, peak at about 18 months and then slowly level off.
- Use their eyes to follow where a favorite toy disappeared to. If they are not mobile yet or just learning to move from a sitting to a crawling position, An infant who isn't mobile yet or just learning move from a sit to a crawl will probably look at where the toy went and then at you as if to tell you that the toy is there and they expect you to get it. When these infants learn to crawl, they may crawl to where the object is and try to retrieve it on their own.
- Demand to play Peek a Boo over and over again.
- Touch, taste, smell and shake, rattle and roll everything they come into contact and everything that comes into contact with them.
- Repeat the same physical action or skill over and over again; drop the same rattle or walk up and down the stairs for as long as you will let them practice.
- Not be good at sharing toys or sometimes even you.

The Preoperational Period (Ages 2 to 7)

Language development plays a big role in this period. Children use their spoken language to change their physical actions and experiences into mental thoughts (Thomas 1992). They are able to think about things that are out of sight or a very long way off. Until this happens, though, children in this period of cognitive development will need you to continue to provide them with lots of hands-on concrete activities. They will still need lots of opportunities to see, hear, smell, touch and talk about new objects and experiences in order to learn. Appropriate expectations about how children's mental abilities develop include come from understanding perception, centration, egocentric speech and intuitive thought.



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Perception

Perception for young children means getting to know something based on what they can see, hear, smell, taste or touch. Children between 2 and 5 learn about the world and solve problems by seeing, touching, tasting, hearing, smelling and using objects, **not what they remember about them**. This process is the foundation of everything they learn.

Centration

If we go back to the sorting shapes example and ask Amaya to put all of the *big yellow squares* in one pile, Amaya will probably get right to the task. She wants to make you happy. She may put all of the *big* shapes in a pile. Or she may put all the *yellow* shapes in a pile. Perhaps she'll just put *all* of the *shapes* in one big pile, no matter what the color or size. This shows you that Amaya is not yet able to think about more than one characteristic that she can directly see at a time. She can't think of big, yellow circles. She can think about big circles, yellow circles or just shapes. Piaget calls this centration. This kind of information lets you know that Amaya is still in the preoperational stage of cognitive development and that she can only think about what she can perceive and no more than one characteristic of an object.

Egocentric Speech

Have you noticed that the 2, 3, and 4-year-olds you take care of talk to themselves? You might hear it from one child when he is playing with a toy cell phone along side another child in your dress-up area. "My Alex's phone. I call gamma." Or maybe you've heard something that sounds more like self talk, the kind of talk adults use when they need to change a negative thought to a positive one, "No hitting, No hitting, No hitting." This phrase is repeated to help this young child not do something. In both of these cases the child is actually thinking out loud (Thompson. 1992). Around the time a child turns 5 or 6 he or she will no longer have to think out loud. It's almost as if the child moves what they say out loud into their heads.

Intuitive Thought

Five-and six- year olds are also beginning to be able to focus on more than one characteristic of an object that they can see. Instead of just being able to put yellow *or* big circles together, 5 year old Chris can arrange all of the shapes by color and size. We can ask Chris to arrange all the yellow triangles from biggest to smallest and he will be able to do this with great success. This is called intuitive thought. Concrete experiences such as physically seeing and moving shapes of different sizes and colors and talking out loud become mental activities. Children at this stage are beginning to use logic and reason – the beginnings of logical mathematical intelligence.

You should expect toddlers and preschoolers in the preoperational period of cognitive development to:

- Continue to touch, taste, smell and shake, rattle and roll everything new they come into contact with.
- Repeat the same physical action or skill over and over again until they master it.



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- Talk out loud to themselves about new objects or actions or when they are trying to combine objects and actions in a new way.
- Begin to learn concepts such as size, color, shape, biggest to smallest, loudest to softest, lightest to heaviest.
- Ask more and more questions.

The Concrete Operations Period (Ages 7 to 11)

It takes years for a child's ability to think to advance to this level. Only as a child gets closer to eleven does he or she have the ability to think concretely and to think like you. Children in this period don't always have to have an actual physical experience with an object in order to know it. During this period you can really see Piaget's background in biology and the importance of logical-mathematical intelligence. It's during this phase that children can perform more complex mental operations.

Operations

Operations are organized, formal, logical mental processes. (Feldman 2001). They are what a 7-year-old can finally do when you ask him or her to put all the big, yellow circles together when you've given him or her triangles, squares, and circles, in three different colors, and three different sizes to sort. It's also what happens when you ask a child to put the teddy bears in graduating order from biggest to smallest or smallest to biggest or heaviest to lightest or lightest to heaviest.

You use operations when you put together your grocery list. Do you write a list of the items you need before you go to the store? Do you organize the items on your list so that all the items that you would find in the dairy section – milk, cheese, eggs, butter or margarine are grouped together, all the items you would find in the produce section are together, and all the meat, fish, and poultry are together? If you don't have a written list, you have one in your head. Once you get to the store, and are standing in the produce aisle you can quickly go through your mental list and pick up the items you need from that aisle.

The sorting task the child does above is an example of a concrete operation, and the ability to go into your grocery store and find like items that are scattered throughout your shopping list is an example of a mental operation. According to Piaget you can't do a mental operation without first being able to do a concrete operation. And even before you can do a concrete operation such as sorting shapes or putting objects in order by size, a child needs to have spoken language.

Here are four logical-mathematical abilities that begin to appear in 7 to 11 year olds. A child's growing ability to decenter, reverse operations, compensate and identify are mental operations characteristic of more abstract thought. These are also mental operations that children need to be able to do to be successful at math and science in kindergarten through fifth grade.

Decentering

A child in this period of development can only pay attention to one visible aspect of an object at a time. When a child is able to decenter, he or she has developed the ability to think about more



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than one characteristic at a time. An example of this is the 7 year old who can sort the shapes by color, size and type all at the same time.

Reversibility

Another ability that is emerging is a child's ability to understand that a process or operation can be reversed. Think about a child in your care who takes a ball of clay and rolls it into a snake and then rolls it back into a ball. This concept is important for school-age children. It's part of learning arithmetic. Children are beginning to understand that $5+3=8$ and $3+5=8$ and then later $8-3=5$ and $8-5=3$. They have made a mental connection between concrete objects and mental symbols. This is exactly what happens when you see the word c-h-a-i-r and see a mental picture of a chair in your head.

Identity

Even though shape changes the amount stays the same. Think about children playing with modeling clay. Children in this period of development will know that even if they roll their ball of clay into the shape of a long snake the amount stays the same.

Compensation

An increase in one dimension such as length is canceled out by a decrease in another dimension such as width. This is what happens when a child rolls his ball of modeling clay into a long snake.

You should expect to see school-age children in the concrete operations period of cognitive development to:

- Continue to need plenty of hands-on experiences with things that are new to them and have had no experience with.
- Repeat the same physical action or skill over and over again until they master it.
- Talk out loud to themselves about new objects or actions or when they are trying to put objects and actions into a new combination.
- Begin to add and subtract.
- Begin to be able to take the point-of view or perspective of another.
- Use simple logic and reasoning.
- Ask more specific, logic bound questions.

The Formal Operations Period (Ages 11 to 15)

Finally, when children reach the formal operations period, they are able to think abstractly. This child no longer needs to have hands-on experience with objects or physical knowledge of objects he or she knows in order to think about them and to solve problems that will result in adaptations to their environment. Everything takes place in the mind. This period of thought is what enables the study of space, the stars, planets, black holes - Quantum Physics or pondering and comparing what others believe to be true about how children develop.



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You should expect to see school-age children in the formal operations period of cognitive to:

- Solve problems in their heads.
- Do more complex arithmetic.
- Understand more complex mathematical ideas.
- Take the perspective of another.
- Use more complex logic and reasoning.
- Ask specific, logic bound questions.

Piaget in Summary

Piaget's theory of cognitive development provides important information about how what you can do to support the mental development of the children in your care. His theory shows us what's happening in a child's head as they are learning to think; an ability that we may take for granted and believe we have no control over. Piaget's theory shows us that:

- Children and adults **do not** think in the same way. Children's thinking is concrete and reflects where they are in their on-going growth and development.
- Thinking begins with a child's actual hands-on experiences with objects and the freedom to move their bodies. Children need to touch, smell, taste, hear, see and manipulate objects in order to be able to think.
- Thinking becomes more complex as children have more experiences and their bodies mature. There are four periods of cognitive development that children go through and there are things that children do and say in each of these periods that tell us where they are in developing their ability to think.
- Language plays a major role in how children learn to think. Spoken language is the bridge between concrete experiences and mental images and symbols. Children need plenty of opportunities to "think out loud" in order to move concrete physical experiences into a mental images and even later into abstract thought.

Knowing these things can help you plan appropriate activities and experiences that will support and promote the cognitive development of each child in your care. In a nut shell, don't expect children to think like you, provide lots and lots of hand-on, concrete experiences and activities and plenty of time for children to use and manipulate new materials and objects. Finally, promote each child's language development. Talk to children. But, more important let children talk and be sure to listen carefully.



Lev Vygotsky's Theory of Sociocultural Cognitive Development

Although Jean Piaget is the person who most often comes to mind when discussing how children learn to think, there is another individual, Lev Vygotsky, a Russian psychologist, who has made some very important and exciting contributions to our knowledge of how thinking develops.

Piaget's view of cognitive development would have us look inside a child's head and glimpse the inborn process of change thinking goes through. Piaget's view helps us to have appropriate expectations about children's mental abilities during different periods of development, especially in terms of logical-mathematical intelligence. Vygotsky's ideas about how mental abilities develop, on the other hand, show us how important and necessary the social and cultural context are to developing each child's mental abilities.

Who was Lev Vygotsky?

Just as it was helpful to know a little bit about Piaget in order to understand some of the complexities of his theory of cognitive development, it's also helpful to know more about Lev Vygotsky and the time and circumstances during which he lived, and how this influenced his theory about thinking.

Vygotsky lived in the Soviet Union after the Russian Revolution. Russia had become a Socialist Republic and Vygotsky was one of many people who worked at the Institute of Psychology in Moscow (<http://home.mira.net/~andy/seminars/chat.htm>) to develop educational programs that would teach the children of this society how to be a socialist. (Thomas 1992). Now it's easier to understand why Vygotsky's view of how children's mental abilities develop focused on the role of the child's social and cultural world. Vygotsky believed that children depend on others to develop their cognitive skills and abilities. According to Vygotsky, each child's understanding of the world and their ability to adapt to it comes from their interactions with their parents, their siblings and others in their environment. (Thomas 1992)

How mental abilities develop

Knowledge is developed as a result of social interactions in which children, working along side others, more knowledgeable and experience than they are work together solve problems and build knowledge. As a result of these interactions children gradually learn to think on their own. (Vygotsky, 1979, 1926/1997; Wetsch & Tulviste, 1992)

Two essential elements of the social interactions that result in cognitive development are scaffolding and the Zone of Proximal Development (ZPD).

Scaffolding

If you are familiar with building construction, then chances are you are familiar with scaffolding. Scaffolding is the structure built alongside a building when a brand new building is being built or



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when a building is being repaired. After the building is completed or the repairs are made, the scaffolding is removed. In Vygotsky's view of cognitive development, the adults or other partners in a child's world provide scaffolding to help children learn new information and develop more complex thinking abilities.

Here's one way you may already be using scaffolding. The children in your care are sitting at a table putting puzzles together. Quanir is having trouble fitting a piece in the puzzle. Instead of taking the puzzle piece from him and putting it in yourself, you may suggest to Quanir that he to turn the puzzle around, or turn the piece around. You may suggest that he look at the colors or objects on the puzzle piece and see where the same color or objects are in the puzzle. This gives Quanir different ways of thinking about the puzzle. You provide support or scaffolding like this until Quanir can put the puzzle together on his own.

You also use scaffolding when you're teaching children conflict resolution skills. When children have a disagreement or are fighting over a toy, you stop the action and talk them through a process of peacefully solving their conflict which includes how they got there and how do the "fix it". Depending on how much previous experience these children have had in resolving conflicts peacefully, you probably provided scaffolding along with opportunities for practice.

ZPD (Zone of Proximal Development)

What do you do about the child who, after what seems like 1000 tries or scaffolding, can't get the puzzle piece into the right space? What then? It's time to put the puzzle away. The task is beyond the child's ZPD (Zone of Proximal Development). The ZPD is what a child is able to do with *some* help. When a child can't fit the puzzle piece into the puzzle, even with support, putting this puzzle together goes way beyond the mental and perhaps physical abilities of the child. The task of putting this puzzle together is outside the child's ZPD. It's up to the adult in this situation to put the puzzle away and find another one that will be challenging for the child, but not impossible.

Now think about the child who comes to the puzzle table, chooses the 8 piece Winnie the Pooh puzzle and puts it together in less than 30 seconds. This activity is also not within this child's ZPD. This puzzle is too easy. It's time to set out more challenging puzzle. Maybe it will have more pieces or a more complicated design.

In order to support the cognitive development of each of these children, you would need to assist them in selecting a puzzle that falls within their ZPD.

Using Observation to Provide Appropriate Scaffolding

Perhaps you are wondering how to tell if an activity or a task is within a child's ZPD. Observation is your key tool. Observe children doing activities. Pay attention to how long they spend. Watch for frustration levels. Is the child experiencing frustration? If so, How much? If the level is on the rise or if a child asks for help, provide it. Providing help doesn't mean giving the answer right away. It means providing some scaffolding. Ask questions that will help the child to think about the task in a new way. Physically move a block or puzzle piece so that a



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child may see what he or she is doing from a different perspective. Change the activity if it is too easy or too difficult.

Vygotsky in summary

Vygotsky's theory of how children's ability to think is ready to use. Vygotsky developed and explained his theory so that the people responsible for educating children in Soviet Russia could use the information. Piaget was more interested in describing a naturally occurring process; not how to change or influence it.

Vygotsky provided a very useful actual strategy- scaffolding. It's a way of interacting with children that helps their ability to think develop. Vygotsky also provided us with the concept of the Zone of Proximal Development. The Zone of Proximal Development helps you decide if a task is too easy or too hard for a child and make changes so that the activity will fall within a child's ZPD. Finally, Vygotsky's theory showed how important *people* are in a child's cognitive development. The children in your care need you to provide scaffolding and to make sure activities and experiences are not too hard or too easy. You are an important tool in a child's developing ability to think and to think well.



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