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Recommendations by curriculum reformers have discouraged superficial, teacher-directed coverage of science content in favor of the adoption of practices designed to engage elementary students. Elementary preservice education students in a northeastern university participated in a course designed to help prospective teachers reduce reliance on textbook teaching. Instead, they examined and practiced active teaching strategies designed to engage their students as they taught science lessons to children. Evidence of specific strategies preservice teachers used as they taught grade 1-8 science lessons is presented.

Learning to Teach Science

Novice teachers rarely apply what they learn in teacher education courses (Darling-Hammond, 1999). Instead, they tend to revert to the methods used when they themselves were taught (Goodlad, 1990). Studies of preservice teachers' reflective practice during various teacher education courses find that the majority retain their initial ideas about teaching and learning (Gustafson & Rowell, 1995; Zeichner & Liston, 1987), including the importance of curriculum coverage, exclusive use of teacher's manuals and textbooks, or control-oriented instruction (Davis & Sumara, 1997). Teaching science is especially challenging for many in elementary education. Elementary teachers feel less prepared to teach science than other subjects (Fort, 1993; Fulp, 2002). The elementary school teacher has been criticized as the "weak link in the chain" of school science (Dana, Campbell & Lunetta, 1997, p. 420).

Tilgner (1990) notes that poor preparation results in teacher dependence on science texts. Typically, when science is taught, students rely on the teacher for information and passively participate in activities (Pearlman & Pericak-Spector, 1995; Weld, 2000). Instead, teachers of science should guide students in the process of conceptual change towards the development of new understandings (Duschl & Gitomer, 1991) using pedagogy appropriate to science to teach meaningful lessons (Dana, Campbell, & Lunetta, 1997).

Science educators advocate engaging children so they are exploring, examining, and discussing scientific information and phenomena beginning in early childhood education (Jacobson, 2002). This study examines the abilities of preservice teachers to use interactive teaching strategies, in two science lessons taught to elementary students, after being taught these practices through model lessons and analysis of preservice teacher videotapes. To what degree can they implement practices that most have not experienced in their own learning of science?

Method

Participants

Seniors majoring in elementary education (n=18) participated in the project as part of a required course in the elementary education program at an urban university in the Northeast. All participants had taken an introductory science methods course.

Description of Course

The professor and participants used guided discovery methods (Duckworth, 1996) throughout the course. Using these methods, the teacher provides children with some direction and hints as they attempt to describe or solve a problem and assists all learners in discovery of the rule, process, or concept. Instead of the typical techniques used to teach science, including students copying definitions from the board, taking turns reading paragraphs from texts, or answering questions at the end of the chapter, prospective teachers in this study were encouraged to implement an approach that encourages student interaction as they designed and taught their lessons. They were to access students' present ideas about a topic, help students connect the new information to present knowledge, make the lesson relevant and real to learners, and promote the sharing of examples and analogies. During lessons, elementary students were to work with materials, use process skills, explore phenomena, ask questions, offer explanations, and talk and write about their science understandings collaboratively. Prospective teachers were particularly encouraged to spend time listening to the ideas of children to support pupils' attempts to rethink ideas before, during, and after lessons (Osbourne & Freyberg, 1985; Osbourne, Bell, & Gilbert, 1983; Wheatley, 1991).

Using these strategies, participants developed two science lessons to be taught and videotaped in urban and suburban, public and parochial New Jersey elementary classrooms. Typically, lessons were about 40 minutes in length. To capture the events in teaching and learning for analysis while promoting reflection (Dana, Campbell, & Lunetta, 1997), lessons were videotaped and each participant had an observing partner who assisted in taping the lesson.

During the class, to support their implementation of these strategies, participants analyzed selected videotapes of student teachers employing active teaching strategies in which children were working in groups to solve problems, complete tasks, discuss phenomenon, and formulate theories. Tapes of novice teachers similar in age and ability made implementation of recommended strategies more likely (Storeygard & Fox, 1995) with supervised peer discussions (Hatton & Smith, 1995). Video clips were analyzed for involvement of children throughout the lesson, including quality and equity of participation, interest and attention, student-generated inquiry, and assessment strategies.

In addition, the professor modeled science lessons that helped students construct explanations on the following topics: the reason for seasons, phases of the moon, the cycle of the moon, sunrise and sunset, static electricity, and capillary action. As participants shared and modified their ideas through demonstration and experimentation with peers, they began to sense what their own students might experience. Analyses of videotapes and class lessons were intended to prepare participants for designing their own lessons, whose purposes were to generate student interest, exploration, active participation, and conversation about science.

Participants kept weekly journals, which included their reflective analysis of videotaped and modeled class lessons. Since guided systematic writing can enhance reflection (Goldsby & Cozza, 1998; Hunter & Hatton, 1998), journal entries were read weekly and returned promptly with questions, extensions of ideas, and supportive comments.

The instructor studied each participant's videotape and chose portions of lessons that illustrated specific questioning techniques, group interactions, children's investigations, and ideas in describing scientific phenomena. Those portions, with the permission of the subjects, were viewed and discussed in class.

Data Collection and Analysis

Weekly Journals. Participant journals were kept concerning the process of designing and teaching science lessons as they related to class discussions, demonstrations, and class videotape analyses. Notes were kept on comments that referred to teaching in the journals and during individual post-lesson conferences. These notes provided background for the instructor who reviewed the videotaped lessons. Incidents and quotations that supported findings of implementation of strategies or difficulties in implementation were collected for potential use in the discussion section of this article.

Participant Videotapes. Each participant completed and reviewed two videotaped lessons accompanied by written and oral reflective practice analyses. The researcher developed an Engaging Children Checklist. Sources for this 8-item descriptive list were recommendations by the AAAS (1993) and NRC (1996) for science education reform and descriptions of constructivist teaching practices. While viewing each videotape, the instructor/researcher categorized each observed behavior, adding descriptive notes on teacher or student reactions. Incomplete or poor examples of a strategy were not recorded.

The preservice teacher was to use the strategy in at least two instances to be credited with implementation of that strategy. For example, in strategy #1 (*Teacher accesses students' present ideas on a topic*) the prospective teacher had to initiate a discussion that enabled at least two students to talk about their science ideas. The same is true for strategy #2 (*The prospective teacher and students provide examples and analogies to make connections to present understandings*), although those who used this strategy tended to have students do so more than twice. For strategy #7 (*Students talk to each other and write about their science ideas*), one observation of students writing up their ideas after discussing them was accepted. Each participant had opportunities to use the strategies in the teaching of two lessons.

Results

Tallies for each observed category were made for each participant. These data were cast in percentages for the overall group. Table 1 shows the number of participants who were able to implement a given number of strategies overall. Five participants were able to implement all of the strategies while one student was unable to use any strategies.

Table 1

Participants' Use of Teaching Strategies to Engage Students

Number of Participants	Number of Strategies Used (n=8)	Percentage of Success
1	0	0.0%
2	2	25.0%
3	3	37.5%
3	5	62.5%
1	6	75.0%
3	7	87.5%
5	8	100.0%

Table 2 reflects the specific strategies used by 18 participants and percentages of use of each strategy by the total group. *Students work with materials* (4) was the most frequently used strategy (94%). Least implemented was *Students talk to each other and write about their science ideas* (7), with 39% implementation.

Table 2

Number and Percentage of Participants Using Teaching Strategies to Engage Students

Constructivist Strategies	Number of Participants (n=18)	Percentage
1) Teacher accesses students' present ideas on a topic.	10	56%
2) Teacher helps students connect new knowledge to present conceptions, makes learning relevant, generates examples, uses analogies.	12	67%
3) Teacher utilizes guided discovery methods.	13	72%
4) Students work with materials (hands-on).	17	94%
5) Students utilize science process skills, (i.e., observing, predicting, formulating hypotheses, analyzing data [minds-on]).	13	72%
6) Students are encouraged to explore phenomenon, ask questions, offer explanations (process of inquiry).	8	44%
7) Students talk to each other and write about their science ideas.	7	39%
8) Students engage in collaborative group work and discussion.	13	72%

Implemented Strategies

All but one participant was able to use the *hands-on* (4) strategy. That participant did provide concrete materials for use in demonstration but did not permit all children to interact with them. Strategies that 72% of the 18 participants were effectively able to implement in their lessons were *use of guided discovery methods* (3), *use of science process skills whereby children were engaged in the processes of "doing science" [such as collecting data, interpreting data, measuring, predicting, or hypothesizing]* (5), and *collaborative group work/whole group discussion* (8).

Two-thirds of the participants were able to *assist children in connecting new knowledge to existing schema* (2). Six participants attempted to make connections, but did not include their students in the process; instead, they told students what the connections or examples would be.

Least Used Strategies

Having conversations with students about science proved to be challenging for the preservice teachers. Slightly over 50% of the prospective teachers were able to *engage children in a conversation about their present ideas and conceptions about science* (1). *Allowing students to explore, ask questions, offer explanations* (6) and *getting students to talk to each other and write about their science understandings* (7) were strategies preservice teachers used less often; less than half of the preservice teachers involved in this study attempted these latter two strategies. One participant indicated that she asked students to discuss their ideas about a science activity, among themselves, only because it was a requirement of the project. She did not believe that they would discuss science and thought that they would socialize instead. During the post-lesson conference, she was excited that the students actually discussed their science ideas with their peers.

Group Results

Overall, of the 18 preservice teachers involved in the study, five participants were able to implement all of the teaching strategies as shown in Table 1, while one participant was not able to implement any of them adequately. The mean number of strategies used by all participants was 5.3 out of 8 strategies (66.2%). Three participants were able to implement 7 out of 8 strategies while five participants were able to effectively implement only a few.

The next section will highlight strategies that were implemented more frequently and those that were implemented less often and suggest possible reasons based on preservice teacher responses and research literature.

Discussion

The strategies of *allowing students to explore, ask questions, offer explanations* (6) and *talk to each other and write about their science understandings* (7) seemed to be the most challenging ones for preservice teachers to use. Ten and nine participants, respectively, were unable to implement these strategies in their lessons. When students ask questions, speculate, and discuss ideas with each other, the novice teacher may perceive that (s)he is no longer in control. Encouraging students to ask questions is one of the recommended cornerstones of teaching science; yet it is difficult for preservice teachers to permit students' questions in the context of a given lesson (Watts, Alsop, Gould, & Walsh, 1997). Active student participation and questioning may threaten preservice teachers who are unsure of their knowledge on a given science topic. In a third grade classroom, students were observing fossil samples and talking about how fossils were formed. They were going to "speed up time" and create fossils using clay (soft mud) and Plaster of Paris (sediment) to make a mold and then cast imprints of an object. The visual aids and examples inspired children to share their ideas and experiences with fossils. Then a boy asked the student teacher, "Do we turn into fossils when we die?" In her journal, she recorded, "I had never thought about this. I did not know how to answer him. I tried to answer him the best way that I could, because honestly, I was not sure. It was amazing to me that he was thinking about that."

During our conference the instructor talked about how this preservice teacher might have allowed other children to give their ideas concerning her question, or used this question as an opportunity for the students to apply their new knowledge of fossil formation. As a novice, she was not able to "field the ball" when startled by a compelling question. Yet, she had a powerful learning experience that hopefully will impact her future lessons.

Limited knowledge and experience reduce flexible responsiveness in prospective teachers. Teachers may not know an answer or may be unfamiliar with the student ideas being offered. New teachers often perceive this "not knowing" as uncomfortable, or as undermining their authority. An inclination to teach as they were taught, difficulties linking theory and practice, and problems with pacing and management may have minimized broader implementation of encouraging student questions.

Implementers who were able to use these strategies, however, had journals that contained rich insights into student thinking. One example was a sound lesson delivered to two classes of second graders. The preservice teacher banged a can with a spoon and some salt jumped on the surface of tightly pulled plastic wrap on a coffee can across the room. She asked the children to explain how the banging of the can made the salt jump. Benjamin stated that the sound of the banging traveled across his arm, down his body, across the floor, up the desk, and onto the other can, making the salt jump. Another child believed that sound could not travel through solids at all while some children thought that sound would not be able to travel through water. As a result of two group investigations, small group science talks, the completion of a data sheet, and a whole class discussion, most students came to the conclusion that sound travels through solids, liquids, and gases (desk, water, and air). Most were surprised and excited by listening to the amplified sound of a pencil tapping on their desk through a bag of water. Sarah noticed that sound traveled better through water than air. The others agreed.

As a result of the lesson, the preservice teacher concluded "Students who had misconceptions about sound now understood more about what happens. The visual and auditory stimuli plus the hands-on activity helped students learn." She also indicated that the first class of students, where she was given more time for her science lesson, grasped the concept better than the second class since "I allowed more time for them to discuss their findings, ideas, and questions." She was disappointed that a time limit on her second lesson forced her to cut the essential science talk short and believed that student learning was negatively affected.

The strategies of *allowing children to present their prior and present ideas on a topic* (1) and *building bridges to new knowledge, promoting a sharing of examples and analogies* (2) had eight and six participants, respectively, who were unable to implement them. While they generally agreed that these strategies offered effective and interesting ways to learn, they had difficulties translating theory into practice. Ellen's comments reflect the concerns of many beginning teachers: "I need to work on helping children build bridges between the known and the unknown and ask children to make associations and provide examples. I am not sufficiently confident in myself to do this. I shy away from it because I am nervous that I will not know the answer if they ask me a question."

Fears of inadequacy and negative judgments are high among novice teachers (Richert, 1990). It is far easier for them to use traditional practices than to risk failure in their efforts to implement ways of teaching that hold no perceived guarantees. The element of risk may be a factor in low implementation of the verbal interaction with students that constitutes good science teaching. Allowing students to talk about their ideas in a lesson can sometimes be perceived as being "off task" or "wasted time" by cooperating teachers, supervisors, and evaluators of prospective teachers.

Participants who used these methods were pleased with the results, however. For example, one preservice student noted in her reflective analysis: "I had provided an analogy of a cupcake pan and jello mold to a cast and mold fossil. Students were able to give additional examples that surprised me. I had never considered the one example of the ice cube tray. The other response of the dental mold was rather creative, and it really related more to our activity than my analogy."

All participants except one were able to use engaging teaching practices with five participants using all eight strategies. Half of the participants were able to implement five or more strategies in their lessons. Practicing the actual lessons in class and having an opportunity to get additional direction before teaching them might have increased the number of strategies used by participants.

NSF (Hoff, 2002) has awarded major funding to assess the effects of using "exploration and experimentation" to teach science. At the same time some policymakers press for easier access to teaching through alternative routes and for limited focus on pedagogy courses. Yet the results of this small study suggest that preservice teachers need assistance with using teaching practices that are in alignment with science standards. In addition, Lowery (2002) found that preservice teachers exposed to instructional practices recommended by science associations and associated with constructivism became more confident and skilled in teaching science as they taught lessons in a field-based methods class. Although both of these studies are based on single classes, they suggest that methods courses taught in this manner are valuable in providing practical instruction on working with interactive, student-centered teaching strategies in science. Additional research could continue to examine the effects of teaching science methods courses on preservice teacher practices and to assess the effects of these instructional practices on student learning.

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