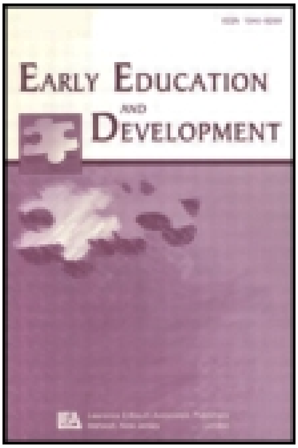

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Science in the Classroom: Finding a Balance Between Autonomous Exploration and Teacher-Led Instruction in Preschool Settings

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Science in the Classroom: Finding a Balance Between Autonomous Exploration and Teacher-Led Instruction in Preschool Settings

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Research Findings: This paper reports on children's use of science materials in preschool classrooms during their free choice time. Baseline observations showed that children and teachers rarely spend time in the designated science area. An intervention was designed to ''market'' the science center by introducing children to 1 science tool, the balance scale. Baseline measures showed that children did not know the scale's name or function. The intervention was expected to increase children's use of the science area and their knowledge about the scale. Children's voluntary presence and exploration in the science area increased after the balance scale intervention compared to in comparison classrooms. Furthermore, children who participated in this intervention demonstrated improved knowledge about the scale's function, whereas students in the comparison group did not. *Practice or Policy:* Adults can increase children's autonomous exploration of science tools and materials, and their knowledge about them, by offering particular kinds of large-group learning experiences.

Recent developmental research suggests that young children think about and understand concepts that relate to the scientific disciplines of physics, biology, psychology, and chemistry. They also possess nascent reasoning skills that they can apply to scientific content (see Duschl, Schweingruber,

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& Shouse, 2006; and Gelman & Williams, 1998, for reviews). This description of the preschool mind contrasts with more traditional views of young children as preoperational and prelogical and thus incapable of engaging in the abstract reasoning involved in science (Flavell, 1963; Piaget, 1953). The newer evidence, however, suggests that preschoolers are able to engage in some forms of logical thinking and that science is an appropriate part of early education. Science inputs can nurture children's natural curiosity and expand their understanding of the world around them (Harlan & Rivkin, 1996).

A number of authors have taken the position that adults can advance children's learning by offering sensitive guidance and carefully chosen science learning experiences (e.g., French, 2004; Gelman, Brenneman, Macdonald, & Román, 2009; Worth & Grollman, 2003). Research suggests that when science is integrated into the curriculum in a comprehensive way, children achieve significant gains in their vocabulary (French, 2004), use of explanatory language (Peterson & French, 2008), understanding of simple experiments (Brenneman et al., 2007), and ability to talk about and understand a range of scientific concepts (Gelman et al., 2009).

An educational commitment to preschoolers as science learners is also represented in the Head Start Child Outcomes Framework (Office of Head Start, 2000) and in statements from the National Association for the Education of Young Children (2009). In addition, most U.S. states have developed preschool science learning expectations (Brenneman, Stevenson-Boyd, & Frede, 2009). A recent review of the content of existing state standards for early science learning and 10 preschool curricula identified eight common process skills (Greenfield et al., 2009). These are observing, describing, comparing, questioning, predicting, experimenting, reflecting, and cooperating. Content areas covered by the standards include life sciences, earth/space sciences, and physical/energy sciences. At the time of the present study, preschoolers in New Jersey were expected to be engaged in learning opportunities that would enable them to develop inquiry skills, observe and investigate objects, begin developing a conception of change in both living and nonliving entities, and develop an awareness of environmental issues (New Jersey Department of Education, 2006).

Assessment tools for preschool learners and classroom environments also reflect current attitudes about the importance of science in preschool. A comprehensive direct assessment of children's science content knowledge and inquiry skills is under development by researchers at the University of Miami (Greenfield, Dominguez, Fuccillo, Maier, & Greenberg, 2008). Performance-based assessments such as the Work Sampling System (Meisels, Jablon, Dichtelmiller, Marsden, & Dorfman, 2001), the Preschool Child Observation Record (HighScope Educational Research Foundation, 2003), and the Early

Learning Scale–Preschool (Riley-Ayers, Stevenson-Boyd, & Frede, 2008) also assess student progress in science learning.

Instruments that assess the general quality of classroom environments and teaching include items devoted to science as well. The Early Childhood Environment Rating Scale–Revised (Harms, Clifford, & Cryer, 1998) includes an item that measures the extent to which classrooms contain a variety of science-relevant items such as collections of objects for sorting, living things, and magnifying glasses. These are expected to be available to children for a substantial portion of the day. A recently published extension, the Early Childhood Environment Rating Scale Extension (Sylva, Siraj-Blatchford, & Taggart, 2006), assesses the materials in the classroom and evaluates staff–student interactions and activities that involve scientific content and inquiry. A number of research teams are developing new tools that assess the quality of classroom science materials and staff–child interactions in a detailed and comprehensive way (e.g., Chalufour, Worth, & Clark-Chiarelli, 2006; Stevenson-Boyd, Brenneman, Frede, & Weber, 2009). A high-quality environment includes tools and materials because these can serve as a basis for planned instructional activities around science. They also support spontaneous science learning as children discover interesting phenomena that encourage further exploration (e.g., Ross, 2000; Worth & Grollman, 2003). The presence of these tools can benefit children and aid in the development of scientific and cognitive skills because tools both suggest and support scientific investigation. The question we study here concerns the extent to which available science materials (in this case, the whole science area and the balance scale located there) are used by children as they play and explore during their free choice time.

Despite current attitudes about the importance of supporting children's curiosity and scientific thinking in preschool, research focused on instructional practices in early childhood education suggests that neither planned nor unplanned science activities are likely to occur in preschool classrooms (Brenneman et al., 2009; Greenfield et al., 2009). Tu (2006) observed teachers' activities and location during children's free choice time. She reported that teachers spent most of their time in the art area and the least amount of time in the science area. Regardless of where teachers were in the room, 86.8% of the activities they engaged in were not science related. Children, too, tend to spend their choice time in the art area or with puzzles and other table toys (Kontos, 1999). Data collected in our lab provide converging evidence. Our informal observations of classrooms suggested that little, if any, time was spent at science tables. This motivated us to conduct focused observations of the various activity centers. We observed these for at least 2.5 hr each in three classrooms during children's free choice time. The adults in these rooms spent most of their time in the art and manipulatives areas.

The dramatic play, art, and manipulatives areas were the most popular among children. Children and adults rarely went to the science and sensory table areas. Similarly, Hanley, Tiger, Ingvarsson, and Cammilleri (2009) found that the science area was less popular among children than all classroom areas except the library, and Hirschler (1994) reported that only 2% of interactions between native language and nonnative, second language speakers in a preschool classroom occurred at the science table.

Taken together, these studies demonstrate that science materials and discovery areas are often neglected by teachers and students and that science learning activities are rarely observed. Several factors could account for this situation. Interviews with teachers have revealed that they believe it is difficult to find time to do science because there are so many other curricular areas that must be addressed (Greenfield et al., 2009). These same teachers report feeling uncomfortable about their own knowledge of science, and that, as a consequence, they shy away from the topic in the classroom. This lack of comfort is not surprising given that science is underemphasized in preservice and in-service teacher education (Brenneman et al., 2009). Beliefs about the importance of autonomous functioning in child development also might contribute to a tendency to avoid recruiting children to come to the science table (or any other area), instead allowing them to choose the areas they want to visit. If teachers, for whatever reason, do not spend time in the science area, children's lack of attention could be attributed in part to their tendency to congregate where the teacher is (Johnson, Christie, & Yawkey, 1987).

Taken together, research results suggest that even if rich science materials exist in a classroom—and this is often *not* the case—teachers and students tend not to use them. The lack of interaction with the tools and objects of scientific inquiry means that children probably are not benefiting cognitively from their availability, either through their own activities or in the context of adult-guided learning experiences. The present study was designed to assess this hypothesis.

Our exploration of the role of science in preschool classrooms began with measuring the extent to which children used the science center and its materials during free play. We also developed a simple intervention to determine whether a relatively small change in classroom group activities would yield increased attention to the science area. The intervention was designed to "market" the science area to the children and to increase their knowledge about a specific science tool, the balance scale. We chose the scale because, although it requires some instruction for proper use and interpretation, young children are capable of coming to understand and reason about it (Kliman, 1987; Siegler, 1978; Taylor-Cox, 2003). We assessed whether the intervention (a) increased children's use of the science area generally,

(b) increased interaction with the balance scale specifically, and (c) yielded initial learning about the balance scale.

METHOD

Participants

The study was conducted in six urban preschool classrooms in central New Jersey (three experimental classes, three control classes). The schools involved are contracted with the state to provide early education for children who attend free of charge. Students ranged from 3 to 5 years of age and came from minority, low socioeconomic status families. Approximately 90% are Spanish speakers who were learning English as well.

All students participated in the circle time activities and were observed during their free choice time. There were 42 students (22 female) in the experimental classrooms and 42 (24 female) in the control classrooms. Only children 4 years old or older participated in the individual interview portions of our study because of the cognitive and linguistic demands of the interview procedure. Children who were not present for at least one of the intervention lessons were not posttested. We ended up with complete sets of pre- and posttest interview data from 15 children (12 girls; mean age = 57 months, range = 48–66 months) in the experimental condition and 19 children (14 girls; mean age = 55 months, range = 49–64 months) in the control condition.[1] Both groups included more girls than boys. This situation reflected the gender breakdown of the 4- and 5-year-olds for whom we had parental permission and complete datasets, not a selection bias. The overrepresentation of girls occurred in both groups; thus, true gender-related differences, say in interest in science or knowledge about the tools of science, would be expected to influence both in similar ways.

Design

The study was conducted in three phases, each of which is described in detail in "Procedure." To preview, Phase I involved the collection of baseline observations of children's presence in the science area during their free choice time and individual interviews to establish a preintervention measure of knowledge about the balance scale and its function. Phase II of the study

[1]Interview data were analyzed from two control and two experimental classrooms because of the relatively small numbers of eligible 4- and 5-year-olds in the remaining two classrooms and because of time constraints on data collection.

was the intervention phase, in which children in experimental classrooms participated in two large-group lessons about the balance scale. The same adult conducted an interactive discussion about a different science topic in the control classrooms. Phase III included postintervention observations of the science area (as in Phase I) and postintervention interviews.

Materials

The materials used during the intervention lessons included a bucket balance scale (already present in all classrooms), standard weights for the scale, countable items commonly found in classroom science areas (e.g., acorns, shells, rocks), and other small countable items (e.g., blocks, plastic toy animals, crayons). In the control classrooms, the lessons utilized color photographs of unusual objects (marmoset, persimmon, statue, robot dog) that were the focus of circle time discussion.

Procedure

Phase I—Baseline

The Phase I classroom observations occurred over several days for a total of 120 min in each classroom. This length of time for observations matched that used by Tu (2006) in her observational study and captured children's typical activities across multiple days. The presence of any children or teachers in the science area, as well as their activities, was recorded using a time sampling method. Every 60 s the observer recorded the number of children and adults present at the time and their current activity. The data were used to determine how much play actually took place in the science area and whether children interacted with the materials found there. Special attention was paid to the balance scale and whether children played with it prior to the intervention.

Individual interview. After the preintervention baseline observation, children who were older than the age cut-off and whose parents signed consent forms were invited to the science area individually. Each was asked questions that probed knowledge about the balance scale. Children were interviewed in their preferred language and could choose to answer in Spanish or English.

During the individual interviews, children were asked three questions about the balance scale to establish a baseline measure of understanding. The three questions asked were (a) "What is this called?" (pointing to the balance scale), (b) "Which side is heavier?" (after putting objects in the buckets, making one side go down), and (c) ‘‘Can you make the two sides even/equal? Show me.’’

The participant’s answer to each question was coded as either incorrect (a score of 0) or correct (a score of 1). For the first question, ‘‘balance,’’ ‘‘balance scale,’’ and ‘‘scale’’ were coded as correct answers. For the second question, the response was coded as correct if the child pointed to or named the appropriate bucket as the heavier one. The response to the third question was coded as correct if the child could successfully balance the two buckets using the materials provided.

Phase II—Intervention

Classrooms were randomly assigned as experimental or comparison classrooms. Each class participated in two circle time lessons that involved all students. The experimental classrooms participated in two discussions about the balance scale, the ways in which it can be used, and the information that it provides about the relative weight of objects. Teachers were present in the classroom during the intervention. They were not told about the goals of the intervention or that children were being assessed for their knowledge about the balance scale.

During the first day of the balance scale intervention, children were introduced to the scale and its function. The group participated in an interactive activity in which they ‘‘used their muscles’’ to find out which of two objects (brought by the experimenter) was heavier. Children then used the balance scale to assess their judgments. They also used the scale to compare the weights when felt weights were too similar to distinguish. This lesson introduced children to the appropriate use of the balance scale and gave them experience reading the scale and explaining what it means for one side to go down. Lessons were presented primarily in English, with key points and vocabulary repeated in Spanish. A portion of the script follows:

> Today we are going to talk about things that weigh a lot and things that don’t weigh a lot. Things that weigh a lot are called heavy. Things that don’t weigh a lot are called light. Can you think something that is heavy? . . . Something that is light? . . . I brought some stuff with me today. I want us to figure out which things are heavy and weigh more. I thought we could play a ‘‘which thing is heavier’’ game today! [Take out two materials that are obviously heavy and light. Let the children hold the materials.] Which one is heavier? [Show balance scale.] This thing can also tell us which thing is heavier. It’s called a balance scale. You guys have it in your science area, and I wanted to play with it today because it can tell us which thing is heavier, too. [Put the objects in the balance scale.] Which one went down? Was that the heavier thing or the lighter one? The heavier one goes down! I wonder if that happens every time. [Repeat with

> obvious objects.] So the one that we decided is heavier goes down every time! Now we see that the balance scale can tell us which thing weighs more or is heavier. Whichever one goes down is the heavier one! [Find objects that are not as obviously different in weight. Let kids hold them. They should have some trouble deciding which is heavier. They might disagree about which one is heavier.] How can we tell for sure? [Wait for children to suggest putting it in the scale.] Remember how we decided that the heavier one always goes down? So even if we can't tell with our muscles which is heavier, the balance scale can help us out. Since the one that weighs more always goes down, we know that _____ is heavier! [Repeat with another less obvious object pair.]

The remainder of the lesson continued in a similar manner. After the lesson, the balance scale was returned to its original place in the science area, and the area was observed for the full length of that day's free choice time (between 60 and 80 min). As in the preintervention observation, the number of children or adults present and their current activity were recorded every 60 s.

A similar circle time activity was completed on the second day of the intervention. The activity reinforced the concepts learned the day before and extended them. Children were again engaged in an interactive activity in which they were asked to place an object on one side of the scale. They were then asked to predict how many items (brought by the experimenter or found in the classroom) it would take to make the other side go down or to make the sides equal (balance the scale). This activity emphasized the idea of making the sides even with equal weights. The balance scale and materials taken from the science area were replaced after the lesson, and the area was observed for 60–80 min.

In the comparison classrooms, two circle time activities provided the children with the same amount of interaction with the investigator as the children in the experimental classes had. Students were shown photographs of unusual animate and inanimate objects (some photos were from Massey & Gelman, 1988). They were asked to describe the depicted items and then predict what was on the inside of each item. We had previously used this technique with large groups to assess children's understanding of differences between animate and inanimate objects. We expected that it would engage children's attention and lead to a great deal of discussion about the topic—as it did. We also chose the activity because it is science related but does not advertise the science area or any materials found there. A portion of the general script of the lesson follows:

> I'm going to show you some pictures that I have and see what you think about them. [Show photograph of marmoset.] What can you tell me about this? What do you notice about it? [Wait for responses.] What else can you tell

> me about it? [Use additional, more specific prompts as necessary, for example, "What color is it?"] What do you think it would look like on the inside? [Wait for responses.] Do you think we'll find anything else on the inside, if we could open it up? Thank you. You did a good job. Now I have one more thing to show you. [Introduce photograph of person-like statue.]

The discussion continued in this way. After circle time concluded on both days, the science area was observed for the duration of the children's free choice time, and all activity was recorded.

Phase III—Postintervention

In addition to the science area observations that occurred after the intervention lessons, Phase III involved individual interviews. Children who had participated in the initial interviews and had been present for at least one lesson were interviewed again 20–25 days after the first group lesson. Interviews were conducted to find out whether children in the balance scale intervention classrooms showed increased and durable knowledge about the balance scale compared to children in the control condition.

RESULTS

Science Area Observation

During preintervention observations the science area was empty 77.6% of the sampled time across all six classrooms. This result was as expected, given the findings reviewed earlier. This figure is even somewhat inflated because of data from one control classroom. The teacher in this classroom used the science area to engage children in nonscience activities, including a shape and sorting task and a matching game. Children spent a total of only 4 min in the area when the teacher was not there herself.

The number of minutes in which one or more children were present in the science area increased from 47 to 333 in the experimental classrooms and decreased from 114 to 38 min in the control classrooms. Figure 1 illustrates the effect of the intervention by showing, minute by minute, the number of children present in the science area for each classroom before and after the intervention. Children's presence in the science area increased so dramatically in the balance scale intervention classrooms that there were times when the area was filled beyond capacity. (Each classroom area had a limit on the number of children who were allowed to play there at one time.) This *never* happened during baseline observations in any of the six classes, nor did it occur in the control classrooms during the posttest observations.

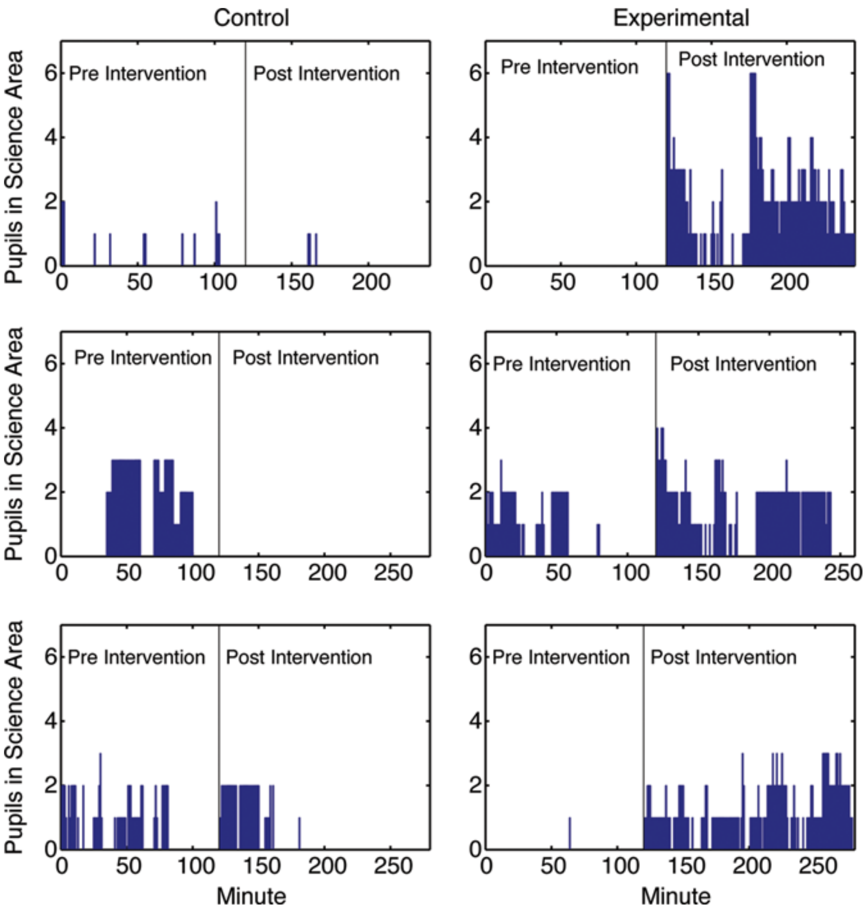

FIGURE 1 Number of students in the science area before and after the intervention in three control and three experimental classrooms. (Color figure available online)

In the experimental classrooms, the number of children at the science area exceeded capacity for about 20% of the total minutes observed. This is especially noteworthy given that classroom rules limited the number of children who could be in the science area to one or two. Still, at times, the number in the experimental group exceeded the limit by three or four. One teacher temporarily increased the limit and added another balance scale. She also dedicated another table to the science area to support the children's increased interest.

A further analysis of the intervention's effect on children's presence in the science area was conducted by calculating the number of students present there during each minute that the area was occupied. We refer to this measure as *child-minutes.* For example, if the area was observed for 3 min and there were two children in the science center during the first minute, one during the second, and two during the third, the total number of child-minutes for that time interval would be 5. This measure was calculated for the experimental and control groups both before and after intervention. The overall number of child-minutes increased from 76 to 638 in the experimental condition and decreased from 224 to 67 in the control condition. This result is also illustrated by Figure 1.

The objects that children chose to play with during their time in the science area were noted during observation. Because our intervention concerned the balance scale, our first review of the data focused on child-minutes devoted to the scale. Before the intervention no child interacted with the balance scale during 720 min of observation. The group time lessons altered this situation. Interactions with the balance scale increased from 0 to 386 child-minutes in the experimental classrooms while remaining at 0 in the control classrooms. In addition, the intervention also influenced the time children spent with other materials at the science table. When the number of child-minutes spent with the balance scale was subtracted from the total number of child-minutes at the science table, the total number of child-minutes spent in the area remained higher for intervention classrooms (252 child-minutes) than for comparison classrooms (67 child-minutes).

Individual Interviews

In Phase I of the study, children were asked three questions about the balance scale to establish a baseline measure of knowledge. In the third phase, children were interviewed 20–25 days after the intervention. The same questions were asked, with one change. To measure understanding in a more stringent way, we asked both the second and third questions twice during the posttest. That is, children were asked to pick the heavier side (second question) and make the scale even (third question) two times with different sets of items. Children had to answer correctly both times to receive credit. Each response was coded as either incorrect (a score of 0) or correct (a score of 1) depending on whether the participant gave the proper response to the question or successfully completed the task. Table 1 displays the proportion of the experimental and control subjects who received credit for each question at pre- and posttest.

TABLE 1
Proportion of Experimental and Control Subjects Who Correctly Answered Each Balance Scale Question Pre- and Postintervention

	What Is This Called?		*Which Side Is Heavier?*		*Make the Two Sides Even/Equal*	
Group	*Pre*	*Post*	*Pre*	*Post*	*Pre*	*Post*
Experimental	0	.20	.27	.73	.13	.60
Control	0	0	.47	.37	.05	.11

Total balance scale scores (out of 3 possible points) were calculated for pre- and posttest. The total balance scale scores of the intervention group improved by an average of 1.13 points ($SE = 0.24$), whereas scores in the control group decreased slightly (mean change $= -0.05$, $SE = 0.19$). A repeated measures analysis of variance was conducted to assess the effects of the intervention on balance scale scores, with time (preintervention vs. postintervention) as a within-subjects factor and type (experimental vs. comparison) as a between-subjects factor. A significant main effect was found for time, $F(1, 32) = 12.693$, $p < .001$; and type, $F(1, 32) = 6.327$, $p < .05$.

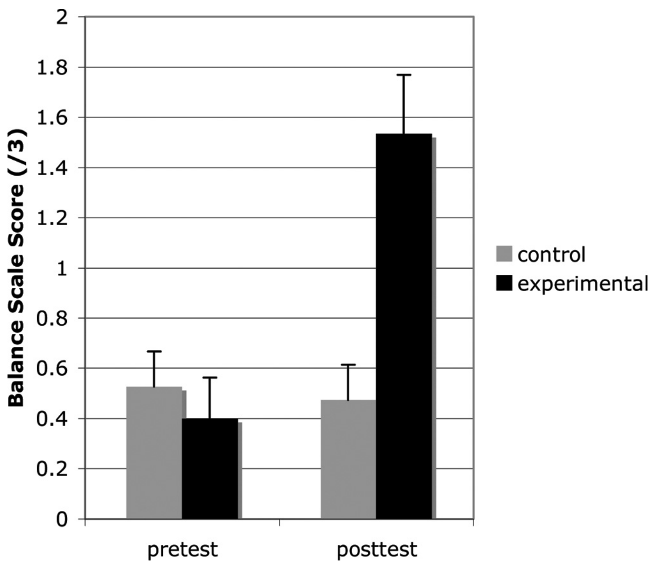

FIGURE 2 Mean balance scale scores pre- and postintervention in control and experimental classrooms.

The interaction of time and type was also significant, $F(1, 32) = 15.286$, $p = .001$. Figure 2 illustrates this result.[2]

If we consider individuals' change scores, rather than group means, the picture is much the same. In the intervention group, the scores of 12 participants (9 girls) increased from pretest to posttest and the scores of 3 girls decreased or remained the same. In the control condition, the scores of 4 participants (3 girls) increased, whereas the scores of the remaining 15 participants (9 girls) did not improve. The distribution of frequencies differed between the experimental and control conditions, $\chi^2(1, N = 34) = 12.08$, $p < .001$.

DISCUSSION

This study explored three main issues: (a) the extent to which children spontaneously interact with materials in the science area, (b) whether a simple intervention involving a science tool can increase children's interest in this area, and (c) whether such an intervention can build knowledge about this tool.

Observation of the Science Area

Despite children's curiosity and ability to grasp some science concepts, our baseline results confirm that they seldom spontaneously engage in activities in the science area. Because many materials in other parts of the classroom (toys, dresses, blocks, markers, etc.) are largely self-explanatory, familiar, and/or used often by teachers, their functions do not need to be demonstrated. In contrast, the purposes of measurement tools, such as the balance scale, and other science tools might not be obvious to young children. These tools likely require some introduction from adults before they can be used in the intended manner.

Our results show that children are unlikely to benefit fully from the presence of science tools through autonomous exploration alone because they do not go to the science area to use these materials *on their own.* A simple adult-guided intervention successfully enticed preschoolers to spend more

[2]We thank a reviewer who suggested analyses to account for the correlation of error among children within the same classroom. The small number of classrooms did not allow us to control clustering effects using multilevel modeling. Instead, to test the assumption of independence of subjects, we compared mean balance scale scores by classroom using a series of one-way analyses of variance. Means did not differ significantly at baseline among the four classrooms in which interview data were collected, $F(3, 30) = 0.129$, $p = .942$. Means also did not differ at posttest for the two control classrooms, $F(1, 17) = 3.25$, $p = .089$; or for the two test classrooms, $F(1, 13) = 0.494$, $p = .494$.

of their free time in the science area (see also Hanley et al., 2009). During Phase III observations, attention to the science area in the experimental classrooms changed dramatically in terms of the children's presence and science-relevant play. Children interacted more with the balance scale and with other science materials as well. The interactive circle time lessons put the balance scale in context for them, introducing children to its purpose and the different ways in which it can be used. Children used this knowledge as a basis for further exploration during free play. During postintervention observations, the investigator observed children using the scale as a bin or "cooking pot" for their toys, but children also played and competed with one another to find out whose toy car or dinosaur weighed more while appropriately using the scientific tool and, perhaps, strengthening their understanding of it. With this foundation in place, their teachers could continue to scaffold children's knowledge by conducting further teacher-led investigations with the scale and by interacting with it alongside children during free play. Of course, interest in the scale could well decrease in the days after the intervention (Hanley et al., 2009). Still, our results indicate that children were ready to attend to and assimilate the offered information and then transfer it to their explorations in the science area. It is important to note that although the learning opportunities were planned and led by an adult, the lessons actively involved children in making observations, answering questions, and reporting on what was happening as they placed items on the scale. This type of guided instruction about the balance scale increased knowledge and participation in the science area in ways that the presence of the materials alone did not.

Durable Learning

Although the main goal of the intervention was to find out whether the science area can be effectively marketed to preschoolers through a large-group interaction about a science tool, we were also interested in whether such an intervention would increase children's knowledge about the balance scale. Not only did children in the experimental group use their new knowledge when playing but they scored higher on the postintervention knowledge interview than their peers in the control condition. The experimental intervention was successful in effectively explaining the purpose of the balance scale and its implications to preschoolers. The knowledge gained (and perhaps strengthened during the resulting increase in interaction with the tool) was retained even 20–25 days after the intervention. We acknowledge that our results are preliminary, as our design did not allow us to tease apart the relative contributions of the lessons themselves and children's subsequent explorations of the balance scale or to account statistically for the nesting of children in classrooms. For now, however, it is clear that without the teacher-guided intervention experiences, the children we observed were unlikely to have begun building knowledge about an important science and math tool. They hardly could have, given that they never interacted with it.

The teacher's role is also critical because he or she introduces relevant vocabulary and opportunities for mathematical reasoning during the balance scale learning experiences. These interactive lessons provided a context for learning and using terms like *lighter*, *heavier*, *equal*, and *measure.* Numerical reasoning was incorporated when children were asked to predict and then count how many items it would take to balance the scale. And, of course, the focus on comparing a measurable attribute of objects is foundational for further learning about precise measurement using other kinds of scales. This work demonstrates that the same lessons can meet multiple learning goals and that incorporating science into a preschool classroom does not require neglecting the development of math, language, and other critical skills (see also Brenneman et al., 2009; Epstein, 2007; French, 2004; Gelman & Brenneman, 2004; Gelman et al., 2009; Worth & Grollman, 2003).

Implications

Preschool education policies emphasize the importance of building mathematical and scientific literacy by providing appropriate learning experiences for young children in these domains. Tools are being developed to assess the quality of classroom materials and teacher–child interactions to support math and science learning (e.g., Chalufour et al., 2006; Stevenson-Boyd et al., 2009; Sylva et al., 2006), as are tools to comprehensively measure children's learning in these domains. See, for example, Clements, Sarama, and Liu's (2008) Research-Based Early Maths Assessment; Ginsburg and colleagues' Birthday Party/Early Mathematics Assessment System (Ginsburg, Pappas, & Lee, 2009); and Starkey, Klein, and Wakeley's (2004) Childhood Math Assessment for math and Greenfield and colleagues' (2008) IRT (Item Response Theory)-based assessment for science. We also know that young children are ready and eager to learn about math and science skills and concepts (Bowman, Donovan, & Burns, 2001; Duschl et al., 2006). For all of these reasons, it is important for teachers to understand children's competence with mathematical and scientific concepts and to find ways to engage and guide them in scientific play that is enjoyable as well as educational. As children learn and play, they build a foundation of knowledge that assists them in solving other tasks and developing further interest in science. Knowledge of children's learning and reasoning skills is critical for providing the scaffolds necessary to support and foster further mathematical and scientific knowledge building through both spontaneous and planned instructional interactions.

Our results have implications for teachers, for educators involved in curriculum and policy design, and for governmental and private agencies that sponsor preschool programs. Preschools are often required to have certain areas and tools in their classrooms. Although it is necessary for materials to be present and available for children to explore, our baseline observations show that the mere presence of science materials ensures neither independent exploration of them nor resulting learning from them. Incorporating appropriate observation and measurement tools in the classroom is just the first step in building a science-rich learning environment (see also Gelman et al., 2009; Worth & Grollman, 2003). For this reason, measures of classroom quality should involve assessments of staff–child interactions (not just materials) to get a more complete picture of the classroom learning environment and the learning experiences in which children are actually engaged, and efforts to improve quality will require much more than simply purchasing materials and supplies. Because many teachers report a lack of confidence in their ability to engage children in meaningful science activities and discussions (Greenfield et al., 2009), preservice and in-service professional development will be critical for supporting educators to improve their own knowledge of science, their understandings of how children learn scientific concepts, and their own knowledge of how to best support children's further science learning through effective scaffolds and instruction. With these understandings, teachers will be better able to provide effective learning experiences for children both by recognizing and extending children's spontaneous scientific play and by planning the type of teacher-led, interactive instructional lessons utilized here to foster children's knowledge building about the balance scale.

The classrooms we studied are delivering overall high-quality supports for children's learning. Each classroom had a well-resourced science area, rich materials in other classroom areas, and well-trained teachers, so our classrooms were not representative of many early care and education settings in the United States. Although our study focused on the science area, science learning and inquiry can occur anywhere in the classroom, so it would be of interest to know how science-relevant activities play out in settings that do not have a science area and that might or might not have science-relevant materials in other parts of the room. Such a study would provide a broader view of the extent to which science learning experiences occur in different kinds of early care settings and the extent to which various tools and materials are used in scientific ways by children and their teachers. We anticipate that we will continue to find that, in many cases, it is not enough to place science learning materials in an environment. Some clues or hints for use will need to be offered by those who know the function of the items (see also Gelman, Massey, & McManus's 1991 study of a science exhibit in a children's museum).

Current educational and psychological research suggests that preschool-age children are capable of understanding some basic scientific and mathematical concepts and that they are eager to explore and learn more. As reviewed earlier, the importance of science learning opportunities for young learners is reflected in various early learning standards and in classroom quality assessments. For those early care and education settings that already provide rich science materials and tools, our work suggests that, in some cases at least, learning is supported more effectively if autonomous exploration is preceded by teacher-led instruction.

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