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Promoting Children's Science Inquiry and Learning Through Water Investigations



Cindy Hoisington, Ingrid Chalufour, Jeff Winokur, and Nancy Clark-Chiarelli

Four-year-old Malik makes a fascinating discovery at the water table. When he pours water into a clear plastic tube, it goes straight to the lowest part and stays there. No matter how much he twists and turns the ends of the tube, he can't get it out. "It's stuck!" he calls out to his teacher, Mr. Myers. "The water's stuck!" Mr. Myers comes over and sits down next to him. "What's happening? What makes you think the water is stuck?" Mary Lou, a 3-year-old at the table, sticks a baster into one end of the tube and squeezes. Water suddenly shoots out the other end. The children laugh and Mr. Myers says, "That sure worked to get the water out! I wonder how?"

RECENT RESEARCH HAS UNDERScored young children's capacity for science learning (NRC 2012). Long before they enter kindergarten, children generate ideas about the world and how it works based on evidence from their own experiences. These early theories, although often inaccurate scientifically (all round things sink; balls can roll by themselves), represent a rudimentary understanding

of science concepts across content areas, including physics. As they seek to make sense of their world, young children also reason in ways that are foundational to later scientific thinking (Center on the Developing Child 2011; NRC 2012).

To reach their potential as young scientists, however, children need the support of knowledgeable and skillful adults. In early education settings, children benefit by having teachers who intentionally structure and scaffold explorations, integrate hands-on and minds-on experiences, and interact with children in ways that support reflection, theory making, and understanding (Minner, Levy, & Century 2010; Worth 2010).

But what strategies are effective in supporting young children's science inquiry and learning? And what kinds of professional development experiences support educators to become master teachers of science at the preschool level? In response to these questions, a team of educators and researchers at Education Development Center, Inc. (EDC) designed, implemented, and evaluated a professional development program in science for early childhood teachers: Foundations of Science Literacy (FSL). In the three-year project, which was funded by the US Depart-

ment of Education’s Institute for Education Sciences (IES), EDC staff worked with participating preschool teachers in a variety of settings (Head Start, public school, and home- and center-based programs) to observe and document how their science teaching evolved as they participated in the FSL program.

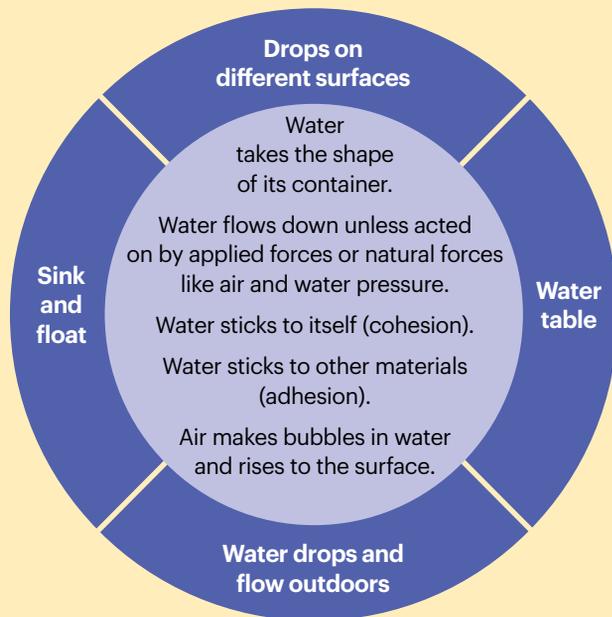
Foundations of Science Literacy

The FSL program centers on physical science—the study of nonliving objects and materials—specifically, water investigations. We chose physical science because children can interact directly with objects and materials and immediately observe how they respond—for example, pouring and spraying water. Water is an especially compelling and familiar material for children, and FSL topics include water flow, drops, and sink and float. These topics provide many opportunities for teachers and children to explore water in large and small amounts. They can investigate how water moves when acted on by forces; how it looks on different surfaces; and how solid objects placed in it behave. These experiences connect both teachers and children to key physical science concepts, as displayed in “Water Concepts and Investigation Topics.”

The primary components of FSL are the four Cs: coursework, classroom-based assignments, coaching, and curriculum. Four day-and-a-half sessions focus on one water topic each. During the sessions, instructors engage teachers in a series of explorations designed to deepen their understanding of the topic and relevant concepts. The balance of each session focuses on children and teaching. Discussions, video analyses, and collaborative activities are all aimed at answering two questions: “What can children learn about this topic?” and “How can I support children’s inquiry and learning about this topic?”

Between sessions, the preschool teachers complete classroom-based assignments that require them to plan, facilitate, and assess a topical water exploration with children. Experienced coaches, hired by EDC, attend all course sessions and work with small groups of teachers in between sessions. During group meetings, they assist teachers with planning topical explorations. They also support assessment as they help teachers collect, reflect on, and share science documentation from their classrooms. They observe and meet with each teacher to provide individualized assistance and support the teachers’ implementation

Water Concepts and Investigation Topics



This diagram was adapted with permission from Karen Worth.

of the water exploration. Teachers use the guide *Exploring Water With Young Children* (Chalufour & Worth 2005) as a resource.

Five science teaching practices

As we implemented and tested FSL’s impact on teachers, classrooms, and children, five key science-teaching practices emerged:

- Create a physical environment for science inquiry and learning
- Facilitate direct experiences that promote conceptual learning
- Promote the use of scientific inquiry and practices
- Plan in-depth investigations
- Assess children’s science inquiry and learning

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FSL preschool classrooms, where teachers facilitated children's long-term investigations of water, provide vivid examples of each of these practices. We describe each practice and outline the FSL instructional approaches that helped teachers master them.

Create a physical environment for science inquiry and learning about water

After the first FSL session, preschool teachers evaluated their current water table areas: How could they provide maximum space for children moving around the water table? Did the areas include accessible storage for exploration materials? Were photographs of water (depicting rainstorms, waterfalls, puddles, and such) displayed at children's eye level? Some teachers moved the water tables away from the wall so children could face each other. Other teachers stored materials on labeled shelves near the water table or in bins under it. Teachers used the backs of doors and shelf units as display spaces and binders with plastic sleeves to hold water photos. Gradually, photos and drawings of children's own water explorations replaced these pictures.

Teachers considered the new materials they provided in the water tables. Which ones draw children's attention to water's characteristics and behavior? Clear containers of various sizes, clear funnels, clear squeeze bottles, spray bottles, basters, and clear tubing invite children to move water, promote close observation, and can be used independently or combined in different ways. Many of these items can be found in the kitchen or are readily available in local stores. Clear tubing of various diameters can be purchased inexpensively at hardware stores.

As children's play became more focused, teachers added items that would extend their explorations.

As preschoolers poured, squirted, and sucked up water using these tools, the water responded by streaming from funnels, flowing through tubes, or dripping from basters. Children reacted with interest and excitement to these phenomena—visible, observable evidence of water's liquid properties. Children also observed phenomena related to air as they squeezed the tops of “empty” containers into the water, causing bubbles to rise to the surface.

As children's play became more focused, teachers added items that would extend their explorations: a second bucket or bin placed next to the water table, plastic connectors to join lengths of tubing (available at hardware stores), and food coloring to make the water visible. Repurposed clear tennis ball containers (free from sports clubs eager to recycle them) with holes drilled in them allowed children to explore air and water pressure.

One teacher showed children tennis ball containers with three holes drilled vertically up the sides and asked,

“How do you think the water will look as it comes out of the holes?” This question sparked an investigation. Children poured water into the containers and closely observed the length and shape of the streams coming out, placing their fingers over the holes and covering the containers to see how the streams would change. With support from the teacher, they documented their observations on chart paper hanging next to the water table. The teacher used this chart the next day to initiate and guide a conversation with children—a *science talk*—that helped them identify patterns in how the water looked as it streamed from the top, middle, and bottom holes.

Facilitate direct experiences that promote conceptual learning related to water

Responding to the shift in K–12 science standards toward core concepts and practices, early childhood educators are paying more attention to science content and the importance of teachers' own science understanding (Brenneman, Stevenson-Boyd, & Frede 2009; NRC 2012). In FSL, teachers themselves investigated water flow, drops, and sinking and floating before introducing the topics to children. Instructors facilitated teachers' direct explorations and science talks to provide opportunities for teachers to make authentic connections to the physical science concepts. As a result, teachers could observe children's water play through a physical science lens rather than a life science (fish live in water) lens or an earth science (ocean water is salty) lens. Once teachers had a deeper understanding of the science concepts, they wanted to know what kinds of questions would support children's direct explorations and spark children's reflection.

We encouraged preschool teachers to observe what children were doing, saying, and noticing related to water *before* beginning a conversation. That way they could ask questions about phenomena that were connected to concepts *and* interesting to children. During sink-and-float explorations, one teacher observed a child repeatedly hold a plastic fish under the water, let it go, and watch it bounce to the surface. She began a conversation by asking, “What happens when you try to sink your plastic fish?” Teachers also used comments like “It looks like you're trying to get water into the baster” or “I'm wondering how you got the water to flow like that” as conversation starters.

We also emphasized questions that stimulate children's inquiry and investigation rather than suggest “correct” answers. These include questions that help children to (1) describe observations, (2) explain procedures, and (3) make predictions; following their investigations, we ask children questions that (4) encourage them to reflect on what they learned.

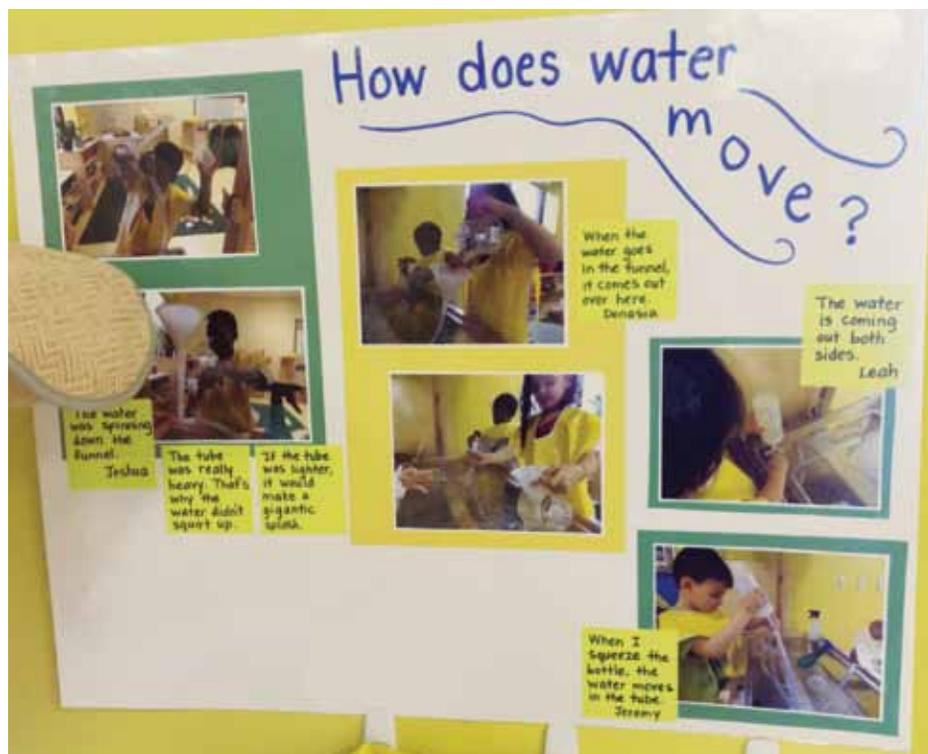
1. Questions that support describing observations.

These questions encourage close observation and collection of evidence. Examples in the beginning of water flow explo-

rations included “What happens when you lift the funnel out of the cup?,” “Where do bubbles appear when you do that?,” and “When does water drip out of the baster?” Focused investigations incorporated more specific questions, such as “How far does the water go through the tube?” and “How fast can you make the water go?”

2. Questions that support explaining procedures. These questions ask children to communicate what they did and how they did it. As children used water exploration materials more intentionally, teachers asked questions like “How did you get water into the baster?” and “How did you get the water to flow in a different direction?” FSL teachers scaffolded multistep responses by asking children, “What did you do first?,” “What did you do next?,” and “Then what did you do?”

3. Questions that support making predictions. These invite children to speculate about what might happen based on their previous experiences and/or try an investigation they haven’t tried yet. Teachers asked questions like



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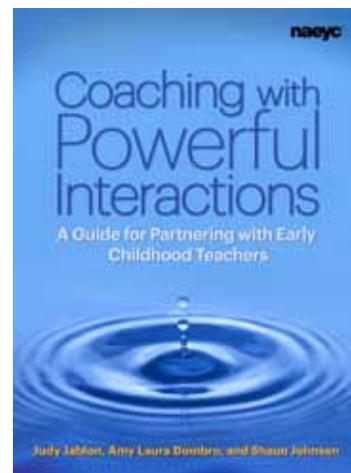
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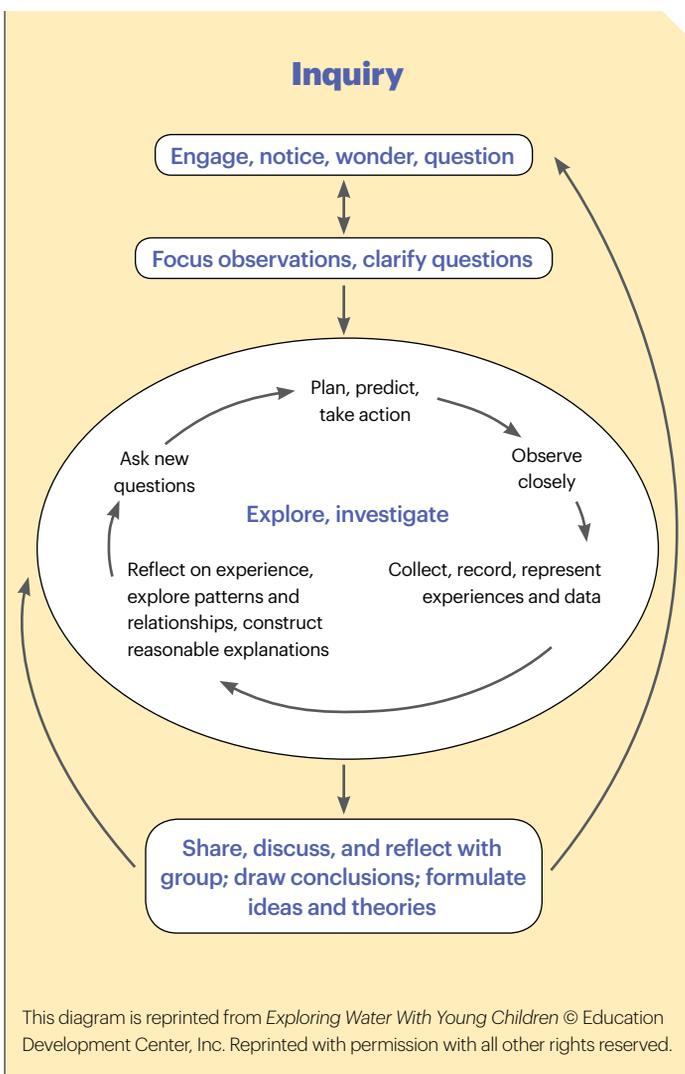
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“What do you think will happen if you fill your boat with pennies?” and “Do you think you can squirt water further with the baster or the squeeze bottle?”

4. Questions that spark children's reflection. After children's direct explorations, teachers ask questions that stimulate reflection. Learning goes from hands-on to *minds-on* when the teacher encourages children to think about the evidence they have collected over time and generate their own theories about why things happen the way they do. We found that asking “Why do you think . . .?” rather than just “Why . . .?” drew more responses from children. During sink and float, one teacher changed her question from “Why does the paper clip sink?” to “Why do you think the paper clip sinks?” The first question generated shrugs and a chorus of “I don't know,” but the second generated lots of responses, including “because it's so small,” “because it has holes in it,” and “because it's silver.”

FSL teachers asked these four different types of questions intentionally. During a sink-and-float investigation, for example, a teacher asked children to describe the boats they had made from plasticene. She then asked them to share ideas about how they had made the boats and why they made them that way. Finally, she asked them to predict which boats would float and why, and encouraged them to see if their predictions were accurate. After the investigation, she invited children to share their theories about why some boats floated and others didn't. According to the children, boats that floated had “bigger walls” than boats that sank. The next day the teacher challenged children to make their sinking boats float by adding bigger walls.

Asking “Why do you think so?” also supports planning. Sometimes it leads to surprises. When one teacher asked a child why he thought a golf ball would sink, he said “Because it's round.” She had assumed previously that he



was basing his prediction on the ball's weight. She decided to facilitate a follow-up investigation of round things rather than heavy things.

Using props is critical for engaging young children in conversations. Some teachers used photographs or children's drawings as visual props. Teachers invited children to point to specific aspects of their drawings and prompted them to “show us where the water went.” They also narrated children's actions and observations, providing vocabulary.

Promote the use of scientific inquiry and practices

FSL introduced inquiry as a *process* that includes foundational skills like exploring, wondering, and raising questions, and more sophisticated practices like collecting and recording data and analyzing previous ideas in light of new evidence (see “Inquiry”).

Instructors modeled inquiry-support strategies during teacher explorations and helped teachers identify evidence of their own inquiry. Teachers also analyzed video vignettes of real classrooms, identifying examples of children's inquiry and how teachers supported it. Teachers used the Engage-Explore-Reflect (E-E-R) cycle to help with planning, facilitation, and assessment of water explorations (see "The Engage-Explore-Reflect Cycle," p. 78).

Engage. During the Engage phase the teacher introduces the topic and new materials, and elicits children's prior knowledge. As explorations become more focused, teachers use this phase to plan upcoming explorations with children and solicit predictions.

Explore. This is the hands-on phase of the cycle, in which the teacher facilitates direct exploration and supports recording data and representing.

Reflect. Teachers initiate and guide science talks after the direct exploration to help children recall, revisit, and reflect on their observations and ideas.

During a drops exploration, one teacher began the Engage phase by showing children a photograph of drops of water on the head of a pin from the book *A Drop of Water*:

A Book of Science and Wonder (Wick 1997) and asking them to describe what they saw. She then drew out the children's prior experiences and knowledge by asking, "Where have you seen drops of water?" and "What did they look like?" Children recounted seeing raindrops, faucet drops, and drops on the side of the water table, and said they were "little" and "round." Then the teacher facilitated the Explore phase by providing eyedroppers, colored water, plastic plates, and hand magnifying lenses so children could make different size drops, move them around on their plates, and observe them closely. She asked, "How do the small drops look different from the big drops?" and "What happens when you put two drops close together?" The teacher suggested that children observe the drops from the side as well as from the top. She provided clay so children could make models of their large and small drops. During the Reflect phase the teacher encouraged children to share, compare, and contrast their observations using their models. She encouraged them to revisit their original theories that all drops are little and round in light of their new evidence. She asked, "What did you notice about the shapes of big drops and little drops?" "How did they look the same as we predicted?" and "How did they look different?"

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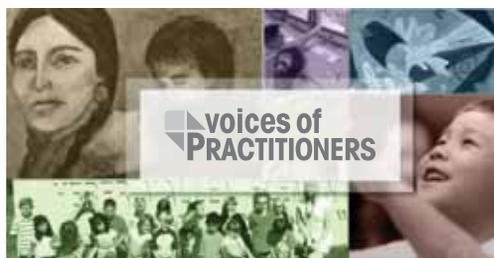
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Plan in-depth investigations of water

Key to effective planning is the amount of time allotted for science exploration and how the teacher sequences children's experiences. FSL-trained teachers used guidelines in *Exploring Water With Young Children* (Chalufour & Worth 2005), planning a minimum of 45 minutes three times a week for Explore, and at least two Engage and Reflect conversations weekly. We encouraged teachers to provide several weeks of open exploration before moving children on to more focused investigations. We emphasized the importance of selecting clear goals for children's inquiry and learning about water. Initial goals included exploring water by using and combining exploration materials, increasing engagement and purpose in water explorations, and communicating about water observations during science talks.

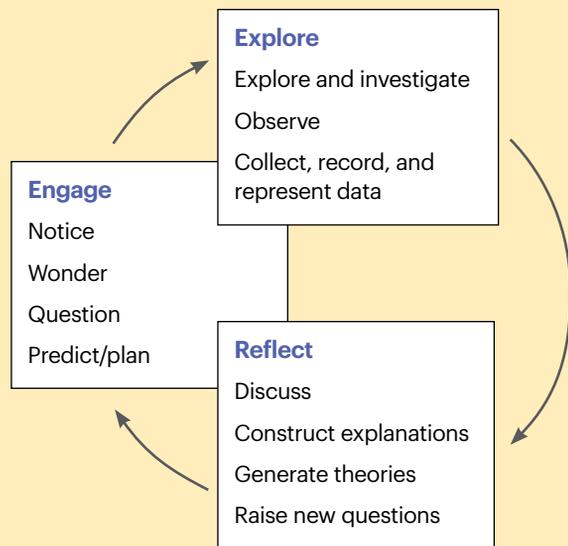
Responsive and focused professional development invites teachers to embrace new ways of approaching science in the classroom.

As water explorations continued, teachers chose more focused goals and used challenges to stimulate children's focused explorations. Since children were typically interested in moving water, many teachers chose goals for focused water flow explorations that included "Children will investigate a variety of methods for 'pushing' water through vertical tubes" and "Children will record distances traveled by water using nonstandard measurement." Challenges were related to goals, including "What materials work best to move water up through a long tube?" and "How can you make water go around in circles?"

Assess children's science inquiry and learning about water

Assessment in FSL is an ongoing process. Teachers use observations and photographs of children engaged in inquiry, children's representations, and transcriptions of children's comments, questions, and predictions. Representing is important in assessment, and it is also a key science practice that promotes close observation and supports communication. Preschool teachers introduced watercolors, paper and markers, and clear straws and blue yarn (representing the clear tubes and water) to help children illustrate what they were doing and noticing. During the focus on drops, teachers introduced clay so children could show how large drops appear flatter and less rounded than small drops. Teachers scaffolded representation for younger children by, for example, drawing the tube and inviting the child to "show me on the paper where the water is." Teachers modeled by making sketches of their own observations.

The Engage-Explore-Reflect Cycle



This diagram was adapted from *Exploring Water With Young Children* © Education Development Center, Inc. The adaptation was developed with permission of EDC.

One assessment focus in FSL is capturing children's theories about water over time. First, knowing children's theories (water has no weight; water can appear and disappear; water stays put in a container) is fundamental to planning investigations that will reinforce or challenge their thinking. Second, an evolving record of children's theories (water stays put in a container water moves and flows when the container is tipped water moves to the lowest point of the container) is evidence of conceptual learning. Since children's theories are often implicit and unspoken, teachers captured theories about water flow such as "It takes a lot of funnels to get water to flow fast" and "Moving the tube up and down makes the water flow through."

Documentation is valuable for making children's learning visible to the school community, families, and to the children themselves (Project Zero & Reggio Children 2001). When meeting with coaches, teachers created visual panels that told the stories of children's learning about sink and float. Teachers used these panels to provide evidence of standards-based teaching and to further stimulate the children's thinking about sinking and floating. A teacher who had facilitated a boat-making activity used a panel to help children reflect on the experience. She provoked children's thinking and stimulated further investigation by asking, "If you were going to make another boat, how would you make it the same or differently than you did before?"

Conclusion

One teacher had this reflection on her learning in Foundation of Science Literacy:

I will continue this work next year with more time for the children to explore and an emphasis on the Reflect part of the process. I saw how everything was connected, from the rhythm of understanding the science to the questions I might ask to initiate and support children's discoveries.

Responsive and focused professional development, centered on key instructional practices, invites teachers to embrace new ways of approaching science in the classroom and interacting with children around science topics. This can result in big changes in science instructional practices. We think that the five practices illustrated here are relevant and applicable to all early childhood classrooms and settings in which science is being implemented, especially in programs that wish to focus on science teaching and learning.

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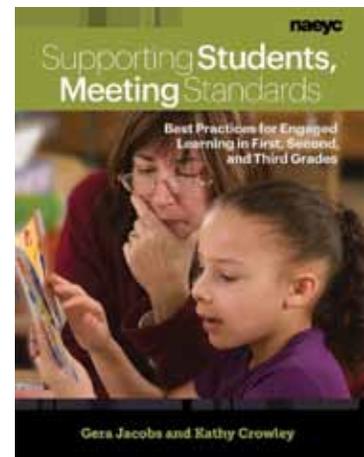
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