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The Influence of Primary Children's Ideas in Science on Teaching Practice

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Abstract: The purpose of this study was to explore how children's ideas in science affects science instruction in the primary grades. The study investigated whether and how primary teachers recognize student ideas, and whether and how they react to student ideas. Two experienced second-grade teachers and one intern teacher were observed and videotaped as they taught 8-week astronomy units. Teachers and students from each classroom were pre- and postinstruction interviewed for their content knowledge of and viewpoints on teaching and the importance of student ideas. Midunit stimulated recall interviews were used to gain understanding of teachers' perceptions of their instruction regarding student ideas. Transcripts of lessons and interviews were coded and analyzed for patterns of eliciting and addressing student ideas. Results showed that all teachers used discussions in a variety of ways to identify and elicit student ideas. The experienced teacher with the highest level of content knowledge had the largest repertoire for eliciting and addressing student ideas. The intern teacher addressed student ideas in ways that discouraged students from continuing to share their ideas. Implications include (a) helping teachers to use their teaching strengths to increase their content knowledge and expertise teaching primary students, (b) helping preservice teachers to develop a deeper understanding of characteristics of the learner, (c) having science educators recognize that primary teachers' goals for instruction focus on developing literate readers and writers and the importance of fitting science into those goals, and (d) recognizing that experienced teachers with knowledge of the importance of student ideas may seek to improve their own content knowledge. © 2000 John Wiley & Sons, Inc. J Res Sci Teach 37: 363–385, 2000.

Current reforms in science education focus on the need for students of all grade levels to understand science conceptually rather than know a breadth of science facts [American Association for the Advancement of Science (AAAS), 1993; National Research Council (NRC), 1996]. Understanding science necessitates conceptualizing content. To understand science conceptually means to know the ideas of science and the relationships among them. It includes knowledge of ways to use the ideas to explain and predict other natural phenomena, and ways to apply them to other events (NRC, 1996). Developing understanding presupposes that students are actively engaged with the ideas of science. The reforms further suggest that scientific understanding can be gained through inquiry instruction generated from student experiences.

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According to Kelly's (1955) theory of personal constructs, thought processes are psychologically developed by experiences that serve to help the person anticipate future events. These experiences form background knowledge that people use to inform inferences made from future experiences. Thus, in most science classrooms, it can be expected that children will have had experiences that helped them develop stable and functional constructs about the world. These constructs or ideas will influence interpretations made of explorations in science. Children's ideas are defined as experience-based explanations constructed by the learner to make a range of phenomena and objects intelligible (Wandersee, Mintzes, & Novak, 1994). These ideas are stable and resistant to change (Carey, 1985; Driver, Guesne, & Tiberghien, 1985; Novak, 1988; Stepans, Beiswinger, & Dyche, 1986). As long as the idea serves the learner in making sense of the world it will remain the learner's theory (Driver, et al, 1985; Osborne & Freyburg, 1985). Children's ideas develop very early, and by the age of 5 or 6 children have evolved a robust and serviceable set of theories about their world (Carey, 1985; Gardner, 1991; Piaget, 1929).

Young children's ideas have been studied for many decades. Piaget (1929) pioneered their study with the development and use of the clinical interview method. Science educators have adapted the clinical interview method to explore children's ideas in a plethora of science content areas (Osborne & Freyburg, 1985; Posner & Gertzog, 1982; Thier, 1965). Results of the study of children's ideas show that school children can proceed through their school careers and retain misconceptions about many science concepts (Anderson & Smith, 1986; Bar, 1989; Bishop & Anderson, 1990; Griminelli Tomasini, Gandolfi, & Pecordi Balandi, 1990; Hashweh, 1988; Hesse & Anderson, 1992; Nussbaum & Novak, 1976). The kinds of science instruction children receive do not seem to be effective in helping students change their conceptions of science. Students may be presented with evidence that their ideas are incongruent with an experiment or problem and reject the evidence, or reinterpret it differently within their own beliefs (Osborne & Freyburg, 1985). Even when students present what appear to be correct responses, they can continue to harbor their own ideas (Driver et al., 1985; Erlwanger, 1975; Herscovics, 1989; Osborne & Freyburg, 1985). In the absence of a teacher who understands and uses knowledge of children's ideas to inform instruction, children are unlikely to develop their ideas toward a scientific understanding (Driver, Guesne, & Tiberghien, 1985). Previous research on children's ideas has focused on describing them, providing knowledge of many misconceptions that are likely to be found in students of different ages in different subject areas (Bar, 1989; Hashweh, 1988; Nussbaum & Novak, 1976; Piaget, 1929).

To help address the need for eliciting and effectively addressing student ideas, various teaching strategies have been developed. Three such strategies are (a) the learning cycle (Karplus & Thier, 1967; Lawson, Abraham, & Renner, 1989; Smith, 1983), (b) analogy (Joshua & Dupin, 1987; Stavy, 1991), and (c) written and oral language (Fellows, 1994; Fleer, 1992). These strategies have been used by researchers to help teachers change student misconceptions.

The learning cycle consists of the following general components: (a) exposing students' misconceptions, (b) creating cognitive conflict by having students discuss ideas or participate in activities that are not compatible with their current ideas, (c) comparing new ideas with old ideas and accepted scientific explanations, and (d) having students apply their new understandings to a novel situation. It is not always evident that the learning cycle is effective in bringing about a desired level of conceptual change. For instance, Smith (1983) found that only one student in a fifth-grade class attained the instructional target conception about photosynthesis. However, Butts, Hofman, and Anderson (1993) found that hands-on activities that included discrepant events designed to confront student ideas, coupled with opportunities to explore new patterns of events significantly increased the number of 5- to 6-year-old students with accurate conceptions of floating and sinking. Thus, there is support that helping primary students to confront their ideas through an activity and application of new ideas through a learning-cycle strategy will improve their conceptions.

The use of analogy is another strategy considered effective in helping students change their conceptions toward more scientific ideas (Joshua & Dupin, 1987; Stavy, 1991). The use of an analogy requires finding something the students understand accurately that is similar to the new idea the teacher is trying to present. Noting the similarities between the two ideas can help the students gain a more accurate understanding of the new idea. For instance, Joshua and Dupin (1987) used an analogy of a train, a concept with which students were familiar, to help middle school students develop better understandings of electrical circuits, a concept about which they were not familiar. According to their findings, a well-chosen analogy should help students develop their ideas toward accepted conceptions.

Oral and written communication between students and teacher is another strategy deemed useful for helping students change their conceptions toward more accurate ideas (Fellows, 1994; Fleer, 1992). Fleer analyzed teacher–child discourse to identify interaction that facilitated conceptual change. She found that a teacher who held shared understandings of the students' ideas; scaffolded those ideas through activities, modeling, and discussions; and developed a social framework in the classroom that encouraged students sharing their ideas with other students was the most effective at influencing conceptual change in primary students. In addition, Fellows (1994) found that students who were encouraged to record their ideas in writing, justifying their ideas by focusing on the meanings made of those activities, developed more scientifically accurate understandings.

The current study focused on how primary teachers addressed student ideas as keys to teaching toward conceptual ideas. Practicing teachers may not use the strategies determined effective by researchers, but may develop and use their own strategies for eliciting and addressing student conceptions. In addition, it is important to note whether practicing teachers even recognize student ideas, or deem them important influences in the science classroom.

Purpose of the Study

The purpose of the current study was to explore how children's ideas in science affect science instruction in the primary grades. Specifically, the study investigated the following questions: (a) How do primary teachers recognize and interpret student ideas? (b) In what ways do primary teachers plan for and react to students' ideas?

Design and Procedures

Subjects

Sixty-one primary (K–2) teachers in a middle-class school district in western Oregon were contacted by telephone to request participation in the study. Eighteen of those contacted responded, and 10 of those agreed to participate. From the pool two second-grade teachers were selected who met the following criteria: (a) the same science content was delivered during the course of the study; (b) teachers had a minimum of 5 years of experience, enough to assure development as an experienced teacher; (c) science was taught as a separate subject; and (d) teachers had adequate knowledge for instructing the students in the topic being taught.

The teachers both delivered a unit of astronomy during the spring quarter at their school. In the first room, the classroom teacher delivered all lessons. The second classroom had an intern, Ms. Harker, who participated fully in the study and presented approximately half the science lessons. The participating teachers had 24 (Ms. Shelton) and 10 (Ms. Bultena) years of teaching experience, mostly in the primary grades. The teachers taught science as a separate but integrated subject. Average lengths of science lessons during the astronomy unit ranged from 0.5 to 1.5 h daily. In addition to separate time devoted strictly to astronomy concepts, the teachers connected art, math, and language arts activities in their 8-week-long teacher-developed unit.

All teachers demonstrated adequate content knowledge of astronomy concepts they were teaching. Before teaching their astronomy unit, the teachers were asked for their content objectives. Using the teacher responses, and the *Benchmarks* (AAAS, 1993) as guidelines, 10 questions were developed and validated to determine teacher content knowledge in astronomy. Teachers were considered to have adequate content knowledge when they responded to the questions correctly with 80% accuracy. The teachers easily met that goal.

The second-grade students in the classes also participated in the study. Each teacher identified 10 of their 20 students to participate in interviews. Although it was intended for a range of student abilities in science to be represented, obtaining the range proved to be difficult. Ms. Shelton provided a list of 10 students, 5 girls and 5 boys, but did not believe it was developmentally appropriate to label second-graders as high, medium, and low achievers. She instead selected the students according to the amount of individual adult attention they already received. If students had already received much individual attention, they were not selected to participate in the interviews. Ms. Bultena did select 10 students to participate in interviews according to achievement levels. Thus, 20 students were interviewed pre- and postinstruction.

Data Sources

A variety of data sources were used to provide answers to the research questions. This variety also allowed for triangulation of results. The data were selected to help provide a picture of teacher views of science teaching, knowledge of astronomy content, understanding of student ideas, and how the teachers addressed those ideas. It should be noted that the role of the researcher was simply as observer. There was no participation in classroom activities or advising of the teachers by the researcher in either classroom.

Interviews. Data sources included video- and audiotaped pre- and postinstruction interviews of the teachers and students. Content questions were developed from teachers' stated goals as well as *Benchmarks* (1993) recommendations for astronomy knowledge. Teachers were also interviewed for their science teaching beliefs and their understandings of conceptual change teaching. All interview protocol questions were presented to a panel of five experts for validation. The panel of experts consisted of university science educators as well as university science faculty. Following negotiation of points raised by the panel, all protocols were accepted. Copies of all protocols are available in Dickinson, Flick, and Lederman (1998). Teachers were individually interviewed in their own classrooms after students were released for the day. Props, including a variety of sizes of balls and paper and pencils, were available to aid the teachers in explaining their ideas.

Further data regarding teacher response to student ideas were collected at a midinstruction, stimulated recall interview designed after the video-stimulated recall format described by Calderhead (1981). The researcher selected videos and stopping points at which (a) students expressed ideas, (b) the teacher recognized student ideas, and (c) the teacher responded to student ideas. The teachers also had the opportunity to select stopping points while viewing the video. A protocol was developed based on lessons presented in each classroom video.

Following the preinstruction interview of teachers, the selected students were interviewed to assess their knowledge of astronomy. The protocol for students was similar to the teacher protocol, but the focus was on student conceptions of content. Each student was individually interviewed while being video- and audiotaped.

All participants in the preinstruction interviews were interviewed postinstruction. Both teachers and the teacher intern were interviewed. All questions in the preinstruction interviews were included to note differences in response that may have been attributed to instruction.

Classroom Observations. Classroom observations were the primary data source and allowed the first author to note the general process of science instruction in each class, using the knowledge gained in interviews. Classroom observations allowed the researcher to note (a) whether and when students expressed ideas, (b) whether and when the teacher recognized student ideas, and (c) whether and how the teacher responded to those ideas. The researcher noted large- and small-group interactions as well as individual student–teacher dyads, during which the teacher was addressing student ideas. Classroom observations were made of 40 h of daily astronomy lessons in each classroom.

In addition, each lesson was videotaped. The videocamera was placed in a location away from classroom activity to remain unobtrusive. The teacher wore a microphone that picked up the teacher's voice and any student talking nearby. The camera's microphone was used in large-group discussions, and the remote microphone was connected when the teacher was engaging individual students in discussion. All videotapes were transcribed daily.

Data Analysis

The researcher formally analyzed all data at the conclusion of its collection. The process began with reviewing each transcript of interviews and classroom observations in totality. While reading transcripts, the researcher made notes in the margins of the transcripts. These notes became broad initial categories for the data, such as "elicitation of idea," and "expression of idea." A second reading of the data allowed for narrower categories, such as "elicitation of idea in large group invitation," later shortened to "idea invitation," "addressing idea by probing question," later changed to "probing questions," and "ignoring of expressed idea," later changed to "ignoring." Separate categories were developed for student ideas that were voluntarily expressed and ideas that were elicited by the teacher. For example, a transcript in which a student voluntarily said, "I think gravity doesn't work in space" was coded as, "student voluntary expression of ideas."

The categories were used to develop a description of each teacher's typical patterns for eliciting and addressing students' ideas. An individual profile was made from analyzing classroom observations of each teacher's classroom practice to describe how the teacher elicited ideas, how students expressed ideas, and how the teachers responded to those ideas that were expressed. A comparison was made of differences among strategies across content knowledge levels of lessons in teaching.

Finally, the researcher discounted the data (Taylor & Bogdan, 1984). In the process of discounting, data were reviewed to see whether other explanations could be given for the results. Solicited and unsolicited data were identified as such. Some responses were given to the researcher that were unsolicited by data collection methods; these responses from the teachers were valuable in determining how the teachers were identifying student ideas.

Results

Before discussion of results relating to the research questions, it should be noted that the two experienced primary teachers in this study used science instruction for three purposes: (a) to serve as a means to teach reading and other literacy skills, (b) to maintain student interest in their learning, and (c) to help students learn meaningful content that would give them a foundation on which to build deeper knowledge. These primary science goals are different from secondary science goals where students are focused on learning a specific body of content knowledge.

It was found that science in these primary classrooms provided students with purposes for reading and writing. It provided the class with interesting topics for discussion that enabled the teachers to help students develop oral language skills. Science also provided a setting for students to communicate their ideas formally in oral and written presentations of their work. Science was a way to help children learn how to talk about the world, ask questions, negotiate and share meanings, and organize thoughts about what was being learned into a communicable form. Thus, the teachers' explicit goals for science were related to attitude, and the implicit goals were related to developing general literacy.

Whereas science played a key role in providing a purpose for reading and writing, language arts played a role in helping students learn science. The entire science program in each classroom was infused around the language arts program. There was much writing and organizing of ideas with individual reports, discussion, and negotiation of ideas in each class. Considerable classroom writing time was devoted to astronomy. The reading time was solely devoted to children reading astronomy books from which they were to take notes about their topics. Student independent reading helped develop scientific knowledge by allowing students to select reading materials and to find information about the astronomy topics. In addition, when teachers read books to the class, the books were often astronomy related and generally nonfiction rather than fiction. This type of instruction combining science and language arts is typical of elementary classroom, particularly given the charge of elementary teachers to produce literate readers and writers.

Students learned organizational skills to help them present their work in communicable forms for written and oral presentation. Students developed oral and written language skills by expressing their ideas gained from readings and experiences. The skills are consistent with the *National Science Education Standards* (1996) recommendations for students to construct reasonable scientific explanations based on their experiences, and to communicate their explanations in written and oral forms. Through comparison of pre- and postinstruction interview responses, it was found that in these two classrooms, the use of discussion, writing, reading, developing categories of information, and hands-on exploration was used to develop better knowledge of astronomy.

Case Studies

Results relating to the study's questions of (a) how primary teachers recognize and interpret student ideas, and (b) ways that primary teachers plan for and react to student ideas are presented below within a case study of each teacher. It must be emphasized that both Ms. Bultena and Ms. Harker were instructing in the same classroom.

Ms. Shelton

Background. Ms. Shelton has worked as an elementary teacher for 24 years, with 16 of those years being in the primary grades. Ms. Shelton had strong interests and endorsements in language arts and reading, with a master's degree in early childhood education. From her interviews, it was found she believed science was an important and integral part of the primary classroom in helping students to study what was most interesting to them—their own world.

Ms. Shelton's content knowledge was fairly substantial and scientifically accurate. When she was unsure of a content question, she felt comfortable stating her uncertainty; yet, she was inevitably accurate in her response. She accurately answered each of the protocol content questions.

Ms. Shelton was unaware of the research literature on children's ideas. However, by an interpretation of her actions and words, it was apparent she shared a research definition of children's ideas. She treated children's ideas as perceptually dominated, structured, coherent, and persistent alternative conceptions about the world. She understood children to have ideas about a topic before formal instruction. She recognized that students did not hold accurate conceptions and that she could influence change in those ideas. She also recognized that students' ideas might persist through instruction. She believed that student ideas influenced children's learning and teachers' teaching.

The following comment illustrates Ms. Shelton's view of children's ideas as perceptually dominated:

> One thing that might be impeding her was just the actual reaching around our balloon [as model of the sun]. . . . I wasn't sure if I were imprinting her . . . about a rather odd orbit because of the lopsided balloon. . . . I knew they were thinking the real sun looked off-balance like the balloon.

The following statement shows Ms. Shelton's views of children's ideas as structured, coherent, and experience based:

> I wanted to . . . understand what he was thinking [about the planets being closer to the sun on one end of their orbit than the other] . . . I wanted to know why he thought that. And I wanted to . . . see if there were . . . some fundamental knowledge that was leading him to believe that. I think he is capable of very remarkable thinking and he is constructing his concepts about how things work, and drawing conclusions all the time. . . . When he talked about the differences in the orbit related to seasons I knew he had thought about this idea, and that he had used his experiences with the seasons to think about it. . . . His idea was wrong, but he still "knew" about the orbit from his own thinking and experience.

Ms. Shelton also viewed children's ideas as persistent and resistant to change:

> What I would like people to understand about kids, even very bright kids, is that they are kids first and very bright second. So that very bright kid . . . he is still saying, "as the sun goes away." I think no matter how many times we revisit that . . . he, on a gut level, knows the sun goes away, no matter what words I make him learn.

Ms. Shelton's Instructional Strategies. Ms. Shelton taught science every day. Students spent time working on individual reports with the teacher circulating the room asking the students questions and interacting with them in to cause them to think about what they were studying. The teacher also spent time on whole-group lessons to help students organize their writing. Their reports were published in a book and they presented them publicly.

Student ideas affected Ms. Shelton's instruction. She endeavored to elicit those ideas and to address them in instruction. Student ideas were an integral part of the classroom instruction and were repeatedly addressed in a variety of ways. Ms. Shelton's classroom practices included a cyclical pattern of instruction. Regarding the research question of how primary teachers elicit ideas, it was evident from classroom observations that she began each lesson with an initial idea invitation question that garnered student ideas about a topic. The idea invitation question was open-ended, such as "What do you know about astronomy?" and all student responses were accepted and recorded on chart paper for the class to see. Students readily responded to her question, sharing their own ideas about the science content. Probing questions followed to determine the number of students who shared the idea and the depth of their understanding. Probing questions included questions such as, "Can you tell me why you think that?" and "Can you tell me more about that idea?" These probes were designed to gather more information, not lead students to answer in a particular way. Students then worked independently as the teacher circulated the room, raising the same idea invitation question to determine individual ideas.

As was found from analyzing videotapes of classroom practice, Ms. Shelton had identifiable patterns indicating several methods of responding to student ideas. When students demonstrated an inaccurate understanding of the topic, she reacted to their ideas by deciding whether to pursue the topic or let it drop. If she believed the concept was too abstract for the student, she often let the idea drop. If she believed the student could gain an understanding on his or her own, she asked the student to do so. From her interview responses, she made it apparent that she purposely selected strategies based on how her students responded to her questions. For example, when the idea was not too abstract, she chose to react to student ideas by addressing them through strategies of (a) lesson development, which consisted of developing a lesson specifically designed to address student ideas; (b) demonstration, wherein she provided a demonstration of a concept using concrete objects; (c) literature connection that consisted of reading a nonfiction children's book to address specific ideas; (d) explanation, where she explained a concept without using manipulatives or visual aids; and (e) scaffolding, where she linked new ideas to old by finding something familiar to the students and using that as a connection.

In the next step of the cycle, she again raised the idea invitation question in a whole-group setting, and student responses were noted. If Ms. Shelton determined students still had faulty understandings, she often raised the question again in small-group dyads. The following subsection provides examples of response strategies used by Ms. Shelton.

Examples of Ms. Shelton's Response Strategies. Demonstration was used to present scientific information using drawings or representations of the concept as well as manipulatives. Ms. Shelton explained as she manipulated or shared the drawings. The following example of demonstration is also an example of lesson development because it was specifically designed to address student ideas about orbits and what it meant for Pluto and Neptune to "switch places." Ms. Shelton drew a set of planetary orbits around a sun on a piece of posterboard. She glued small pictures of the planets in orbit around the sun, not all lined up in a row. She used small pompoms as model planets to move around the orbits, and then asked students to move the model planets around the orbits on her drawing and in patterns at their desks.

Ms. Shelton used the drawing as a manipulative as well. She asked students to manipulate a toy planet individually around the orbits she had drawn on the poster board. She again used the poster board drawing to encourage the students to think about scale in the interchange that took place while students were manipulating the toy planets:

Teacher: Okay—let's talk about the orbits. We talked a little bit about my drawing not being to scale. Does anyone know what that means, "to scale"?

Student 2: The planets aren't really that close to each other. The sun is really lots bigger.

Teacher: She is right, exactly. If I made the picture with the sun in scale I wouldn't have room for the rest of the planets. By my drawing I am not trying to show their distances or relationship to the sun, just their orbits.

The teacher used the poster board drawing to illustrate why it appeared that Neptune and Pluto switch places. "Switch places" was a term used by students to describe the change in the orbits of the two planets. Ms. Shelton illustrated that it was the shape of the orbit that made it seem like the planets were switching places, not that they were actually moving on one side or the other of each other.

Teacher: When we talk about the planets trading places, do they really like switch places? No, they don't, they move around each other, and what happens is, Pluto's orbit is goofy in that the rest of the orbits are more circular, but Pluto's is highly elliptical, meaning it is shaped more like a bit fat cigar than a circle. . . . Sometimes the orbit is closer to the sun than Neptune's. They don't really switch, they don't move around each other, they don't stand in front of each other. So, even though they trade places [she moves back and forth with a student] they are not doing this—planets are just moving around their own orbits.

The entire lesson shows how Ms. Shelton used demonstration to illustrate a concept to address ideas she had previously elicited. She began with a manipulative and visual aid, presented scientific knowledge through her explanation, and asked students to describe their own thinking about what was happening. She alternated between large- and small-group discussions to assess changes in understandings and asked students to use manipulatives to demonstrate their idea of how the planets move about in orbits and what it really means when people say that Pluto and Neptune switch places. A point Ms. Shelton continually brought up in interviews and discussions was the difference between "kid language" and how children interpreted what adults meant with "adult language." She saw one of her roles as helping children reconcile the difference between their interpretations of adult language and their own "kid language." Helping them to understand what Pluto and Neptune switching places meant is an example of this instruction.

The lesson below shows the typical sequence of reading, and discussion about the book in the literature connection strategy:

Teacher: I will start reading now. [Reads.] Look up in the sky and you will see . . . [holds up book with large illustration].

Students: Sun.

Teacher: The sun is a huge . . .

Students: Ball of fire, ball of burning gas, star

Teacher: All of those would be right. [Continues reading.] "Star. The sun is made of . . ."

Students: Burning gas.

Teacher: What are the objects called that move around the sun?

Students: Planets.

Teacher: Good. Somebody asked me this week why the moon wasn't a planet. Why don't we call the moon a planet? Why do we call it a satellite instead of a planet? Planets orbit a what?

Students: Sun, star.

Teacher: Yeah, a star. What do moons go around?

Students: Planets.

Teacher: The difference between a moon and a planet is what they go around.

In this interchange, the teacher was able to address students' ideas, which were previously expressed, about the sun as a star and to confront an idea that the moon was a planet. It seemed that most children agreed on the difference between a moon and a planet, and thus the teacher continued with her lesson.

Another method of explicitly teaching science content was to use explanation. During explanation, the teacher always used questioning to help assess student understandings of the concepts she was explaining. In the explanation the teacher was giving below, she used student understandings of the earth's movement to help them understand why the stars appeared to move across the sky.

Teacher: Stars are not in orbit. The universe is expanding. The stars are moving, but you would not be able to observe that movement. The reason you think the stars are moving across the sky is the same reason you think the sun is rising and setting. Is the sun moving around the earth? [Chorus of "no."] The stars aren't moving, either. What is happening to the earth?

Students: It is turning.

Teacher: Right—it is moving around the axis, so that makes it look like the stars move with the season, but they're not. There aren't really changes with the constellations; they are also occurring with the movement of the earth around the sun and the movement of the earth around its axis.

Ms. Shelton used student understandings of everyday objects to help scaffold (Palincsar, 1986) their understandings of new ideas. A way for teachers to help students change ideas is to scaffold them to a more accurate level of understanding (Rogoff, 1990; Vygotsky, 1986). Scaffolding can be defined as a process in which a more experienced person helps less experienced people understand or solve a problem they would be incapable of doing alone. Scaffolding children's thinking in curricular areas is a strength of primary teachers, particularly through the use of language (Cazden, 1988). Primary children are active and willing to describe what they are doing and thinking. Attentive primary teachers are able to elicit student ideas with little prompting. Teacher input in the discussion regarding activities helps scaffold students to new understandings (Gallas, 1995).

In the interchange below, Ms. Shelton found an idea the student understood—the idea of pierced ears—to help the student understand what it meant for something to be pierced. The lesson is taking place with an individual student during the student's research of her own topic.

Teacher: [Reading student's notes.] "Cloud piercing radar records data . . ."

Student: Kind of like on a computer.

Teacher: Right, it is like information. Sometimes computers translate that data. That means that this space probe has been able to send back more detailed pictures of Venus than anything before.

Student: Probably they wanted to land on there to see what it is like. We wanted to see what is under the clouds.

Teacher: Very good. How come Magellan can take pictures through the cloud? Do you know what piercing is? What are pierced ears? Like when your ears have little holes in them and the earrings go through? So, Magellan used cloud-piercing radar. . . . The radar . . . pierces the clouds, touches the surface, and bounces back and records data about what Venus is like.

Thus, Ms. Shelton had several ideas she cycled through small and large groups through discussions. She made decisions whether to continue discussing the idea, allow it to drop, encourage the student(s) to continue thinking about the idea, or teach the concept explicitly using the variety of strategies described.

Ms. Bultena

Background. Ms. Bultena had a background that can be considered to be typical of most elementary teachers. She held a master's degree in early childhood education and had a strong interest in literacy and teaching language arts. She had 10 years teaching experience, all in the primary grades. From her interviews, it was apparent she saw science as serving an important role in the primary classroom. She believed science could help students maintain their interest in learning.

Ms. Bultena's knowledge of astronomy was not as strong as Ms. Shelton's. She was unable to accurately answer all questions related to the teacher goals for students to attain. For instance, she had to be reminded that the planet she could not think of the name of started with an "N" by her intern teacher, in which case she recalled "Neptune." She was unable to describe any orbits, and could not name the planets in order from the sun, although that was a goal she held for her students to attain. She had a faulty understanding of gravity. She knew that the question was "the gravity question," but was visibly flustered at her inability to respond to it other than using words such as *pressure, weight,* and *force*. She expressed concern with her own lack of knowledge.

Ms. Bultena did not state a researcher definition of children's ideas. However, her definition did include elements similar to the researcher definition of perceptual dominance, structured, coherent, and experience based, and persistence and resistant to change.

The following comment illustrates Ms Bultena's view of children's ideas as perceptually dominated:

> I think what students see in their day-to-day lives affects what they learn. I expected that a student might ask about Superman. . . . Maybe a child would ask about why we weren't studying Planet Krypton. . . . But we got pretty typical responses. . . . But it is true that Superman could have come up because it has happened before.

The following statement shows Ms. Bultena's view of children's ideas as structured, coherent, and experience based:

> She said, "It would take four Earths to make one Jupiter. Where would she have heard it, or put it into a way that would be understandable to her? . . . Generally, second-graders cannot even understand the size of Corvallis, let alone the earth sizes and how they would fit into a planet the size of Jupiter. . . . Where she would have figured out that information?

Ms. Bultena also viewed children's ideas as persistent and resistant to change:

> I wondered whether the student believed there was a star factory out there with some kind of assembly line where different parts get put on *like he might have seen somewhere* [author emphasis]. I wondered what the picture looked like in his brain. I think even after the unit . . . *he still might put it together that way* [author emphasis]. . . . He has an answer for what he knows, and doesn't need to find out more because he already thinks he understands the idea.

Ms. Bultena's Instructional Strategies. Children's ideas in science influenced Ms. Bultena's instruction. From classroom observations, it was evident she was motivated to know student ideas and used an idea invitation question similar to that of Ms. Shelton, and accepted student responses in small- and large-group settings. Her initial question for the astronomy unit was similar to Ms. Shelton's: "What do you already know about astronomy?" She used probing questions, such as, "Tell me more about how you think that rocket engine works," to clarify and gain understanding of the depth of those ideas. She reassured students that she was interested in their ideas, and not scientific knowledge.

Student ideas also influenced Ms. Bultena to develop strategies to address those ideas. She did not use a cyclical style. Each idea was addressed once in the setting where it was raised. From analyzing the videotapes of classroom practice, it was evident that she used a variety of strategies to address student ideas: (a) explanation, or providing accurate information by telling it to the students; (b) literature connection, by reading a nonfiction book; and (c) activity debrief, where she held a discussion following the intern's presentation of a hands-on activity. The following section provides examples of Ms. Bultena's strategies.

Examples of Ms. Bultena's Response Strategies. Like Ms. Shelton, Ms. Bultena often used literature connection and read nonfiction children's books to her class to provide them with accurate science content. She did not have as much opportunity to read to the class as Ms. Shelton because Ms. Harker did most of the reading. However, while reading a book, the teacher elicited ideas the students were developing from the text by questioning them:

Teacher: [Reading nonfiction book.] Anyone know why Neptune is blue?
Students: Because of the gases.
Teacher: Yes, the gases. [Continues reading.] What do you think about Pluto?
Student 1: Some scientists think that Pluto used to be one of Neptune's moons and it broke off and became a planet by itself.
Teacher: What else do you know about Pluto? Anything else you can tell us?
Student 2: That it is very cold . . . it is smaller than the earth.
Teacher: Okay. [Continues reading.] Is there anything past Pluto? Any other planets?
Student 3: Well, I saw on the news there might be something past it, like, it could be a star or a moon, or another planet, but we don't know for sure yet.
Teacher: They are still researching it and thinking about it.

Although Ms. Bultena did not teach the activities herself, she did make suggestions to Ms. Harker about which activities to present to the students. Ms. Bultena circulated among the students when she was present while they were engaged in the activity presented by Ms. Harker. Ms. Bultena often joined in the debriefing of the activity lessons, using an activity debrief strategy by asking questions and raising points to help students think about the activity. The following passage illustrates a discussion led by Ms. Shelton after an activity delivered by Ms. Harker. The objective of the intern's activity was to illustrate to students the difficulty astronauts have in manipulating items while wearing thick insulated gloves.

Teacher: I had people tell me you would keep oxygen in your gloves. Why would you want to keep oxygen in your gloves? Is there something you were thinking about?
Student 1: All of your body needs oxygen; you don't just need it to breathe.

Ms. Bultena used the discussion above as a segue to provide information that she found about the Hubble telescope to students. She then asked students to problem solve ways to fix the Hubble telescope:

> Teacher: They are trying to get the Hubble fixed because it is having problems. They want it to last 5 months, and if they don't get it fixed it will last only half the time. What could they do? What are some possible things they could do to get it fixed?
> Student 2: They could see things in space with it.
> Teacher: That is what they could use a telescope for, but if it isn't working, what could they do to make it work?
> Student 3: If they had another one, they could send one up, or they could bring the other one back and fix it.
> Student 4: Maybe they could find a spaceship with a crew in it to fix it.
> Student 5: I think that whatever part is missing, they could trade the parts by carrying it in the space shuttle.
> Student 6: They could take the other one down to Earth and work on it, and maybe build another one.

It seemed the discussion was off the topic of using gloves in space, but Ms. Bultena connected the interchange back to using gloves in space in the exchange below. She focused the lesson away from the purposes of gloves in space to friction and movement under weightless conditions:

> Teacher: Actually, they have already worked on the Hubble telescope. . . . They actually trained crews to go up there with robotic crews. So, would they need these kinds of gloves to work on the telescope?
> Students: Yeah!
> Teacher: Now you have some ideas of what would be helpful to have on your gloves—friction would be helpful to help you hang on to things. How could you keep your things from floating away?
> Student 7: Use Velcro.
> Student 8: You could have a kind of a cord that is hooked on to your tools and it is hooked on to you so it won't go away.
> Student 9: You could have lots of pockets and stuff to carry things in.
> Teacher: All these things had to have someone thinking about them and saying, "This would be a good idea."
> Student 10: Maybe magnets would work.
> Teacher: These are areas you might think about in your futures—you may have to use some of these things if you get a job in space. I'm glad I got to talk to you, because it was most interesting.

Ms. Harker

Background. Ms. Harker was completing a Master of Arts in Teaching in Elementary Education degree. The only teaching she has ever done has been as an intern, and the only science she has ever taught was in this second-grade classroom. She recently took and received an A in a college astronomy course at the same university at which she was earning her master's degree. True to her perception of her knowledge, Ms. Harker's content knowledge was not strong.

For instance, she was inaccurate in her definition of astronomy, believing it to be “the study of everything in space.” She had faulty understanding of gravity, believing it “held us on Earth by pushing on us from the air.” She was hesitant about her responses and concerned that she appeared not to know much.

In addition to weaker content knowledge, Ms. Harker’s definition of student ideas differed from that of both the experienced teachers and from the clinical definition. Her interpretation was that students can become expert in areas they study, and their expert ideas could be shared with their peers. She had words to describe appropriate development of student ideas such as “schema” and “developmental appropriateness”:

> You have to make it age appropriate. They need the concept to be concrete, and some things are too abstract. Especially with astronomy. Many of the concepts are abstract. So, actually a lesson needs to be concrete.

> They’ll get astronomy again. They will need it. This will just give them a basis, and a schema about comets.

Her interpretation did not include all components of perceptual dominance, persistence, coherence, and structure as are found in clinical definitions. Ms. Harker believed students gained ideas and conceptions through the activities and worksheets that she gave them. Student understanding was related to remembering the facts they learned from activities or worksheets, not necessarily to a set of coherent thoughts:

> Some things kids will forget. . . . I don’t think it is a failure of the teacher or the student. They just forget what they learn.

> We had just done that page . . . so I was hoping someone would remember . . . he remembered! . . . I just wanted to see if they still knew it.

Thus, whereas the experienced teachers seemed to share an interpretation of student ideas similar to the clinical definition, Ms. Harker did not.

Ms. Harker’s Instructional Strategies. As was evident from analyzing classroom videotaped teaching episodes, student ideas did influence Ms. Harker. Like the experienced teachers, she endeavored to know their ideas through idea invitation questions at the beginning of each lesson. However, she did not expect their responses to be so unconventional and attributed them to her own weak questioning ability. She did not use probing questions to follow up on student ideas and did not elicit ideas in small-group or dyad settings. Although she elicited student ideas, she did not address them in ways that encouraged continual expression of ideas. A pattern was noted in Ms. Harker’s teaching that showed she generally responded in ways that discouraged expression of ideas, using a variety of strategies that enabled her to keep on the track of presenting the information she believed she needed to cover. These strategies were: (a) leading, consisting of repeating student responses in a question form that led students to restate their response with the opposite reply; (b) partial acknowledgment, which focused on acknowledging only the portions of a student’s statement that helped the intern direct the lesson in the way she wanted; and (c) ignoring, consisting of not acknowledging the student response at all. The following section illustrates examples of Ms. Harker’s strategies.

Examples of Ms. Harker's Response Strategies. Instead of probing for reasoning behind student responses, Ms. Harker sometimes addressed student responses by using a leading strategy that consisted of repeating them in a question form that led students to restate their response with the opposite reply. The exchange below, during a discussion about how rockets propel into space, illustrates the change in student response following such a question by Ms. Harker:

Teacher: Is the fire pushing down or up?
Students: Up.
Teacher: The fire is pushing up?
Students: Down.

When Ms. Harker wanted to focus on only part of a student's response to encourage a certain line of thinking, she used a partial Acknowledgment strategy. This strategy focused on acknowledging only the portions of a child's statement that helped the intern direct the lesson in the way that she wanted. She conducted a lesson on Newton's third law. The lesson was developmentally beyond the level of the second-graders, particularly the terminology. Ms. Harker tried to connect it to their experiences with swings, but could not do so effectively. When Student 1 expressed her idea of what happened with a swing, Ms. Harker focused only on the first part of the student's response. Ms. Harker tried to explain Newton's law with the drawing, but was not able to get the scientific information across to the students. Student 2 took the line of reasoning into a different direction when he discussed the swing as being attached to the bar of the swingset. The swing was probably not an appropriate example of the law because, as every second-grader knows, when a swing is pushed it does go back and forth and does not immediately go back to its resting point, as Ms. Harker had drawn on the board:

Teacher: When Newton was talking about every time there is an action there is a reaction. When you push the swing that is an action. What is the reaction?
Student 1: It goes back and forth.
Teacher: It goes back. [Ignores student's full response.] Let's draw a little picture. Here is a swing. Let's say you push it this way, it goes back to look like this at its first place. . . It will go up, and when it goes back it is the reaction.
Student 2: Yeah, because the metal bar holds it so it doesn't come off. If you pushed it and it wasn't stuck it wouldn't ever come back.

An example of Ms. Harker using an ignoring strategy to redirect a student response is in the interchange below. The class discussion surrounded an activity to plan balanced meals for the astronauts to take with them to space. When Student 1 responded with an idea of what the astronauts could drink, Ms. Harker did not include the word *mineral*, but was insistent on listing only water, and then only with another beverage included in the menu. Earlier in the same lesson, another student suggested sourdough toast as a breakfast food, and Ms. Harker listed only "toast."

Teacher: Now we need something to drink.
Student 1: Mineral water.
Teacher: We already have water.
Student 1: Mineral water. It has sort of a lemon, lime, or raspberry flavor to it.
Teacher: We'll have water as an option, but what else could we have? I think we need another dairy.
Student 2: Milk.

Discussion

Whereas none of the teachers used specific strategies recommended as effective by prior research, such as the learning cycle (i.e., Lawson, et al., 1989), analogy (i.e., Stavy, 1991), or oral and written communication (i.e., Fellows, 1994; Fleer, 1992), it can be shown that they did strive to use their strengths to teach their students, while meeting other curricular objectives. Portions of the recommended strategies can be seen within different strategies that the teachers did use with their classes. In addition, differences in experience and content knowledge level seemed to hinder or help with effective response to ideas.

The following section will discuss how teachers elicited and responded to student ideas, limitations to responding to student ideas, and teacher practices related to experience and content knowledge level.

Elicitation of Ideas

A focus of literacy education is to foster student oral language development. Primary teachers are adept at orchestrating discussions to help students develop their oral language. Both Ms. Shelton and Ms. Bultena elicited student ideas using the discussion strategies of idea invitation and probing questions. Ms. Shelton, the teacher with the most experience and content knowledge, also elicited the same ideas repeatedly, in small- and large-group settings, to track changes in conceptions. Ms. Harker only elicited ideas in large-group settings using an idea invitation question, and did not use probing questions to determine the depth of student understanding.

Teachers did not elicit student ideas specifically to change those ideas toward scientific accuracy, although that was one of their goals. In fact, the experienced teachers recognized it was not possible for them to help all students develop scientifically accurate ideas. Teaching students accurate content was secondary to goals for developing literacy. Teachers' reasons for eliciting student ideas ranged from wanting to (a) help students learn to express ideas and interpret their experiences, (b) assess development in student understanding of a concept, (c) know what their students thought about the content before instruction to help them plan instruction, and (d) gain a sense of the range of thought applied to astronomy concepts. The last three goals parallel language arts goals of purposeful communication through reading, writing, speaking, and listening (International Reading Association/National Council of Teachers of English, 1996). Indeed, elementary language arts methods texts recommend elementary teachers hold class discussions and writing activities regarding a shared experience to help students develop understanding of the content and their own skills of communication (Rubin, 1995; Templeton, 1995; Tompkins & Hoskisson; 1995, Tway, 1991).

There were instances in each classroom where students held ideas that were not elicited. One student whose idea remained hidden received no instruction and did not change her idea. From such a case it might seem that it is important to note all ideas so they can be addressed in the classroom, enabling all children to develop accurate ideas. Yet, this might not be feasible in classroom practice. The girl who categorized stars as "regular, shooting, and wishing" was the only student in either classroom identified by the researcher who held such an idea. It would not have been a good use of classroom time to address an idea held by only one student in a whole-class setting.

Responding to Student Ideas

The teachers made a concerted effort to guide student ideas toward convergence toward scientific ideas that could be shared by the class. Although teachers were aware students would not come completely to scientific understandings of concepts in astronomy, they believed students could come to a better understanding of concepts. Ms. Shelton, with the greatest experience and highest level of content knowledge, had a wider repertoire of strategies. True to her claim, she planned activities to address specific student conceptions. Her use of scaffolding may be seen as similar to the use of analogy (i.e., Stavy, 1991) in developing conceptual change, and other strategies, such as lesson development and explanation, included elements of instruction that confronted student thinking, which could be seen as part of the learning cycle (i.e., Lawson et al., 1989). Ms. Bultena used fewer strategies (explanation, literature connection, and activity debrief) to address student ideas, and had fewer opportunities to do so given the fact that Ms. Harker also taught in the same classroom. Elements of the kinds of oral discourse that encouraged conceptual change (i.e., Fleer, 1992) were apparent in the activity debriefs with her class. Thus, although neither of the experienced teachers used specific conceptual change strategies, elements of those strategies were contained within their teacher-developed methods.

Ms. Bultena responded to student ideas in a manner that differed from Ms. Shelton. First, when students held a fairly accurate perception of a concept and were not expressing it clearly, Ms. Bultena rephrased students' statements to reflect a correct understanding of the concept. For example, Ms. Bultena rephrased a student's statement, "The astronauts wear thick clothes so they don't freeze," to "Astronauts wear special insulated suits to protect them from lots of dangers in space." She knew the student recognized the protective nature of the clothing, and rephrased that knowledge to reflect a more accurate use of the language. Ms. Bultena's rephrasing of the expressions of nearly accurate ideas is like second-language teachers' rephrasing of sentences second-language learners are making to help them become more accurate in English (Allen, 1991; Finocchiaro, 1974; Finocchiaro & Bonomo, 1973; Ovando & Collier, 1985).

The teachers most often used their experience to teach broad ideas across the classroom, not to address individual ideas. This finding, that teachers present material that addresses most students' needs, is consistent with previous research regarding expert teachers (i.e., Berliner, 1987; Bromme, 1987). Whereas teachers were not aware of each student's ideas, student ideas were similar enough in most instances for the teachers to be able to elicit ideas from some students, address those ideas, and meet most students' needs.

The experienced teachers in this study were more able to respond quickly to students' ideas than was the intern, Ms. Harker. Ms. Harker, with a lower level of experience and content knowledge, addressed ideas differently from those of the experienced teachers. Her methods of addressing student ideas discouraged their expression so she would not have to deal with them. She was more focused on eliminating student ideas from being in the way of what she intended to teach. Thus, it seems with experience teachers will begin to expect, elicit, and address ideas. Although Ms. Harker was able to say the right words and to use the right terminology regarding helping students to develop schema and making lessons developmentally appropriate, she was unable actually to do so in her classroom practice. On the other hand, the experienced teachers did not use jargon words, but simply recognized that students would have prior knowledge and sought to know their ideas and use them in instruction.

Limitations to Responding to Ideas

The teachers' beliefs that knowing students' ideas is important and that ideas should be addressed were not always confirmed in their instruction. The teachers' abilities to respond to ideas in ways consistent with their beliefs were mitigated by different factors. Clark and Yinger (1987) found that teachers were more likely to teach in a manner consistent with a belief they strongly held. However, previous studies have delineated factors that limit teaching in manners consistent with beliefs (Calderhead, 1987; Huberman, 1985). These competing factors include a concern with classroom management and colleagues or parents. In the current study, the concern with classroom management and colleagues and parents was not manifested except in the case of the intern, Ms. Harker. Ms. Harker was concerned with management of the classroom, particularly of small-group activities. This finding is consistent with that of Hollingsworth (1989), that a major concern of all teacher interns is classroom management. Because Ms. Harker was distracted by management activities, she did not respond to student ideas in settings where they were investigating materials, but instead focused students on following appropriate procedures. Her concern could be attributed to inexperience in dealing with inquiry and other activities. Ms. Harker's focus contrasted with Ms. Bultena's questioning of students as they were experimenting. Ms. Bultena, with fewer management concerns and more teaching experience, was able to ask questions of students as they manipulated objects that required students to give explanations of what they were doing and seeing. Ms. Harker emphasized procedures in her lesson plans rather than discussion of ideas or meanings. She did not want to lose control of the class in front of either her supervisor or Ms. Bultena.

There are other factors that influence teaching in any classroom setting; indeed, often a cost-benefit decision is made (Calderhead, 1987). In these two classrooms, the cost in time was the greatest consideration against the benefit of student change in knowledge. Labbo, Field, and Watkins (1995) also found that a third-grade teacher was often constrained by time and based instructional decisions on whether there was sufficient time to allow her to present a lesson. The astronomy unit was taught toward the end of the school year, and the teachers began to feel constrained by the limited time they had left in the school year. When an idea or concept took more than the available time to address, the teacher decided not to respond. One such example was the idea of constellation in Ms. Shelton's class. Ms. Shelton intended to deliver instruction on constellations and relate it to the story she had read at the beginning of the term, but was not able to find time before the end of school to do so.

Another reason for not addressing an idea was a teacher's incomplete understanding of the concept. When the teacher did not understand the concept, it was often heard but not addressed. An example is from Ms. Bultena's class, where the intern did not follow through in her discussion of the spinning of the earth because of her own lack of knowledge. However, when teachers had sufficient time to learn about a concept, they often used that idea as an impetus to their own learning. Both Ms. Shelton and Ms. Bultena read books and researched information about concepts about which students had questions, and then brought their research back to their classes. Again, the key was sufficient time to do the research and present it to the class.

An additional reason for not addressing an idea was lack of materials. Ms. Shelton wanted to demonstrate the movements of the earth, moon, and sun using a professional model, but was unable to locate one. Thus, she was unable to use that demonstration. She did use a teacher-made model, but thought she could do a better demonstration with a proper model. Her belief that a specific model would be required to present a concept could indicate lack of understanding various representations of a concept (Shulman, 1986, 1987).

Implications for Primary Science Teacher Education

Teacher educators must be aware that elementary teachers are sufficiently intelligent and resourceful to be able to find ways to increase their content knowledge if they are given the tools and shown the importance of doing so. Thus, elementary science methods courses can provide experiences wherein teachers can become confident in their abilities to conduct scientific investigations, confront their own ideas, and increase their own content knowledge. Another way to improve content knowledge may be to have interns practice teaching the content. At the conclusion of the current study, Ms. Harker held more accurate content knowledge of astronomy and planned to teach it again when she had her own classroom. Scholz (1996) found that the act of teaching influences subject matter knowledge. Having teachers practice lessons in content areas could improve their knowledge in those areas. This finding implies that providing time for preservice teachers to practice lessons can improve not only their pedagogical knowledge, but also their subject matter knowledge.

However, it is obvious that simple content knowledge is not sufficient in helping teachers in their abilities to teach science as inquiry as recommended in the reforms. It is necessary to help those teachers with the knowledge and experience further to develop their teaching toward the goals of reforms in science education.

In addition to knowledge of subject matter, knowledge of the learner is also crucial to recognizing and addressing student ideas. Ms. Harker did not recognize student responses as being serious ideas. The experienced teachers in this study were aware of the developmental levels and capabilities of their students, and were able to use that knowledge to help them present concepts in ways students could understand. Teacher preparation programs should take the information provided from experienced teachers and focus on understanding the learner. Preservice teachers need to be taught to recognize and interpret student responses as serious conceptions if they are to address these ideas appropriately in instruction. Coursework in educational psychology exists in teacher preparation programs, but primary students are different from intermediate, middle, and high school students. Without explicit instruction in those differences and the capabilities of students in primary grades, teachers will need to learn the same knowledge through experience. Primary children are capable of understanding many ideas and can engage in different activities. The role of early childhood education is to use the children's capabilities of learning from experience to improve their comprehension by creating opportunities for meaningful and challenging experiences (Paris & Cunningham, 1996). These experiences need to be concrete in that they must be something children can at least imagine while they are discussing the idea. One solution to the problem of noticing the differences of capabilities among students of different grade levels is to have preservice elementary teachers participate in internship experiences in both primary and intermediate grades. Providing preservice elementary teachers experiences in multiple grade levels will give them opportunities to note how children differ in their abilities with maturity.

Science educators should also note that primary teachers' main curricular goal probably includes development of their students as literate readers and writers. This goal must be kept in mind when helping primary teachers become effective science teachers. Previous research has found that the ability to read is a major factor in a child's choice to remain in school, and that early oral language development contributes to learning to read (Paris & Cunningham, 1996). Science can provide a purpose for oral language development and reading, which contributes to literacy development. It is possible that using science to help develop literacy can also help children stay in school. Helping elementary teachers recognize that science can be a tool to developing student literacy can encourage them to teach science. Elementary teachers are typically specialists in language arts and reading, topics they are comfortable and confident in teaching. These strengths in teaching language arts can be tapped to allow elementary teachers to use strategies they have developed and used in other subjects to help them provide science instruction (i.e., Dickinson, Burns, Hagen, & Locker, 1997). The teachers in the current study taught science on a daily basis with the knowledge they were helping students not only learn science, but also develop reading, writing, speaking, and listening skills. Science can connect to the interests students have about the world and help them develop literacy skills. It can provide a purpose for reading, writing, and discussion. In the meantime, students can develop more accurate conceptions of scientific ideas, building a new level of understanding on which new ideas can rest. Teachers in the current study developed language and discussion skills in their own students using science as a key motivator. Teachers should receive instruction in helping students reconcile and understand adult meanings of words with their own interpretations. It cannot be assumed that what an adult says will be understood by a 6- or 7-year-old as the adult intended. Teachers need to be aware of strategies for helping students understand the language of science, and for helping teachers themselves understand what students mean when they are talking about their understandings. It is important to help practicing teachers use their strengths, which they develop through experience, to become even better science teachers to match the reforms.

Finally, children's ideas in science influenced teachers in the current study to confront their own thinking about science content by questions that were raised by students. It is important for teacher education to provide elementary teachers with the tools to improve their own content knowledge when they are faced with teaching an area about which they are unfamiliar. Student ideas influenced the teachers' desire to improve their own knowledge. Dobey and Schafer (1984) found that teachers with an intermediate level of content knowledge increased their abilities to teach elementary science using inquiry strategies. These findings were confirmed in the current study in that the teacher with the intermediate level of knowledge was more readily able to address student ideas, which is a component of inquiry instruction. Content knowledge alone does not guarantee elicitation of, or response to, students' ideas. Teachers of primary students need to know enough about the subject matter to be able to recognize and address student ideas. When teachers are confronted with student ideas, it can provide a reason for them to improve their own knowledge.

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