

"You Don't Have to Be Sighted to Be a Scientist, Do You?"

Issues and Outcomes in Science Education

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Abstract: This qualitative study explored the issues and outcomes associated with implementing Playtime Is Science for Students with Disabilities, a curriculum and materials that were modified for students who were visually impaired. It found several student-related outcomes, such as persistence, positive peer-related skills, risk taking, and making meaningful connections about the world, and themes regarding implementation of the curriculum, such as teachers' interest level, issues associated with power, and how teachers supported students' learning.

Interviewer (who is sighted): If you were teaching a class about this activity, what would you tell the kids?

Adaline (fourth grader who is blind): I would tell them that this is Oobleck, and this is how you make it with two cups of cornstarch, a cup of water, and two drops of food coloring; mix it up with a popsicle stick, and see what happens. I would like to be a scientist. That would be fun. You don't need to be sighted to be a scientist do you?

Interviewer: No. Absolutely not. Everything you've done today and last time is science, and you've done it, right?

Adaline: And Ellen (an observer who is blind) isn't sighted. If I become a scientist, maybe we [Ellen and I] can work together. You [the interviewer] can be the assistant scientist.

Science is an exciting process that involves observation, discovery, critical thinking, and reflection about the environment. Science education represents the opportunity to forge an interactive relationship between children and the world around them. If the primary focus of science education is to help children make sense of their world, then teachers have an enormous responsibility to design learning opportunities and experiences that foster children's natural inquisitiveness and thirst for knowledge. One of the most important questions that teachers can ask is, How can I support students' inquiry about the world? This question is particularly important for teachers who work with children who are visually impaired (that is, those who are

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blind or have low vision). Children can and should have positive, frequent, and successful experiences in science that will allow them to explore, discover, and ask questions about the world in which they live, so they can develop a deep respect not only for the environment in which they live, but for all living things. In schools in which there is a preponderance of children with disabilities, a critical examination of the science curriculum and its accessibility for all students has yet to be conducted, however. It is just such an inquiry that was undertaken for this research. Given the opportunity to study a hands-on science curriculum developed by Educational Equity Concepts and implemented with children who are visually impaired, this study posed some important questions to educators and curriculum specialists who are interested in science education for all students.

Although the literature on the pedagogy of science and children with disabilities is growing (Cawley & Cawley, 1994; Mastropieri & Scruggs, 1992, 1995; Parmar & Cawley, 1993), there is a dearth of knowledge specifically about science and children with visual impairments. Most of the information on science curricula and adaptations for students who are visually impaired was written over 20 years ago (Franks & Butterfield, 1977; Linn, 1977; Linn & Thier, 1975; SAVI/SELPH, 1975).

According to Huebner (1986), teaching science to students with visual impairments must be firmly grounded in a multi-sensory approach if students are to receive positive benefits, such as activities related to tactile and auditory interactions, and ample opportunity to manipulate and explore equipment and materials must be

provided. Davidson and Simmons (1984) contended that it is necessary to provide access to new content within the environment, guide exploration and discovery, and encourage interpretation.

This article describes a qualitative study of the impact and implementation of a science curriculum, *Playtime Is Science for Children with Disabilities (PSCD)*. The study examined the PSCD adaptations and modifications for children who are visually impaired to gain a better understanding of the issues, challenges, and outcomes associated with teaching and learning about science and visual impairment. Because the documentation sought to understand how PSCD is taught to children across a range of visual disabilities, the researchers relied upon qualitative methods to document the micropractices of teaching and learning (Bogdan & Biklen, 1998; Denzin & Lincoln, 2000; Fine, Weis, Weseen, & Wong, 2000). The study was designed to include participant observations of two classrooms for seven months, structured interviews with nine students and two teachers, and a focus group of teachers. Two research questions drove the design:

1. What outcomes emerged from PSCD for students with visual impairments, such as science vocabulary, independent inquiry, and knowledge of scientific methods or concepts?
2. What pedagogical decisions and practices do teachers use in implementing this curriculum?

Method

SETTING

Initially the curriculum developers and researchers sought a school with a sufficient

number of students who were visually impaired and were mainstreamed into traditional classrooms. This search yielded no such school in the urban Northeast. Therefore, the study was conducted in a large state-funded residential school in the northern United States that serves children who are visually impaired. Although the students leave the classroom for specialty classes, such as gym and individual counseling, they spend most of their day with each other, a teacher's aide, and one teacher.

PARTICIPANTS

Students. A multiracial sample of five boys and four girls from two classrooms (a fourth-grade and a first-grade classroom) participated (see Table 1 for demographic information on these students). Parental consent was obtained for each student before the observations began.

Teachers. The two teachers of the classrooms studied—Mr. Pearson and Ms.

Caruso (the names are pseudonyms)—were selected based on their interest in participating and received training in the PSCD activities. Mr. Pearson, the fourth-grade teacher, had taught children with mental retardation and severe cognitive impairments for 11 years and had a degree in special education. Ms. Caruso, the first-grade teacher, had been a teacher for five years and had recently earned a master's degree in the education of students with visual impairments; this was her first year teaching at this school.

PSCD

Funded by the National Science Foundation Program for Persons with Disabilities, PSCD is a model project that builds and expands on Playtime Is Science: An Equity-Based Parent/Child Science Program, developed by Educational Equity Concepts, a national nonprofit organization founded in 1982 to foster equal educational opportunities for all children, regardless of

Table 1
Demographic data on the student-participants.

Participants' names	Gender	Age	Ethnicity	Status of vision and hearing
Teddy	M	12	African American	20/200 in both eyes, hearing impaired
Candice	F	12	African American	Totally blind, no hearing impairment
Adaline	F	12	Caucasian	Totally blind, no hearing impairment
Dale	M	12	African American	20/200 in the left eye, 20/20 in the right eye; no hearing impairment
Josh	M	11	Latino	20/200 in both eyes, no hearing impairment
Roy	M	6	African American	20/200 in the left eye, blind in the right eye; no hearing impairment
Pilar	F	8	Latina	Totally blind, no hearing impairment
Julie	F	7	Caucasian	20/200 in both eyes, no hearing impairment
Carlos	M	8	Latino	20/200 in both eyes, no hearing impairment

gender, race, ethnicity, disability, or family income, and equal access to the study of science.

PSCD incorporates science and scientific thinking into the daily routines of children who have a variety of disabilities to reinforce the connection between children's play and science learning. The PSCD curriculum focuses specifically on the priorities and capabilities of children with disabilities. Its goals are to

- increase the ability of teachers, staff, and parents to motivate and empower children with disabilities in kindergarten through the fourth grade to develop their science skills in a supportive environment;
- help children with disabilities build on their strengths and develop confidence and skills in science that will persist beyond school and will inform later career options; and
- provide opportunities for parents of children with disabilities to become involved in their children's early science learning and to convey positive messages and expectations to their children about science.

Hands-on staff development was conducted for all the elementary-level teachers, paraprofessionals, and parents. The physical science activities were implemented in various inclusive and special education classrooms. Modifications were developed to meet the needs of students who are blind or have low vision, deaf or hard of hearing, physically disabled, learning disabled, speech and language impaired, or emotionally disabled. Classroom observations and feedback from teachers were used to design the modifications for the activities.

The administrator selected the teachers who participated in the study. The teachers chose five activities, including these:

1. *Building with Wonderful Junk*: problem solving, mathematics, physical science, gross motor and cooperative learning skills (fourth grade).
2. *Sink and Float*: first-hand experience in understanding why some objects stay on top of water and others sink to the bottom (fourth grade).
3. *Bubble Science*: students creating their own bubble makers and exploring cohesion (first grade).

The two teachers taught the same lessons, as determined by an age-appropriate match of tasks and students.

DATA COLLECTION

To determine how the curriculum was implemented and what outcomes were achieved, the researchers (who were trained in the PSCD activities and curriculum-specific interview techniques) used three methods: systematic participant observations in each classroom (three times: at the beginning, middle, and end of the semester), individual interviews with nine students and the two teachers, and a focus group of teachers.

Participant observations. Each researcher directly observed the students in one class (in the classroom or related settings, such as the gym and lunchroom) in early March, late April, and early June for approximately 3 1/2 hours each session. The PSCD project coordinator, who was actively involved in the development of the PSCD curriculum and staff training, was also present during each session. A common coding scheme was deployed throughout to collect and analyze teacher-student interac-

tions, interactions among peers, and the students' engagement in the activity. The data were recorded in the form of detailed field notes, and the two primary observational data collectors met weekly (during the period of intensive observation) to ensure interrater agreement on the coding categories.

Interviews with the students and teachers. Each on-site researcher conducted two to three individual interviews of about 10 minutes each with each of the nine students who participated in the study. The design called for three interviews with each student, but for some students, time or absences did not permit three interviews. All the interviews were audiotaped.

During the interviews, the students were asked the following questions:

1. What did you learn today?
2. What observations did you make?
3. Do you know what a solid and liquid, balance, gravity, sink, float [whatever was relevant to activity] are?
4. What questions would you like to ask the other students about the science lesson?
5. If you were teaching this class, what would you tell the kids?
6. What would you like to tell the people who are running the science program about what works and what doesn't work?

The students' responses were analyzed for content and evidence of science vocabulary and presentation of scientific concepts.

During the first and third participant observations, the two teachers and a paraprofessional were also interviewed about the curriculum and the students' experiences. The interviews, which lasted approx-

imately 30 minutes each, followed a predetermined set of questions to ensure consistency across the interviews.

Focus group. The focus group, conducted at the school in June, involved the two classroom teachers; a school administrator; the PSCD project coordinator; and the research team, which included the authors of this article, as well as two of the developers of the PSCD curriculum. The focus group was conceptualized as an informal two-hour meeting to share ideas and information about the curriculum and its implementation; to check for accurate or reliable impressions and observations; and to discuss challenges, questions, or issues that emerged from this project. The preliminary findings were presented, and the staff was invited to give feedback.

DATA ANALYSIS

A content analysis was conducted for a set of a priori theoretical variables and variables that emerged empirically via grounded theory. Data generated from the participant observations and individual and focus group interviews were reviewed regularly by the two researchers during and following the data collection to extract themes, patterns, and questions that were emerging from the data. In-person and phone meetings were also arranged between the two primary researchers and the first and last authors to examine patterns and themes.

Triangulation of the data sources (the participant observations, individual interviews, and focus group discussion) occurred to ensure the accuracy and consistency of the themes. The following categories served as a framework for initially organizing the data: (1) the students' inter-

actions with the teachers, (2) the students' interactions with their peers, and (3) the students' interactions around the activity. The themes regarding students' outcomes that emerged a priori from the curriculum goals and, in a more grounded form, from the observational and interview data (Glaser & Straus, 1967) included (1) enthusiasm; (2) persistence; (3) the desire to perform as a scientist, use scientific language and concepts, and share observations; (4) risk taking; (5) making meaningful connections; and (6) positive peer-related interactions. The results presented focus next on the themes that were specifically related to the process and outcomes associated with implementing the PSCD curriculum.

Results

OUTCOMES

Enthusiasm

One of the more striking pieces of evidence of the students' engagement with the PSCD activities was the students' enthusiasm, evident in anticipation, during, and after activities. Here are some examples from the field notes:

Adaline was immediately excited upon hearing the observers enter the room, saying, "Yay! This is gonna be fun."

During one activity, the discussion involved writing up what they had done and then sharing it with the class. The students were very excited to do this task, often continuing to write after the teacher had asked them to stop.

Even in subsequent observations, the students vividly remembered the activities in

which they had participated and would refer to them in other contexts. Enthusiasm is an important learning outcome, since children associate science with something that is fun, interesting, and worth doing and, what is most important, something they are or can be fully capable of doing. It also helps children retain what they have learned. As one teacher explained: "I think they get very excited right from the beginning, extremely excited . . . sometimes . . . I worry about them getting overstimulated such that it diminishes comprehension, but usually the opposite happens: They retain what they discover."

Persistence

One behavior that is essential to the scientific process and that the students exhibited often is persistence—continuing to try experiments in spite of unexpected outcomes or wrong turns. Persistence is also evidence of meaningful engagement and active participation.

Ms. Caruso noted that the students tended to be focused for a longer period of time on science than on other activities and that they tended to stay with it. As the field notes indicated:

During the Looking at How Liquids Move activity, Julie initially had trouble measuring the depth of the water. However, Julie did not seem to become frustrated after she positioned the ruler several different ways but did not arrive at the answer. Instead she persisted and tried it again and again until Ms. Caruso acknowledged that she reached the answer.

Learning vocabulary and sharing observations

That the students seemed to have a strong desire to be “scientists” was evident in their desire to show or share with others (their parents, peers, teachers, or visitors) the inquiry skills they had developed. They seemed to have a strong sense of pride in their work and their discoveries. The following is an example from the field notes:

The students often invited the involvement of others and shared their scientific findings and skills with one another. For instance, during the Looking at How Liquids Move activity, Julie, who had just learned how to measure the depth of water in a pan with a ruler, shared her newly acquired skill with her classmate Carlos when she observed that he, too, was struggling with how to position the ruler properly. Specifically, she offered him tips on how to approach measuring the water by demonstrating for him how she had done it: “Like this, Carlos, make it [the ruler] go straight up.”

Taking pride in one’s work as a budding scientist and wanting to share that work with others is a reflection of a child’s self-esteem and interpersonal interactions skills, as well as developing competencies and confidence in the realm of science. When students have the confidence to share their newly acquired knowledge with others, it is also a reflection of how they have mastered new material.

Risk taking

Children who are visually impaired are sometimes discouraged or protected from

taking risks at home or in school. Risk taking involves taking a chance, particularly when there is the threat of not achieving one’s desired goal or there is a real or perceived danger. Every PSCD experiment conducted in this study involved a certain amount of risk. There were also opportunities for students to make predictions about things that were unfamiliar, as in this example from the field notes:

One of the more striking examples was with Carlos, who is tactilely defensive—reluctant to touch things or put his hands in any strange substance. He surprised his teacher by dipping his hands in whatever substance was being used during the various PSCD activities (like the Oobleck, the Bubble solution, and the Liquid mixture) and thoroughly enjoyed it. During the Oobleck activity, Carlos even encouraged his partner, who was at first reluctant to touch the Oobleck, by saying, “Hey Pilar, touch this, come on, it’s not sticky so don’t worry.”

Wanting to take risks and to participate actively in new experiences is an important skill for children to master. Taking risks is not only necessary for the scientific process, but it is a necessary skill that is used throughout a person’s entire life.

Making meaningful connections to the world beyond school

The students made important connections to the world in which they live in many ways. They not only mastered the new vocabulary associated with the activities, but they often generalized new vocabulary and concepts across time and contexts

(for example, applying previously learned words to other class lessons or other PSCD activities). Ms. Caruso commented that one way she can determine whether students have grasped the materials is when they use the newly learned words or concepts in other contexts:

The ingredients for the Looking at Liquids Move activity are similar to the ingredients for the Oobleck activity. During the Looking at Liquids Move activity, after putting the cornstarch in the water, Roy felt the bottom of the pan and exclaimed, "I feel Oobleck down there!"

The vocabulary words were not only introduced at the beginning of the activity and discussed after the activity, but were incorporated into the hands-on part of the activity, as in the following example:

Teacher's aide: Is this a liquid or a solid?

Students: Both.

Teacher's aide: How do you know?

Dale: Because it gets dry when it spills.

Observer: Why do you think it got dry?

Dale: The paper is dry and the Oobleck is wet so it absorbed it.

Observer: Good science word . . . *absorb*. Why did it dry up on your hands? Your hands don't absorb the water, do they?

Dale: The air dried it.

Observer: What is that called?

Dale: Evaporation.

Teacher's aide: You all just learned two new science words—*absorb* and *evaporation*.

Associating science with other important aspects of life was another way in which the students learned to make meaningful connections. Ms. Caruso described how the students were able to make connections with how things work. The students were also learning how to speculate, theorize, and imagine through science, as in this example from the notes of an interview with Ms. Caruso:

Ms. Caruso explained that the students are starting to see that there is a scientific process, an order to things to make it successful . . . improving measuring, listening, reasoning skills, learning to figure out why [They are] putting out hypotheses [to] deduce why certain things happen the way they [do].

In an interview, Mr. Pearson discussed the connections he was making between writing and science. He explained that writing is also important. It is another part of the scientific process. You cannot just do the activity. You also have to describe it and write about it. The connection between science and the world in which children live is rich. Making those connections for and with children provides an invaluable and long-term benefit.

After the Sink and Float activity, Mr. Pearson asked the children what they had learned. When the students were immersed in the Building with Wonderful Junk exercise, Mr. Pearson asked if the students thought they could do this activity at home.

Ada responded, "I don't think my mom will let me do this because she doesn't like to waste stuff. . . . I mean, we recycle and so that's what we have to do with the junk. . . . We're poor and we get money for recycling." Connections to home are always complex and revealing.

Positive peer-related interaction

The students worked together cooperatively during the PSCD activities. Although the teachers sometimes paired or grouped students to work together, turn taking and other prosocial interactions often occurred without the teachers' facilitation. Here is an example from the field notes:

During the Sink and Float activity, one student in a group would feel the object to see whether it had sunk or had floated. Then the other student would feel the object and record the observations on a chart. However, turn taking also occurred between two groups. For example, while Josh, who was in group one, was recording the previous observation on his group's chart, Candice, who was in group two, said, "Come here, Josh, and see the bottle. I'm surprised that it floated. Aren't you?"

In addition, the students often assumed responsibility for organizing or leading the group's activities in a collaborative manner, as these two examples illustrate:

At one point during the Bubble Science activity, the students, in agreeing to do something together, synchronized their actions through song. I think it was Pilar who began saying, "Let's do it all together: a-one, a-two—a-one, two, three, four."

During the Building with Wonderful Junk activity, the teacher initially delegated responsibilities to the students. For example, it was Teddy's responsibility to supply everyone with strips of tape; Adaline's, to choose the objects to add to the structure; and Candice's, to pick the place to put the object on the structure. By the end of the activity, the students had rearranged the responsibilities so that everyone contributed to each aspect of the activity.

There were also numerous times when the students worked cooperatively to resolve a problem or issue. The activities in the PSCD naturally facilitated social interactions among peers in a way that gave them the confidence and competence to interact positively with one another.

ISSUES ASSOCIATED WITH TEACHING SCIENCE

Although there were activities and suggestions to assist the teachers in preparing what to teach, other factors, such as the teacher's style, history, and pedagogical practice, played a critical role in how activities were presented and the students participated. The teachers' personal perspectives drove the decisions they made about how to teach the science curriculum, which ultimately had a significant impact on how the science activities were implemented.

TEACHERS' LEVEL OF INTEREST

Teachers' interest and motivation in an activity greatly affected on their actions. Largely because of the clarity and specificity of the PSCD materials, the two teachers and the administrator who were involved in this project were extremely enthusiastic about the PSCD curriculum.

Participant Observation

Participant observation is part of the ethnographic toolkit: It is a qualitative research method in which the researcher participates in and observes people in specific sociocultural situations and, thus, gains important insights into aspects of everyday life, including valuable non-verbal cues and other actual behavior not captured by self-reported data. Consequently, participant observation can be a helpful tool for measuring outcomes of a program.

The authors of “‘You Don’t Have to Be Sighted to be a Scientist, Do You?’ Issues and Outcomes in Science Education,” exemplify the benefits of participant observation with regard to outcome measurement. This study had two goals: to determine (1) teachers’ pedagogical decisions and practices in instituting a new science curriculum, *Playtime Is Science for Children with Disabilities (PSCD)*, and (2) what outcomes emerged for students as a result. These goals highlight that there is potentially a gulf between what the teachers do in the classroom and the outcome, i.e., what the children have learned at the end of the program. The latter is important in determining the success of the new science curriculum.

Although both participant observation and the structured interviews conducted with students were aimed at assessing the outcomes of what students had learned as a result of this new curriculum, each approach gathers a different type of data. For example, being able to recite definitions of particular vocabulary words is a different skill from being able to use them in new and appropriate contexts, as Dale did when describing the differences between evaporation and absorption. Moreover, by being active participants as well as observers in the classroom, the

researchers were able to contribute to student learning and to its assessment, as in the case just mentioned, by probing further into how Dale understood the difference in these concepts.

In addition, participant observation allows for the recording and inclusion of other observations, such as the location in physical space of students and teachers, the significance of body positions and gestures, tone of voice, the amount of touch or eye contact used, and the amount of peer instruction. The authors demonstrate this possibility with some beautiful illustrations from their field notes. For example, they were able to record instances of sharing and peer-related interaction, which might have gone unrecorded without direct observation, such as when Candice says to Josh, “Come here and see the bottle. I’m surprised it floated, aren’t you?” or when Julie demonstrated to Carlos how to manipulate the ruler successfully during another exercise.

This research turned up many unexpected outcomes besides learning science for kids engaging in the PSCD activities, such as fostering self-esteem and enhancing social skills through teamwork, sharing opinions, and turn taking. It also pointed out a number of specific skills necessary to teach science successfully to children with visual impairments, strategies that promoted a more equitable and democratic classroom, and that can be replicated. The findings would not have been so rich or detailed, nor would they have incorporated as much unanticipated data, had the researchers not opted to conduct participant observation as part of their study design.

Elaine Gerber, Ph.D., senior research associate, American Foundation for the Blind.

During the focus group, in response to questions about the adequacy of the PSCD curriculum, Ms. Caruso said:

The curriculum is well put-together and well constructed. It's easy to prepare. I [prepared for the activity anywhere from] one half hour to one hour before the activity. . . . I selected activities that were multisensory. In the morning I do individual work, but in the afternoon I use lots of tactile materials. I avoid activities that are not hands on or that are individual.

Mr. Pearson, who was also enthusiastic, was quite explicit about the instructional difficulties he confronted when trying to educate a diverse class in which students had different strengths, academic histories, and ability levels. He discussed the issues involved in accommodating students who were fully blind when working with specific activities.

We as teachers need to prepare more. I wanted to match activities with abilities. I had fun, but it's difficult to match the students' ability levels. Something as easy as using tape requires a lot of instruction for blind kids. The [PSCD instructional] cards were excellent; the materials were there, and the kids actually enjoyed it. I like the integrated and interdisciplinary curriculum.

Both teachers expressed a great deal of enthusiasm in working with the actual curriculum and with their students. The teachers' high level of interest in the subject matter was an important factor in implementing the curriculum. The teachers' perceptions of the implementation process was

also crucial because it raised questions and ideas about the teachers' individual practices.

Issues of disability-related access and power

In many ways, children who are visually impaired have limited access to opportunities for self-direction both within and outside school. Looking at the opportunities and choices the students had to be self-directed, for example, was one indicator of how power was shared among the teachers and students or appropriated by the teachers for (or despite) the students. There were numerous examples of the teachers and students sharing power. The teachers encouraged the students, for instance, to decide for themselves the ways in which they wanted to experiment with the materials, by saying "You can decide what you want to do" or "What would you like to do to finish this activity?" There were various options and choices throughout the activities to enable the students to make meaningful decisions about their own learning. The students were consistently encouraged to "have a say" and to give voice to their own opinions, engaging in what often appeared to be a classroom in which children's voices, strengths, and wishes were taken seriously.

Another pedagogical issue that emerged concerned the students' varied access to participation, depending on the teachers' style and the students' levels of vision. For example, throughout a sensory science activity, one teacher commented to a pair of students, "Can you see this?" "That is what it should look like," and "Look how your friend did it." Although one of the students had a visual impairment that enabled him to use his residual vision, the other student

was totally blind and thus was completely excluded from the conversation because she could not "see" what the material looked like. The latter student could have been included if she had been encouraged to touch the material. Later, during the same activity, another member of the classroom staff made great efforts to include the student who was blind by describing to her what was being done around her and directing her to explore by saying, "Feel the substance . . . does it feel lumpy?" This student was also encouraged to decide for herself what step to take next, which provided meaningful opportunities for her to be an active and included participant in the classroom community.

How teachers support students' learning

Teachers' beliefs in their students' abilities can have a profound impact on students' performance. Sometimes teachers may not be aware of their powerful influence on students. At the end of one activity, one teacher remarked, "Wow, you guys did better than I thought you would do." The students may have interpreted this statement to mean that the teacher had been doubtful that they would succeed and had low expectations of them.

How teachers actually facilitate an activity also influences students' learning. Ms. Caruso was particularly interested in fostering peer interactions and recognizing peer expertise, and her interest was reflected in her teaching manner. She encouraged turn taking by suggesting, for instance, that the students "give Pilar a chance to talk," or encouraged the students to share their work with one another by asking, "Can you show the others what you did?" In another example, when a student

asked, "How will we tape this together?" during an activity that involved students building structures with junk, Mr. Pearson suggested that the group try to figure it out together.

At other times, the teachers were particularly skilled in converting "opportunities" or disruptions into teachable moments, as in the following example:

During the Bubble Science activity, Roy and Carlos had taken two tennis rackets (tools they had previously chosen as bubble makers) and began swinging them to see the bubbles come out of the small holes. They seemed to be almost sparring, at times banging the rackets together. Instead of confiscating the rackets, Ms. Caruso and the teacher's aide intervened and asked them to talk about the differences between the rackets they were holding. The students noted that one was smooth, while the other was hard. Ms. Caruso continued probing until they noted that the difference between the rackets made a difference in terms of bubble-blowing efficiency, and the size of the bubbles had to do with having holes or not. As Ms. Caruso noted, the object of this lesson is to "inspire wonder in children and adults of all ages, the way they seem to float along, the way they reflect rainbows, the way they suddenly disappear. During this activity, children decide how to make their own bubble makers and create their own varieties of bubbles, experiencing the concepts of cohesion and surface tension." In this case, Ms. Caruso and the teacher's aide focused on the lesson on bub-

bles—size and what kind of bubble makers the rackets were—not on discipline.

The teachers in this school played a significant role in helping the students to make important connections between the specific PSCD activities and other situational contexts. For example, Mr. Pearson likened the preparation of Oobleck to baking activities at home, such as making cookies or cakes. Similarly, Ms. Caruso explained that one ingredient in the Bubble Science activity (glycerin) was also an ingredient in commonly used moisturizing lotions. The teachers played essential roles in connecting what the students were learning in science to previous familiar experiences in the students' lives.

Conclusion

STUDENT-RELATED OUTCOMES

This study examined the anticipated and unanticipated outcomes and issues associated with implementing a science curriculum for children with visual impairments. Several important student-related outcomes were observed, such as enthusiasm, persistence, positive peer-related outcomes, the acquisition of scientific language and concepts, and meaningful connections made to the world beyond school. All these attributes can play a part in fostering a child's self-esteem and relationships to others as well as to the world.

The PSCD activities allowed the students with visual impairments to exercise their voice; engage in teamwork; enhance their turn-taking skills; broaden their science knowledge base; and, most important, understand that they, too, can be scientists. These learning outcomes were facilitated

by the PSCD strategies outlined in the curriculum, such as encouraging exploration and experimentation in answering questions and drawing on multiple senses to explore observations. The teaching strategies, in turn, promoted a more equitable and democratic process in the classroom.

Teachers of children who are visually impaired need to have specific skills to teach science, including the knowledge of how and where to obtain appropriate materials, knowledge of the processes of science, and verbal skills in providing descriptions of diagrams, photographs, and visual observations of experiments (Huebner, 1986). In addition, they need to encourage the students to use their tactile and other senses as modes of observation. The classroom staff should also be supported, by means of professional development and technical assistance, in their efforts to implement PSCD and other similar kinds of activities so as to foster a learning environment that is characterized by equity. Vital resources to support teachers' efforts should include a structured time and space in which teachers' experiences, challenges, and insights can be shared across educational settings to expand their knowledge base, strengthen their area of expertise, offer critical peer reflection, and enhance and support their own teaching and learning processes.

LIMITATIONS

Although the data presented were powerful with respect to teaching and learning, a number of limitations need to be explicated. First, this study was conducted in a specialized school, one in which mainstreaming is not implemented and students with visual impairments, particularly those with dual

diagnoses, are the exclusive student body. Therefore, the implications for teaching this curriculum in a mainstream classroom require further explication. Even in this setting, the students with low vision had far greater access to the material than did the students who were blind.

Second, the observations focused on two teachers and a small group of students. Although this in-depth analysis allowed the authors to observe the micropractices of educational access to scientific practice, it would be difficult to generalize across teachers and students.

Third, it would have been beneficial to be able to study the same children over time to assess their development and retention of scientific language, skills, and approaches to inquiry. An intellectual base within science enables students to assume a curious and agentic stance on their own lives—taking nothing for granted, always looking for evidence, and searching for alternative explanations. Given the typical social and educational treatment of children with disabilities, it would be enormously useful for schools to work with them to develop these skills and to sustain the skills over time.

IMPORTANCE OF ACCESSIBLE LEARNING ENVIRONMENTS

One of the most important responsibilities that teachers of students who are visually impaired face is to create a climate of inquiry that is both accessible and meaningful for *all* the students. Given that children learn by doing, they need multiple and consistent opportunities to engage in hands-on, cooperative, and fun activities that are driven by their own interests and questions. Creating an accessible and meaningful learning environment that balances

student-driven and teacher-guided opportunities enables children to follow their own natural curiosity and assume responsibility for their own learning. When children are active participants in their own learning, important science-related outcomes can be achieved. These and other skills are vital because they serve as the knowledge base that children can use throughout their lives.

References

- Bogdan, D., & Biklen, D. (1992). *Qualitative research for education: An introduction to theory and methods*. Boston: Allyn & Bacon.
- Cawley, J. F., & Cawley, L. J. (Eds.). (1994). Science education for students with disabilities [Special Issue]. *Remedial and Special Education, 15*(2).
- Davidson, I. F. W. K., & Simmons, J. N. (1984). Mediating the environment for young blind children: A conceptualization. *Journal of Visual Impairment & Blindness, 78*, 251–255.
- Denzin, N. K., & Lincoln, T. S. (Eds.). (2000). *Handbook of qualitative research*, (2nd ed.), Thousand Oaks, CA: Sage.
- Fine, M., Weis, L., Weseen, S., & Wong, L. (2000). For whom: Qualitative research, representations, and social responsibilities. In N. Denzin & T. S. Lincoln (Eds.), *Handbook of qualitative research* (2nd ed., pp. 107–132). Thousand Oaks, CA: Sage.
- Franks, F. L., & Butterfield, L. H. (1977). Educational materials development in primary science: Simple machines. *Educational Handbook of the Visually Handicapped, 9*, 51–55.
- Glaser, B. G. & Strauss, A. L. (1967). *The Discovery of Grounded Theory: Strategies for Qualitative Research*. Chicago: Aldine.
- Huebner, K. M. (1986). Curricular adaptations. In G. T. Scholl (Ed.), *Foundations of education for blind and visually handicapped children and youth: Theory and practice* (pp. 363–403). New York: American Foundation for the Blind.
- Linn, M. C. (1977). An experiential science curriculum for the visually impaired. *Exceptional Children, 39*, 37–43.
- Linn, M. C., & Thier, H. D. (1975). Adapting science material for the blind (ASMB):

Expectation for student outcomes. *Science Education*, 59, 237-246.

Mastropieri, M. A., & Scruggs, T. E. (1992). Science for students with disabilities. *Review of Educational Research*, 62, 377-411.

Mastropieri, M. A., & Scruggs, T. E. (1995). Teaching science to students with disabilities in general education settings. *Teaching Exceptional Children*, 27(4), 10-13.

Parmar, R. S., & Cawley, J. F. (1993). Analysis of science textbook recommendations provided for students with disabilities. *Exceptional Children*, 59, 518-531.

SAVI/SELPH. (1975). *Science activities for the visually impaired: Science enrichment for learners with physical handicaps*. Berkeley: Lawrence Hall of Science, Center for Multisensory Learning.

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