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Picturing What's Possible—Portraits of Science Inquiry in Early Childhood Classrooms

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Abstract

This article describes examples of teacher planning, implementation, and evaluation of inquiry-based science explorations in early childhood classrooms from the perspective of a science mentor for early childhood teachers enrolled in the *Foundations of Science Literacy* (FSL) project. FSL is a multicomponent professional development project that includes college-level coursework, mentoring, and classroom-based assignments. Four distinct areas of science teaching practice are covered, including preparing the classroom environment for inquiry and establishing routines that help children make meaning, facilitating children's open exploration, and promoting children's reflection through representation and conversation. Example scenarios of teacher practice are used as well as examples of challenges that teachers face in each of these areas.

Introduction

Olivia holds one end of a 3-foot plastic tube in her hand and hops excitedly around the water table. Her friend Nancy patiently holds the other end of the U-shaped tube poised over an empty cup. "Pour the water in here, Victoria!" Olivia calls to a third girl. "Hold the cup up, Nancy, the water's gonna come out!" In the background, their teacher takes note of the unfolding action. Victoria attaches a funnel to the end of the tube, pours some water into it, and the three watch closely as the water flows toward the lowest part of the tube. "It's going down! It's going down!" Olivia calls as the water settles at the bottom of the U. The three girls look at one another in surprise. Why did the water stop? And what can the teacher do that will support these children's inquiry and learning about water?

Video 1. Nancy and friends explore water.

In my role as a teacher mentor for the project Foundations of Science Literacy (FSL) developed at Education Development Center (EDC), I witnessed many such examples of young children enthusiastically caught up in experiences that connected them to the "big ideas" in physical science—specifically, how water's characteristics as a liquid, along with applied forces, and forces like gravity, air pressure, and water pressure, influence how water moves and behaves in different circumstances. These children were not only learning about water, they were immersed in inquiry—the process of doing science—and they were learning, using, and practicing discrete inquiry skills like observing, predicting and planning, investigating, collecting new information, and raising questions. Over time, these children would have opportunities to deepen their understanding of water's characteristics and behavior, and they would participate fully in the processes and practices of science. Based on evidence, they would generate theories to explain their observations. In order for this to happen, however, they will need the support of skilled and knowledgeable teachers who understand content and process in science and young children's conceptual development, and who use teaching strategies that are responsive to how children learn (Duschl, Schweingruber, & Shouse, 2007). FSL was developed with this in mind. It includes a college-level course delivered in four day-and-a-half sessions, on-site mentoring, assignments that require teachers to implement long-term water investigations in their own classrooms, and a curriculum resource guide for teachers, *Exploring Water with Young Children* (Chalufour & Worth, 2005).

My role, working with teachers in a variety of early childhood settings, was to help them incorporate the content and strategies they were gaining in the course into their own practices and help them figure out "what to do next." I observed and videotaped them facilitating children's science experiences, and I met with them to analyze the videos for evidence of children's science learning and plan next steps. Although mentoring, like inquiry, is a dynamic process, my work with teachers evolved over time in parallel with the course sessions. I worked with teachers in four overlapping but distinct areas:

- Preparing the classroom environment for inquiry and establishing routines that help children make meaning
- Facilitating children's open exploration
- Facilitating children's focused exploration
- Promoting children's reflection through representation and conversation

As I collected videotapes of teachers and children engaged in doing science, a vivid portrait emerged of what IS possible in early childhood classrooms when teachers receive the professional development supports they need. Alternatively, my mentoring experience brought into stark relief the contrasts between what is possible and what is often probable in classrooms. It fueled my own reflection on the challenges that teachers face as they try to implement an inquiry-based approach to science teaching and learning.

Preparing the Classroom Environment for Inquiry and Establishing Routines that Help Children Make Meaning

Teachers left the first session of FSL with a bag of open-ended water exploration materials—clear containers in various shapes and sizes, lengths of clear tubing, basters, squeeze and spray bottles, tube connectors, and wire racks—and three frameworks designed to support their implementation of water explorations: Open/Focused Exploration, the Inquiry cycle, and the Engage-Explore-Reflect (E-E-R) cycle. Mentors were charged with supporting teachers to prepare classroom environments that would promote children's beginning inquiry (exploring, asking questions, and making observations) of water and water flow.

Although a water table was a staple in most classrooms, teachers generally did not think of it as an area for science learning, and how they used it varied from classroom to classroom. Some teachers rarely opened it. Others opened it daily because they valued water play as a sensory activity, particularly for children with behavioral challenges. Yet others used it as a learning area in concert with a theme-based or skills-based curriculum—placing plastic insects in it during a unit on "Bugs" or eyedroppers in it to promote fine-motor skills.

In our first planning sessions, teachers and I talked about how to transform the water table into a focal area for science inquiry. All of the teachers agreed to remove the wide variety of materials currently in their tables and replace them with the open-ended course materials. We also talked about placement of the table to maximize children's access and ease maintenance routines, display space for photographs and pictures of water that would stimulate children's explorations, and storage of materials that would promote self-selection. Several teachers moved water tables away from walls so children would be able to stand on either side of them, facing one another. Teachers dedicated wall space or used free-standing display boards for photos and pictures. Identifying space for storing materials proved to be a challenge for teachers who were unaccustomed to devoting shelves to the water area. As teachers and I watched videos of children's initial water explorations, we noticed that, when all of the materials were left in the table, children tended to pick up the first thing they saw, and the crowd of materials even inhibited their access to the water. "What might support children to choose materials more intentionally?" I asked one teacher. "How do you decide if there's enough water in the table?" I asked another. Teachers agreed that at the very least, a separate storage bucket for the water materials was a necessity.

Figure 1. Children use a variety of open-ended materials to explore water.

Setting up the environment for inquiry included making *time* for direct exploration, a particular challenge in classrooms that had stringent management routines. Although in FSL we recommend 45 minutes of exploration time, several classrooms only allotted 10 minutes at each learning center. How could teachers extend children's time at the water table without interrupting the flow of other children through centers? They devised a plan for adding a second water table, thereby doubling children's water exploration time to 20 minutes.

In FSL, teachers were introduced to the idea that "hands-on" exploration alone is not enough to support children's science conceptual development. They need multiple opportunities and support to reflect and "make meaning" of their direct water explorations. This meant that teachers had to find time for two vehicles for reflection—science talks and representation. Some teachers needed help to understand the importance of these practices from a science perspective and to process their skepticism about children's ability to participate in them.

Many classrooms already had a consistent routine for daily group meetings that included attendance, calendar, and the weather, and teachers were reluctant to change it. One teacher decided to have small-group science talks directly before and after each exploration with only the children who would be exploring that day. Another teacher thought mealtime would be ideal for science conversations. As teachers tried to initiate regular science talks, we pondered questions in our conferences like, "Why does a child who seems so engaged at the water table seem so disengaged during a conversation?" Teachers quickly realized how important it was to have props available so children could demonstrate what they had been doing at the water table while teachers injected the relevant vocabulary and language. Some teachers began to take photographs of children exploring and held these up during science talks to support children as they recalled and revisited their water experiences.

Some teachers were enthusiastic about providing opportunities for children to represent early on in the water study because representation made the water explorations appear more relevant to literacy-based curricula. "How do you think representing is important to children's science learning as well?" I asked these teachers. Supporting representation was more difficult for teachers who thought that their children lacked the fine-motor ability or attention spans to draw from observation. I encouraged teachers to make representation materials accessible during or immediately after children's explorations—paper, markers, watercolors, clear straws, and pieces of yarn. I also asked them to think about how they could scaffold children's early attempts at representation: "How can you help the child show how the water moved without her having to draw all of the materials she used?"

Facilitating Children's Open Explorations

As teachers and I watched video that reflected their implementation of these new set-ups and routines, they were delighted by what children were doing and saying during the water explorations and related conversations. One teacher remarked about a child, "He usually moves from area to area. I can't believe how he concentrated on getting the water through the tube; he even volunteered to talk about it in front of the group!" Mentors pointed out evidence that specific teaching strategies were effectively stimulating and maintaining children's interest. "Notice how Adele leans down to look more closely at the bubbles when she observes your enthusiasm!" I remarked to one teacher.

Teachers were sometimes surprised by how children persisted in their actions even when they didn't seem to be effective. As we watched a video, one teacher said, "She keeps trying to pour water into the baster using a cup even though it's all splashing down the sides!" I noticed that the child kept looking down at the baster as if looking for evidence that her strategy was working. "I wonder if she thinks some of the water IS going into the baster. How could you help her make a closer observation?"

Figure 2. A child tries hard to get water into a baster by pouring.

In course sessions, teachers engaged in their own facilitated inquiry-based explorations of water flow, and mentors helped teachers make connections between children's actions and the relevant science they themselves had learned in the course. As a teacher and I watched a video of children using cups with holes, water streamed out further from the lower holes. "The water pressure is stronger there," the teacher said, "because there's more water above that hole." Teachers were sometimes tempted to give children specific science information or to provide direct instruction. When a teacher said to a small group, "Water flows down because of gravity", I asked, "I know you understand what that means, but how do you think the children interpret it?" and "What are some ways you could provide opportunities for children to experience gravity's effect on water flow?" Another teacher said, "It was hard for me not to just tell her how to get the water through the tube! I felt like I wasn't doing anything to help her learn!" This prompted a conversation about inquiry and how questions like, "What are you trying to do?" and "What happened when you did that?" promote children's thinking and problem solving. Helping teachers feel more comfortable with the inquiry process was a focus of my work throughout FSL.

Figure 3. A child looks at the tube as if wondering, "Is any water going in?"

Some teachers were dismayed when water explorations revealed that children didn't know as much about the relevant science as they had previously assumed, and this was especially apparent when it came to air and air bubbles, which played a significant role in children's water investigations. When a teacher asked, "What are bubbles made of?" and a child responded, "water", the teacher said to me, "I talked about air a lot during a previous unit on wind and weather! I don't understand why she didn't remember that bubbles are air!" "Why might it be logical for a child to think that bubbles are made of water?" I asked, and "How might air as wind seem very different from air as bubbles?"

Figure 4. A child observes bubbles that appear inside the squeeze bottle.

Explicit strategies for facilitating children's open explorations of water were presented in the context of the *Engage-Explore-Reflect* (E-E-R) cycle. Strategies for the Engage conversation included drawing out children's prior experiences and knowledge of water, introducing new materials, and inviting children to share ideas about how to use the new materials to move water. One teacher introduced the basters and clear tubing to a small group. "What do you think we could do with these tubes at the water table?" "Put water inside," responded a child. "Oh…put water inside! And how do you think we could get water inside?" A child who is an English language learner (ELL) positioned the baster pointing into the tube and slid her finger along it while the teacher provided a verbal description. "Oh, you'll use the baster to squeeze water into the tube, and the water will go all the way through it?"

Video 2. Children talk about basters and tubes.

Strategies for facilitating the Explore included supporting children's use of the materials and drawing their attention to how the water moved and flowed in response to their actions by asking descriptive ("What does the water do when you…?"), procedural ("How did you get the water to go…?"), and thoughtprovoking ("What do you think would happen if...?") questions.

Video 3. Children use basters and tubing and get some surprises.

We talked about questions that would support children's inquiry and learning about water rather than imply one correct answer. As she used a baster and clear tubing, for example, one child discovered that she could make water shoot out of the end of the tubing even when there was NO water in the baster. "How did you make the water go up like that?" asked the teacher, and "Is there anything in your baster?" "No!" said the child. "What kind of question could you ask that would encourage children to find out more about air?" I asked. The teacher decided to ask the children, "What do you think would happen if you squeezed the baster on other things like the surface of the water or your own skin?"

Strategies for guiding Reflect conversations during open exploration included using photographs to help children recall and revisit previous explorations and suggesting related follow-up explorations that would provide more evidence of a concept. One teacher discussed photos from an exploration the day before with a small group: "You found a lot of ways to make bubbles yesterday! Teshawn made bubbles by squirting his baster into a tube and Sheila made bubbles by putting her tube slowly down under the water." Then she added, "Do you think you can find any more ways to make bubbles today?" Teachers also used reflection as a lead-in to more focused investigations.

Video 4. A teacher supports reflection on ways children have found to get water through tubes.

As children's experiences with water continued over days and weeks, they became familiar with the materials, frequently combined them, and approached their explorations more intentionally.

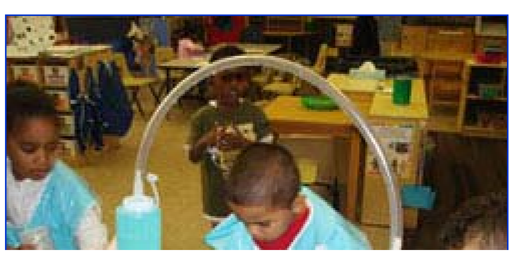


Figure 5. Children begin to combine materials in intentional ways.

They used language to name the materials and describe water's movement. "It's pouring out!" said one ELL child in a video. "There's a little water and a lot of air in there!" said another child, talking about his squeeze bottle. Teachers were comfortable commenting on what children were doing and noticing, and they interacted in ways that focused children's attention on how their actions influenced the water's movement. Children's questions were clearly emerging and children and teachers were ready for focused investigations.

Video 5. Teachers were comfortable commenting on what children were doing.

Facilitating Children's Focused Explorations

Focused exploration, introduced at the second FSL session, provided opportunities for children's inquiry at the level of predicting, investigating, collecting information, generating new ideas based on evidence, and raising new questions.

Teachers felt comfortable with predicting as an inquiry skill and utilized it frequently. Placing it in the context of an inquiry *process* was more challenging. I asked teachers questions like, "What information do you think children need before they can make a prediction?" and "How can you use children's predictions to support their further learning and inquiry?" We talked about how children make predictions based on previous experiences, and one teacher made this explicit in a science talk. "You have all used cups, basters, and squeeze bottles to move water through tubes," she said. "Today we are going to move water UP," and she indicated two tubes placed vertically over the water table. "What do you think will work best to do that?" she asked. As individual children responded "the cup," "the baster," or "the squeeze bottle," she followed up with, "Why do you think that will work best?" She then documented children's predictions on a chart that she saved to revisit with children after the investigation. "Some of us thought the squeeze bottle would work best to move water up, but we found out that the baster worked best. Why do you think the baster worked so well?" "Because it blasted the water hard!" said one of the children.

Video 6. *Children made predictions based on earlier experience.*

As investigations got more focused, teachers wondered about the dramatic play that often emerged in context of water explorations. In one video, two girls said they were making a “vacuum.” They had placed two funnels upside-down in beakers full of water and connected them with a piece of clear tubing. The girls indicated that when they moved the funnels up and down inside the beakers, water should be drawn up through the tubes, “But it doesn’t work,” one of them said. “That’s really interesting!” the teacher replied. During our conference, she told me, “I was impressed that they put ‘the vacuum’ together and combined so many materials but I didn’t want to encourage dramatic play.” This prompted a conversation about dramatic play as a vehicle for inquiry. Together we decided that the teacher could pose a challenge in her next science talk by first inviting the girls to show and describe their vacuum to the group. “Marleen and Anna made a water vacuum, but it didn’t work the way they expected. Does anyone have an idea about how to make it work using the materials we have?”

Facilitating these explorations meant maintaining the group’s focus on a specific aspect of water investigations—while still supporting individual children’s observations and experiences—and teachers and I talked about how to do this. Introducing a clear and compelling question or challenge that reflected children’s own interests was definitely key. Having a well-planned set-up, facilitating in a way that kept the original question front and center, and having paper available for children to record outcomes also helped.

One teacher skillfully used these strategies. She fixed several long tubes vertically on a wire rack and brought the set-up to the Engage conversation, asking children for ideas about how they could move water through the long tubing from bottom to top. As she facilitated the Explore, the teacher drew children’s attention to the method each child was trying and noted how the water was responding by making a mark on the tubing and helping them record the results on paper. She also drew their attention to what was happening inside the tubes. When she noticed a child squeezing an empty baster into a tube, next to a child squeezing a baster full of water, she raised a new question “I wonder if an empty baster can push the water just like a full baster can.” “No way!” said a child “empty basters can’t push water!” After the investigation children concluded that you “need something that squeezes the water” to make it go “really high up” AND they had another question to investigate.

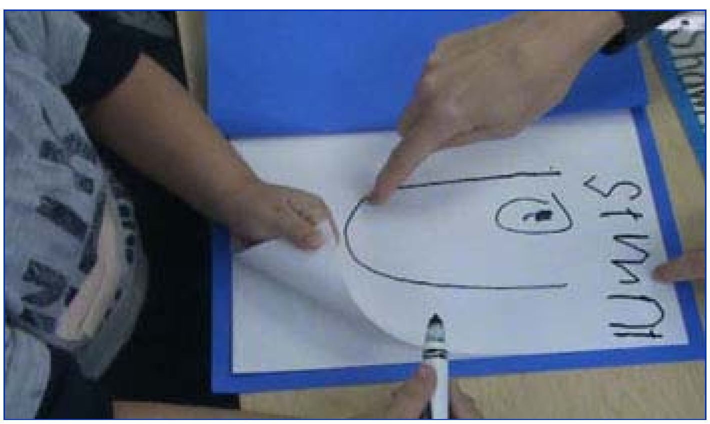
Video 7. *A teacher helps children explore their ideas.*

Supporting Children’s Reflection through Representation and Conversation

Reflection was a focus for both children's and teachers' learning in FSL. During mentor meetings, we discussed ways of supporting representation and using it to promote reflection on the children's water experiences. Teachers began to take water props to the writing area or invited children to represent right at the water table. One teacher modeled representation and supported reflection for an ELL child right at the water table. The child was slowly spinning a circular tube half-filled with water and watching the water fall to the bottom each time he turned it. The teacher drew a large ring on the paper and asked him to "show me on the paper where the water is." This stimulated a lot of looking back and forth between the real ring and the representation of it on paper before he pointed to the bottom of the paper ring saying, "The water here!" In our conference, I pointed out how many goals she met—modeling representation, supporting his emerging understanding that water always flowed to the lowest part of the tube no matter how he moved it, and building his vocabulary and language skills in context.

Video 8 (coming soon!). A teacher modeled representation and supported reflection for an ELL child.

Sometimes children used the act of drawing as a way to express the speed and direction of the water flow. In one video, the teacher encouraged a child to show where the water went, and he at first drew curvy lines at the bottom of the paper. "That's the water in the water table, yes. Where did the water go when you squeezed the bottle hard?" "Like this!" said the child as he drew a vibrant vertical line straight up the paper.



Video 9 (coming soon!). A teacher encourages a child to show where the water went through drawing.

I encouraged teachers to use children's drawings to help them reflect in science talks. "So you're saying the water went up through the tube this way?" one teacher asked, and she moved her finger along the tube in the child's drawing to indicate the direction. "Does water usually go up, or did you have to do something to make that happen?" she asked the whole group.

It was easy for teachers to get sidetracked by the sophistication of children's representations. One teacher became consumed with teaching the children how to draw arrows correctly to indicate the direction of water flow. "Why is it important for kids to draw the arrows correctly?" I asked, and "Are there any other ways children could indicate direction that might be easier for them?" She decided to make the arrows herself on separate slips of paper for children to add to their representations.

Group science conversations were an ongoing topic in conferences, and many questions arose related to the best groupings, the best timing, and the best ways to facilitate them. Promoting group reflection in science talks meant helping children compare, contrast, and see patterns among their separate experiences. In one video, a teacher asked several children to demonstrate and describe how they had moved water through the tubing from one tub to another, as she also displayed photos to illustrate. She then said, “There’s something the same I’m noticing about how each one of you placed the tubes. Is anyone else noticing what all of you did?” “The tubes are sideways,” said one child. “They’re flat,” said another. “Interesting,” said the teacher, “And what did you notice about how the water moved when the tubes were sideways and flat?”

Some teachers expressed that children weren’t interested in Engage or Reflect conversations. “My kids really like to have their hands in the water, so we have our conversations there” or “My children aren’t comfortable with just talking, they don’t have great language skills.” I encouraged teachers to think about how they could make these conversations more interesting and accessible to children. Were teachers themselves interested, engaged, and comfortable in the conversation? Science talks had an unpredictability to them that was very different from the usual group-time routine, and we talked about the uncertainty that teachers sometimes felt in leading them. Were they drawing children with limited language skills into the conversation and making sure that these children had the time and supports they needed to express what they were doing and noticing at the water table? Videos revealed that teachers sometimes relied on more verbal or talkative children to drive the conversation, and this meant that other children had fewer opportunities to communicate and sometimes lost interest as a result. It was also clear, however, that children’s science explorations provided interesting things to talk about and that inquiry was an ideal context for supporting language.

Conclusion

By the end of the water study, many classrooms still had children actively engaged in water flow explorations with teachers facilitating them at a high level. Children were putting longer tubes together in more complex configurations, trying to move water even greater distances and in multiple directions. In other classrooms, the water study wound done quickly once the project was over. What contributed to these differences? I have tried to paint a portrait of what is possible in classrooms when early childhood teachers receive the professional development supports they need in order to teach science well. I’ve also tried to illustrate some specific challenges that teachers face as they try to plan and implement inquiry-based science experiences—challenges that sometimes reflect overarching issues that are bigger than individual teachers, classrooms, or programs.

From a science professional development perspective, these challenges raise questions that bear further consideration. How can we help teachers let go of some standard early childhood routines and practices in favor of finding the space and time they need to engage children in long-term, inquiry-based investigations? How can we help them view their daily interactions with children as critical opportunities to engage them in inquiry and support high-level thinking skills and conceptual development? Last, how can we give teachers the space and time they need to engage in collaborative inquiry of children’s behavior and learning and to engage in joint reflection on their own practices with colleagues and other support staff?

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