Preschool

Good Thinking!

Fostering Children's Reasoning and Problem Solving

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Sandy teaches 3- and 4-year-old children in a Head Start classroom. She often asks children to be investigators and to solve problems or questions that arise. For example, during outside time one day, Sandy notices Keira and Amir playing on the slide. Sandy hears Keira say, "Hey, Amir, you're going really fast down that slide! How come I'm not going so fast?" Sandy comments, "Keira, you made a really interesting observation. You noticed that Amir is going down the slide faster than you. Why do you think that might be?" "Well," Keira says thoughtfully, "maybe because his pants are more slippery than mine." Sandra responds, "That is really good thinking! You've made a guess, a hypothesis. Can you think of some way we could test out whether Amir's clothing is making him go faster?"

Keira decides that she can test whether clothing makes a difference by using clothes from the dramatic play area. She finds two pairs of pants: one pair from a wizard outfit that is very shiny and made of what Keira calls "slippery" material, and the other a pair of jeans from the construction worker outfit. They look rough and less slippery. Sandy times Keira as she goes down the slide to see whether the slippery pants make her go faster. They find that Keira can indeed slide faster with the slippery pants on.

From this experience Keira learns several things. She learns, for example, that the texture of a material—whether it is smooth or rough—affects how quickly or slowly an object (in this case, a person) moves down a ramp. She learns that if she doesn't know the answer to a question she can make a guess and then test that guess to determine if it is correct (she also discovers that another word for *guess* is *hypothesis*). If something puzzles Keira, she now knows that she can ask her teacher for help and information.

If asked, Sandy could identify particular content areas she supported during this interaction. She could respond that she fostered Keira's knowledge about the physical world and how things work (science), encouraged her thinking about inclined planes (mathematics), and expanded her communication skills by teaching her new words and how to explain her thinking (language). As important as these skills are, however, there was more to this learning experience than just science, mathematics, and language. In this interaction, Sandy encouraged Keira to construct a possible explanation, a hypothesis, and then test that explanation to better understand cause-and-effect relationships. Sandy promoted "good thinking," the ability to logically think and reason about the world.

Critical thinking skills span multiple domains. They include focusing to pursue knowledge, using self-control to define a problem and determine goals, making connections to brainstorm solutions, and communicating to justify actions and share evaluations (Galinsky 2010).

Forty-four percent of the preschool day is spent on learning activities, primarily literacy and writing activities (Early et al. 2005). Too often, such activities focus on skill attainment and not on the critical thinking, reasoning, and problem solving that are foundational to learning and development. Such skills warrant attention, and it is important that teachers foster them *intentionally*. This article summarizes research on the development of preschool children's critical thinking skills and suggests practical, research-based strategies for supporting them.

Reasoning and problem-solving skills

Definitions of critical thinking skills vary, although nearly all include reasoning, making judgments and conclusions, and solving problems (Willingham 2008; Lai 2011). Although it was previously believed that these were higher-order thinking skills that developed only in older children and adults (Piaget 1930), research demonstrates that children reason and problem solve as early as infancy (e.g., Woodward 2009). Between ages 3 and 5 children form complex thoughts and insights, and during the preschool years their cognitive abilities—including logical thinking and reasoning—develop substantially (Amsterlaw & Wellman 2006). These skills enable children to recognize, understand, and analyze a problem and draw on knowledge or experience to seek solutions to the problem (USDHHS 2010). Some researchers conclude that reasoning and problem-solving skills are domain specific (e.g., reasoning skills in science do not necessarily transfer to mathematics); others, however, argue that teachers can foster young children's general critical thinking skills (see Lai 2011 for a review).

Reasoning and problem-solving skills are foundational for lifelong learning. Analyzing arguments, making inferences, reasoning, and implementing decisions to solve problems are important skills across all content areas

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and thus critical for school success. The ability to efficiently gather, understand, analyze, and interpret information is increasingly necessary to function in school and in the workplace (Schneider 2002). Educators and policy makers, now more than ever, recognize the need to foster critical thinking skills in young children. This is evidenced in the Common Core State Standards, which emphasize the importance of reasoning and problem-solving skills in preparing children for "college, workforce training, and life in a technological society" (NGA Center & CCSSO 2010, 4).

Key ideas about children's thinking

Three key ideas emerge from the research on young children's thinking:

1. Young children are capable of developing reasoning and problem-solving skills
2. Children's early reasoning and problem-solving skills support their later development and learning
3. Early childhood educators can foster children's reasoning and problem solving

Research suggests how these ideas relate to everyday practice.

Young children can develop reasoning and problem-solving skills

Scholars long believed that true logical reasoning does not develop until adolescence (Piaget 1930). However, recent research suggests that logical thinking and reasoning begin in infancy and develop gradually throughout childhood (Gopnik et al. 2004; Hollister Sandberg & McCullough 2010). From infancy on, children pay attention to people's intentions and goals, and infants as young as 6 months old demonstrate rudimentary reasoning skills (Woodward 2009).

Early reasoning skills. Woodward and her colleagues explored how infants make sense of their physical and social worlds and develop reasoning skills (e.g., Hamlin, Hallinan, & Woodward 2008; Cannon & Woodward 2012). The researchers tested whether 7-month-olds would copy an experimenter's actions if they understood the experimenter's intention (Hamlin, Hallinan, & Woodward 2008). Infants were shown two toys, and then they watched as the experimenter reached for one of the toys and grasped it. The experimenter pushed the toys within reach of the infants and said, "Now it's your turn!" Infants reliably touched the same object the experimenter had grasped. This was not the case when the experimenter simply brushed the toy with the back of her hand rather than grasped it (suggesting that the touch was unintentional, not goal directed). In both cases the experimenter's actions drew attention to the object, but infants responded only when they interpreted

the experimenter's actions as goal directed. These results, along with others from a series of studies Woodward and colleagues conducted, demonstrate that infants as young as 7 months old can analyze others' intentions and use this information to reason about things in their world (Woodward 2009).

Understanding of causality. Between 9 and 12 months, infants begin to understand that one event or behavior causes another (Woodward 2009), and 2-year-olds are adept at using causality in their thinking (McMullen 2013). Gopnik and colleagues (2000; 2001) designed a series of experiments to explore how young children construct and test explanations for events. They showed children a "magical" light box that glowed when it was activated. Although the experimenter controlled the box, the box appeared to be activated by placing a block on top of it. The experimenter showed 2- to 4-year-old children different blocks, some that turned the box on (the experimenter called these *blickets*) and some that did not (not blickets). The children were asked which block was the blicket. Children as young as 2 were able to

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draw causal conclusions about which object was the blicket, correctly choosing the block that had "activated" the light. In another experiment with 3- and 4-year-old children, the task was modified so two blocks were placed on the machine and children were asked which block to remove to make the machine stop lighting up. Children correctly predicted which object they should remove from the box to make it stop.

The blicket studies are important because they demonstrate that very young children understand how one thing affects another and that as children get older, their reasoning skills are more sophisticated. Children are increasingly able to generate theories about the causal effects of objects and to test those theories by asking questions and making predictions.

Inductive and deductive reasoning. Understanding cause and effect is an important component of both inductive and deductive reasoning, which develop between the ages of 3 and 6 (Schraw et al. 2011). Young children use *inductive reasoning* when they generalize the conclusions they draw from the consequences of their own behaviors or experiences. *Deductive reasoning* is the process by which individuals use facts or general rules to draw a conclusion, being able to understand the premise "If *P* happens, then *Q* will too" (Schraw et al. 2011).

Three-year-old Maya has a fireplace at home and has learned through experience that fires are hot and should not be touched. When she sees the flame on a gas stove in the kitchen at her early childhood program, she reasons that the stove is also hot and should not be touched. "Hot," she says to her friend. "Don't touch!" Maya uses inductive reasoning in this situation, generalizing and extending her knowledge about fire and heat to a new situation.

Although young children's deductive reasoning becomes more sophisticated with age, their development of this reasoning is complex.

Three-year-old Brandon knows that if it is nighttime, it is time for him to take a bath (if *P,* then *Q*). Through repeated experiences—nighttime (P), then bath (Q)—Brandon connects these two events using deductive reasoning, the basis for making predictions. Inductive and deductive reasoning skills grow substantially during the preschool years as a result of children's increasing knowledge and varied experiences and interactions with the world around them.

Analogical reasoning. Goswami and Pauen (2005) have spent many years researching how *analogical reasoning,* a form of inductive reasoning that involves making and understanding comparisons, develops in young children (Goswami 1995; Goswami & Pauen 2005). In a series of three experiments, they tested the ability of 3- and 4-year-olds to make comparisons, or relational mappings, based on size (Goswami 1995). An experimenter read *Goldilocks and the Three Bears* to a child, and then said they were going to play a game about choosing cups. The experimenter said, "We are each going to have a set of cups, a daddy-bear-size cup, a mummy-bear-size cup, and a baby-bear-size cup, and you have to choose the same cup from your set that I choose from mine." The experimenter named the cups in her set (e.g., "I'm choosing the Mummy cup") but not in the child's set. To choose the correct cup, the child had to work out the size relationship between the two sets of cups using one-to-one correspondence. Not only did 3- and 4-year-old children choose the correct cup, they could do so even when the positions and colors of their cups were different from those of the experimenter's cups.

However, when experimenters asked 3- and 4-year-olds to make analogies (comparisons) involving concepts rather than physical characteristics (e.g., *A* is hotter than *B* is hotter than *C,* or *A* is louder than *B* is louder than *C*), only the 4-year-olds were successful (Goswami 1995; Goswami & Pauen 2005). Goswami concluded that children as young as 3 can use analogies as a basis for reasoning only if the analogy is based on a familiar structure, such as the characters in *Goldilocks.* This skill develops and becomes more sophisticated over time, doing so rather rapidly during the brief time between ages 3 and 4.

Reasoning with abstract ideas. Research demonstrates that although young children's deductive reasoning becomes more sophisticated with age and that 4-year-olds can reason using abstract ideas, their development of this reasoning is complex. For example, a teacher is working with a small group of children. She says, "We're going to think about some silly stories together. Some of the stories may sound funny, but I want you to think carefully about them. For each story,

I'm going to ask you to use your imagination and make a picture in your head. In this story, all cats bark. So the cats that are in your head, are they barking? Are they meowing? Now, Jeremy is a cat. Is Jeremy barking? Is Jeremy meowing? How do you know?" Problems like this actually get more difficult for children as they get older and acquire more real-world experience, because they are more likely to know of counterexamples ("I know a cat that can't 'meow'!"). However, children eventually overcome this and draw the correct conclusions from complex, even absurd, premises (Hollister Sandburg & McCullough 2010).

Children's early reasoning and problem-solving skills support their later development and learning

Cognitive learning. Children's reasoning and problem-solving skills are associated with a range of important literacy learning (e.g., Tzuriel & Flor-Maduel 2010) and mathematics outcomes (Grissmer et al. 2010). In an analysis of six longitudinal data sets, researchers found that general knowledge at kindergarten entry was the strongest predictor of children's science and reading skills and a strong predictor of math skills (Grissmer et al. 2010). General knowledge includes children's thinking and reasoning skills, in particular their ability to form questions about the natural world, gather evidence, and communicate conclusions (USDOE 2002).

Social-emotional learning. Children's reasoning and problem-solving skills are also important components of social and emotional competence. Social problem-solving skills include generating a number of alternative solutions to a conflict and understanding and considering the consequences of one's behaviors (Denham & Almeida 1987; Denham et al. 2012). These skills are linked to children's long-term behavioral outcomes (Youngstrom et al. 2000), school adjustment (Bierman et al. 2008), and academic success (Greenberg, Kusché, & Riggs 2001).

To see how reasoning and problem solving apply to the social-emotional domain, let's return to Sandy's classroom a couple of months after Keira's first experience with creating an experiment to test a hypothesis:

> Keira notices Andy and Eric creating a zoo with animals and blocks in the block area and asks, "Can I play with you?" Andy responds, "No, there's not enough animals for three people!" Upset, Keira says to her teacher, Sandy, "Andy won't play with me because I'm a girl." Sandy bends down to Keira's eye level and says, "Are you sure? I saw you and Andy playing together just this morning on the playground. Can you think of any other reasons Andy might not want to play with you right now?" Keira says, "Well, maybe because there aren't enough animals for me too." Sandy asks Keira where she might find some other animals to add to the zoo. Keira finds several animal puppets in the book area and takes them to the block area.

As this situation demonstrates, children's daily experiences offer opportunities to construct explanations about cause and effect. When teachers provide enriching experiences and materials and support children's interactions with each other, they enable children to develop their reasoning

Checklist of Teaching Practices and Strategies to Support Preschool Children's Problem Solving and Reasoning

- [ ] **Facilitate children's play.** Support children's exploratory play experiences by providing challenging, varied materials that appeal to all of the senses—sight, sound, smell, touch, and taste. Encourage communication during play by extending children's language with their peers and with you. Ask them to talk about their play both during and after their play experiences.

- [ ] **Help children understand the difference between guessing and knowing.** A guess, or hypothesis, needs to be tested. Assist children with simple experiments in which they make predictions based on their hypotheses, gather evidence by making observations that they document (e.g., through pictures, dictated stories, graphs), and seek information to help them support or reject their original hypotheses and make conclusions. Do they prove their hypotheses, or do they need to do additional experimenting?

- [ ] **Foster categorization skills.** Provide materials that allow children to explore, compare, and sort by a variety of attributes (size, shape, sound, taste, etc.). With younger children, use objects that differ in just one attribute (e.g., balls of different colors). Ask children to describe the similarities and differences and to put the objects into categories. Use and reinforce vocabulary that helps children describe their comparisons (e.g., *short, round, loud, quiet, blue, red, smooth, bumpy*) and use problem-solving language (e.g., *hypothesis, compare, observe, interpret*). During play, notice how children use materials. Do they sort them? Do they comment on similarities and differences?

- [ ] **Encourage children to think before responding.** Help children learn to freeze—to take a moment before answering a question to think about their best or most reasonable response to a problem and how they would test it. With a group of children, discuss different ways they solved a problem to demonstrate that there is often more than one way to do so. Point out that children sometimes think about and approach things differently, but that everyone's ideas should be respected.

- [ ] **Model and promote scientific reasoning, using the language of problem solving.** Teachers demonstrate good habits of problem solvers when they encourage children to use their senses to observe the world around them, help children form questions about what they observe and make predictions, share their own thinking and problem-solving processes aloud with children, model and conduct experiments to test predictions, and facilitate discussion about the results of children's experiments.

and problem-solving skills. In both scenarios with Keira, Sandy encouraged her to think and to generate hypotheses to solve her questions and problems. In the second scenario, Sandy pointed out that evidence did not support Keira's initial hypothesis and encouraged Keira to problem solve to find a solution. Further, Keira's response provided Sandy insight into Keira's concept of herself in social situations, in particular those involving playing with boys and playing in the block area. From this experience, Keira may begin to learn the importance of producing alternative solutions to interpersonal problems, a key social problem-solving skill (Youngstrom et al. 2000).

Early childhood educators can foster children's reasoning and problem solving

Although children are naturally curious and like to explore, they need adult support to make sense of the world around them. Early childhood educators can foster children's reasoning and problem-solving skills in the context of the developmentally appropriate practices in which they already engage. For example, teachers can provide experiences and materials and engage in interactions that build on children's natural curiosity.

Facilitate children's play. As stated in NAEYC's (2009) position statement on developmentally appropriate practice, "play is an important vehicle for developing self-regulation as well as for promoting language, cognition, and social competence" (14). Play also supports children's reasoning and problem solving (Schulz & Bonawitz 2007; Ramani 2012). Through play, children actively explore their environments, manipulate objects and interact with others, construct knowledge about the way the world works, and learn vital concepts such as cause and effect. Play also provides children opportunities to plan, negotiate, and develop social perspective-taking skills by considering others' points of view. In the previous scenario, Sandy helped Keira understand why Andy might be hesitant to allow her to join their play and to negotiate a possible solution. Like Sandy, all teachers have an important role in supporting, yet not interfering with, children's play experiences not only by providing materials and opportunities but also by offering suggestions for solving problems.

Scaffold children's understanding of the difference between guessing and knowing. Teachers scaffold children's learning by providing hints, offering a range of answers, and encouraging children to use additional resources. These strategies help children understand the difference between guessing and knowing—and realize that guessing requires testing. The ability to distinguish when there is and is not enough evidence to draw conclusions is fundamental to good problem solving. The more information children have about a particular topic, the better able they are to form reasoned theories and to be confident that those theories are correct. Young children need to learn to find and use evidence to confirm hypotheses, identify trustworthy sources, and reject hypotheses that cannot be supported by evidence.

Sample Lesson Plan: Sink or Float

Learning domain: Science Knowledge & Skills, Physical Science (Properties of Materials)

Learning objectives: Children will develop initial understandings of the concept of buoyancy, and will observe and predict whether objects sink or float and classify them accordingly. Children will observe and describe the ways sinking objects can be made to float and floating objects can be made to sink.

Activity setting: Small group

Materials:

- Plastic bottle cap (one per group)
- Cups of water (one per teacher and one per child)
- Objects that float (three to five per group—foam peanuts, plastic bears, etc.)
- Objects that sink (three to five per group—coins, pebbles, solid rubber balls, balls of clay, etc.)
- Pennies (three per group, not plastic)
- Large transparent container of water, such as a glass bowl or an aquarium
- Paper towels

Big idea: The concept of floating and sinking is a tricky one! It is hard to accurately describe the characteristics of an item that will float or sink because the concept of buoyancy may be too advanced for most preschoolers. The goal of the activity is for children to make predictions and then to experiment with, observe, and describe items that float or sink. It is not necessary or appropriate to draw conclusions about buoyancy as a result of this activity.

Planned activity:

1. Say, "Today we are going to learn about objects that float and sink."

2. Demonstrate how to make a floating object sink.

- Fill a large, transparent container with water. Float an upturned plastic bottle cap in the water. Ask the children to predict what will happen as pennies are placed into the bottle cap "boat." Ask children to describe what happens as each penny is added.

3. Encourage children to experiment with materials that float or sink.

- Give children cups of water and objects that float or sink.
- Ask children to describe each object's shape, weight (heavy/light), and material.
- Ask children to predict whether each object will float or sink.
- Ask children to place the objects in the water to see if they float or sink.
- Ask children to group the objects according to whether they float or sink.

Foster categorization skills: The teacher encourages children to sort items according to whether they float or sink.

4. Experiment to make floating items sink and sinking items float.

- Encourage children to describe the objects that floated.
- Challenge children to see if they can make those objects sink.
- As a group, brainstorm ways to make an object float or sink using classroom materials. For example, attach an object that sinks to a foam peanut or shape the clay ball into a boat to make it float; add small blocks or pennies to make a floating object sink.
- Test the modifications, revising as children offer other ideas.

Model and promote scientific reasoning: Ask children to brainstorm ways to make an object float or sink and then encourage them to test those hypotheses.

5. Say: "Today we learned about things that float and sink." Ask questions such as the following:

- "Were we able to make something that floated sink? How did we do it? Why do you think that worked?"
- "Can anyone think of a way we made something that sank be able to float? How?" (e.g., changing a ball of clay or foil into a boat shape can allow it to float)
- "What was the same or different about the items that were able to float? What was the same or different about the items that were able to sink? Was that *always* the case?"

Scaffold children's understanding of the difference between guessing and knowing: Review with children what was the same or different about the items that floated. Scaffold their understanding of whether there was enough evidence to conclude that the characteristics they identified *always* made the items float or sink.

Adapted, by permission, from M. Kinzie, R.C. Pianta, J. Vick Whittaker, M.J. Foss, E. Pan, Y. Lee, A.P. Williford, & J.B. Thomas, *MyTeachingPartner—Math/Science* (Charlottesville: University of Virginia, Curry School of Education, The Center for Advanced Study of Teaching and Learning, 2010), 258–9.

In addition to these general teaching practices, there are specific strategies that promote preschool children's reasoning and problem-solving skills. These strategies, described in detail in the following three sections, promote "thoughtful decision making" by developing children's planning and reflecting skills (Epstein 2014). (See "Checklist of Teaching Practices and Strategies to Support Preschool Children's Problem Solving and Reasoning," page 83, for further explanation of strategies.)

Foster categorization skills. Understanding how to compare and contrast, categorize, and sort enables children to generalize information from one category or situation to another—to reason inductively (Hollister Sandberg & McCullough 2010). Generalizing helps children determine how to approach new objects or events with confidence. For example, 4-year-old Justin was once bitten by a dog and now is afraid of all dogs. During neighborhood walks, his parents have helped him categorize dogs by watching for behavioral signs: a dog with a wagging tail and relaxed demeanor is most likely friendly, but a dog that is barking and has its ears pinned back and teeth bared should be given some space. When they visit the park, Justin generalizes the information he learned about which dogs he can feel safe with based on how he categorizes their behavior.

To promote categorizing, provide children with objects or sets of objects that have contrasting qualities and encourage them to explain how the objects are alike and not alike (Loewenstein & Gentner 2001; Mix 2008; Christie & Gentner 2010). Challenge children to categorize by attributes beyond size and shape; for example, ask them to group objects according to color, width, or function (e.g., "find tools that can cut") (Kemler Nelson, Holt, & Egan 2004). Also, notice how children spontaneously categorize during play; what attributes are they using to categorize in sets they create?

Teachers also foster categorization skills by modeling strategies for children. Children as young as 3 can understand and imitate categorization strategies they see a teacher use without the teacher explicitly stating the strategies (Williamson & Markman 2006; Williamson, Meltzoff, & Markman 2008; Williamson, Jaswal, & Meltzoff 2010). For example, with a group of children watching, Sandy arranges several toys in front of her. Some of the toys make noise and some do not. Without telling children what characteristic she is using to sort, she carefully picks up each toy, shakes it and listens to it, and then puts the toy in the appropriate group. For the last few unsorted toys, she picks them up one at a time and says to a child, "Sort the toys the way I did." To do so, the child must have attended to what Sandy did, understood her goal, and learned her sorting rule as she modeled the strategy (shaking the toys and listening). This requires deeper-level mental processes and more complex problem solving than if Sandy had simply told the children her sorting rule.

Encourage children to brainstorm multiple solutions to problems. Young children tend to act on their first impulse in a situation or on the first thing that comes to mind. But to be good thinkers, they need to develop *inhibitory control*, "the ability to ignore distractions and stay focused, and to resist making one response and instead make another" (Diamond 2006). Inhibitory control helps children regulate their emotions and behavior and problem solve more effectively. Teachers can help children learn this important skill by encouraging them to pause before acting; consider multiple solutions to questions, tasks, or problems; and then choose a solution to try out.

Model and promote scientific reasoning. Scientific reasoning involves constructing hypotheses, gathering evidence, conducting experiments to test hypotheses, and drawing conclusions (Hollister Sandberg & McCullough 2010). It requires children to distinguish between various explanations for events and determine whether there is evidence to support the explanations. Although this is a complex type of reasoning for young children, teachers can support it through modeling and scaffolding. For example, after encouraging children to construct multiple reasonable explanations for events (hypotheses), teachers can help children talk through the steps they will take to test their hypotheses, as Sandy did in the first scenario with Keira and the slide. As children test their hypotheses, teachers should encourage them to use their senses (i.e., smell, touch, sight, sound, taste) to observe, gather, and record data (e.g., through pictures or charts). Finally, teachers can help children summarize the results of their investigation and construct explanations (i.e., verbalize cause and effect) for their findings. When teachers ask children questions such as "Why do you think that?" or "How do you know?," they help children become aware of their own thinking processes, reflect on the results of their experiments, and evaluate outcomes. (See the sample lesson plan, page 85, for an example of how teachers support scientific reasoning.)

Conclusion

Children's ability to problem solve and reason is integral to their academic as well as social success. Each day, early childhood teachers support these skills in numerous ways—for example, by facilitating children's play, scaffolding learning, and offering interesting and challenging experiences. With a better understanding of how young children's reasoning and problem-solving skills develop, and a plan for implementing strategies to support them, teachers will become more intentional in helping children become good thinkers.

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