

## Learning to Teach Science for All in the Elementary Grades: What Do Preservice Teachers Bring?

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*Received 15 June 2001; Accepted 14 March 2002*

**Abstract:** Implicit in the goal of recent reforms is the question: What does it mean to prepare teachers to teach “science for all”? Through a teacher research study, I have encountered characteristics that may assist prospective elementary teachers in developing effective, inclusive science instruction. I describe these strengths, link them to requirements for teaching, and suggest how science teacher educators might draw on the strengths of their own students to support teaching practices aimed at universal scientific literacy. My conceptual framework is constructed from scholarship concerning best practice in elementary science education, as well as that which describes the dispositions of successful teachers of diverse learners. This study is based on a model of teacher research framed by the concept of “research as praxis” and phenomenological research methodology. The findings describe the research participants’ strengths thematically as propensity for inquiry, attention to children, and awareness of school/society relationships. I view these as potentially productive aspects of knowledge and dispositions about science and about children that I could draw on to further students’ development as elementary science teachers.

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Good science teaching and learning for all children is the primary goal of current national reform efforts [American Association for the Advancement of Science (AAAS), 1990, 1993; Atwater, 1996; Atwater & Riley, 1993; Kyle, 1998; National Research Council (NRC), 1996]. Implicit in this goal is a question for teacher educators: What does it mean to prepare teachers to teach science for all? Several science education researchers have delved into what the goal of powerful science education for all children in the United States implies for teaching practice, particularly in diverse and urban settings (Calabrese Barton, 1998b; Cavazos, Bianchini, & Helms, 1998; Fradd & Lee, 1999; Gallard, 1993; Lee & Fradd, 1998; Rodriguez, 1998). Appropriate visions of scientific inquiry, as well as a good grasp of scientific concepts, appear to be central to these requirements (Lee & Fradd, 1998). Studies of preservice elementary teachers’ content knowledge and visions of scientific practice have indicated, however, that candidates for

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Contract grant sponsor: Spencer Research Training Grant, Teachers College, Columbia University.

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DOI 10.1002/tea.10049

Published online in Wiley InterScience (www.interscience.wiley.com).

elementary teaching are not strong in these areas (Atwood & Atwood, 1996; Bianchini & Colburn, 2000; Gins & Watters, 1995; McDevitt, Troyer, Ambrosio, Heikkinen, & Warren, 1995; Mullholland & Wallace, 1999). Programs and courses have been designed to support preservice students in developing their knowledge about scientific content and inquiry (McDevitt et al., 1995; Zembal-Saul, Blumenfeld, & Krajcik, 2000) and to help them become comfortable with inquiry models of science teaching as well as inquiry into their own teaching practice (Bianchini & Colburn, 2000; Bryan & Abell, 1999; Smith, Conway, & Levine-Rose, 1995; van Zee, 1998, 1999, in press). There are also efforts, in education courses as well as in research, that aim to help students develop more authentic conceptions of scientific practice itself (Akerson, Abd-El-Khalick, & Lederman, 2000; Calabrese Barton, 1998a; Richmond, Howes, Kurth, & Hazelwood, 1998; Rodriguez, 1998; Roychoudhury, Tippins, & Nichols, 1993–1994; Smith & Anderson, 1999).

Nonetheless, a prototypical picture persists of preservice elementary teachers as lacking what it takes to teach science. I do not excuse myself from this perspective and do not deny that there is plenty for our students, as well as ourselves as teacher educators, to learn as we try to implement the dream of teaching science well with all children. I have been inspired, however, to set aside a focus on what preservice teachers lack in favor of studying my teacher education students' strengths. Through a teacher research study, I have encountered characteristics that I believe assist prospective elementary teachers in developing effective and inclusive science instruction. My goal in this article is to describe these strengths, link them to proposed requirements for teaching science for all, particularly in urban public schools, and suggest how science teacher educators might draw on the strengths of our own students to support teaching practices aimed at scientific literacy for all students. I make the claim that realizing our commitment to the success of all children in science calls for an antideficit approach through which we seek out, identify, and nurture the strengths that our own students bring to teaching science for all.

The vision of science for all that I employ in this study is informed by explications of science literacy that go beyond those set forth in standards documents (AAAS, 1990, 1993; NRC, 1996). It is well agreed among critics of science and of these standards documents that science is a construction of Western, European societies (Calabrese Barton, 1998a; Harding, 1998; Schiebinger, 1993; Norman, 1998). The standards' definition of scientific literacy falls short of one that recognizes its interaction with social systems that construct science for their own purposes, whether they are oppressive, liberatory, or purportedly neutral (Howes, 2002; Rodriguez, 1997). An objectivist construction of science literacy, based in Western, middle/upper-class, White male ways of knowing and behaving virtually guarantees that the current exclusionary functions of science education will continue to prosper in schools. Our responsibility for educating all of the children in our pluralistic country demands something different. We would do better, as educators focusing on liberatory and egalitarian educational goals, to keep the boundaries of science porous (Calabrese Barton, 1998b), while also working to create stronger relationships between Western science and multiple knowledge structures and practices concerned with understanding the natural and human world (Hammond, 2001; Norman, 1998; Pomeroy). Only thus can we hope to create settings in which all students, and their teachers, will have the opportunity to develop as practitioners and critics of contemporary Western science.

I examine in this article some dispositions that I see in students preparing to become elementary teachers who are developing scientific literacy in themselves as well as in their students. I also illustrate how I might draw on these particular dispositions to engage students in applying pertinent insights. By dispositions I do not mean talents or knowledge, but outlooks, attitudes, and expectations concerning one's own relationship with science, as well as toward children as learners of science. To illustrate with an imaginary case: Preservice teacher Anna says

that “all children can learn science,” whereas preservice teacher Betsy states, “White middle-class boys excel at science.” I would expect Anna to be disposed to support all of her children in learning science. Anna would look to her curriculum and her instruction as causes for an individual’s failure, and develop ways to support particular children or groups of children as she gains experience in science teaching. Conversely, Betsy may well not question herself, but instead regard students’ struggles as endemic to their home culture, gender, ethnicity, race, or any other of a variety of causes that she considers to be rooted outside of the classroom, and thus beyond her influence. Of course, teachers and preservice students fall along a spectrum between these two points, although most of them will explicitly state in their teacher education courses that all children can learn science. Therefore, one might say that one can only collect indirect evidence for one disposition or another. My work here is meant to help us to think about this issue, and to elucidate what dispositions it is I wish my students to develop to learn to teach science well with whomever they encounter in their elementary classrooms.

### Science for All: Relevant Pedagogical Recommendations

Two domains of research and theory support my conceptual framework: that which studies and describes best practice in elementary science education, and that which describes the dispositions of successful teachers of diverse learners. I will outline each domain individually, then explicate the links between them that provide the rationale for this study.

#### *Elementary Science Pedagogy*

Science education reformers currently characterize professional science as both a specialized form of inquiry and as a body of knowledge consisting of descriptions and explanations of the natural, social, and technological world (AAAS, 1990; NRC, 1996; Vellom & Anderson, 1999). For example, in *Science for All Americans*, science is defined as a way of learning about the world as well as a set of ideas about the world (AAAS, 1990, pp. 3–13, 188). The AAAS proposes that students in the early grades become familiar with their surroundings and learn to observe and study them in scientific ways through experiences with the basic empirical and analytic tools of science. This vision of science (along with mathematics and technology) is applied to pedagogy as follows: “To understand [science, mathematics, and technology] as ways of thinking and doing, as well as bodies of knowledge, requires that students have some experience with the kinds of thought and action that are typical of those fields” (p. 188). The creators of this influential document view scientific content itself as a tentative body of knowledge; thus, the teacher is advised not to present herself or himself as an “absolute authorit[y] whose conclusions are always correct” (p. 191), and to avoid creating a classroom in which “getting all the right answers [is] the main criterion of success” (p. 192). The authors of *National Standards for Science Education* (NRC, 1996) are also explicit about the dual roles of inquiry and content in science, stating that young children should learn to use practical as well as intellectual tools such as sharing data and analyses with classmates and making connections between evidence and explanations (p. 122). These documents do not argue that students should not develop understandings of the natural world based in scientifically established concepts. Rather, the point is to portray science as an ongoing construction of explanations of natural phenomena, developed through rules of evidence and argumentation. This model highlights the teacher’s role in guiding children to create scientific questions and the inquiries to address these questions (p. 121).

Related to the above discussions is the understanding of science as a “discourse-practice” (Cherryholmes, 1988, pp. 1–15) with rules for creating and evaluating knowledge about the world

(Driver, Asoka, Leach, Mortimer, & Scott, 1994; Lee & Fradd, 1998; Moje, Collazo, Carrillo, & Marx, 2001; Rosebery, Warren, & Conant, 1992; Smith & Anderson, 1999; Vellom & Anderson, 1999; Warren & Rosebery, 1993). Neither the norms of this discourse-practice nor the knowledge it generates will be discovered through children's unguided interaction with the natural world (Driver et al., 1994; Roth, 1991, 1996). It is the teacher's role to explicate the norms of scientific discourse and to scaffold the construction of scientific concepts. The successful teacher will provide activities, including discussions and physical experiences, that allow students to encounter new ideas as well as phenomena, and to discuss these ideas fruitfully with each other and their teacher (Bianchini & Colburn, 2000; Driver et al., 1994; Roth, 1991; Shapiro, 1994). Ongoing attention to learners' thinking is essential to create appropriate scaffolding (Gallas, 1995; Roth, 1996; Shapiro, 1994). Requiring knowledge of both the discourses and content of science, these pedagogical considerations are doubly important in teaching children whose first language is not English and thus may require more direct instruction in the verbal conventions of science (Ballenger, 1996; Lee & Fradd, 1996; Moje et al., 2001).

### *Teaching Science Well with All Children*

An assumption of *Science for All Americans* is that all children are capable of and "expected to study the same subjects at the same level as everyone else and to perform as well" (AAAS, 1990, p. 192). Excellent science teaching for all children will include the practices described in the previous section, or what Lynch calls "just plain good teaching" (2000, pp. 189–192). However, "just plain good teaching," as currently defined in standards documents, is not in itself sufficient in educating all children in science (Ladson-Billings, 1995a; Lynch, 2000, p. 16). In the interests of enacting the imperative to educate all children well in science, a great deal can be gained by attending to the literature concerning teaching diverse populations (e.g., Delpit, 1995; Hollins, King, & Hayman, 1994; King, Hollins, & Hayman, 1997; Ladson-Billings, 1994, 1999; Nieto, 1999; Oakes & Lipton, 1999; Sleeter & Grant, 1993). Central to this literature is the belief that all children can learn deeply and well and attain academic success (Ladson-Billings, 1994, 1995a; Huber, Kline, Bakken, & Clark, 1997; Oakes & Lipton, 1999; Nieto, 1999). The confidence in all children's "capacity to learn" (Celia Oyler, personal communication, November 3, 2000) is accompanied by respect for individual children and the families, cultures, and communities in which they participate, and the will to learn from these families, cultures, and communities about how better to teach their children (Delpit, 1995; Ladson-Billings, 1994; Nieto, 1999; Rosebery, McIntyre, & González, 2001). This requirement is grounded in a commitment to identify strengths that children bring to the classroom, thus providing a corrective to the deficit model that continues to guide much of the teaching of children of color and children in poverty. A comprehension of the role that schooling plays in maintaining (and sometimes challenging) unfair social structures can also dispose a teacher toward pedagogy that actively resists the perpetuation of injustice (Collazo, 1999; Delpit, 1995; Dillard, 1997; Haberman, 1996; Howard, 1999; Ladson-Billings, 1994; Moll, Amanti, Neff, & González, 1992; Nieto, 1999; Valdés, 1996). Basic to the conclusions of this work is the recommendation that teachers of science respect and use the knowledge of the natural world that students bring from their home cultures, and value rather than reject students' first languages (Atwater, 1996; Ballenger, 1996; Gallard, 1993; Lee & Fradd, 1998; Moje et al., 2001; Rosebery, Warren, & Conant, 1992).

Science education for all students would engage students in exploring a variety of methods for understanding the natural world, methods that are neither mystical nor philosophical but in interaction with the phenomena under study, and through communication with others like and unlike oneself, rather than through textbook dogma or sanctified proclamation (Collazo, 1999;

Gallard, 1993). Coupled with this would be the comprehension of scientific activity and the knowledge it produced as ineluctably embedded in the social and political institutions and habits from which it takes its means and creates its products (Norman, 1998). This vision of scientific literacy, therefore, is one that enables its possessors to critique the questions that scientists ask, how and why particular research projects are funded by governmental and corporate institutions, and in what ways scientific knowledge and connected technologies are used to support or work against social justice in a democracy.

Teacher dispositions play a large role in determining whether socially equitable education will become a reality (Delpit, 1995; King, Hollins, & Hayman, 1997; Nieto, 1999). The brief review above suggests that teacher dispositions that support science for all include a commitment to study and use children's cultures and knowledge in teaching along with the ability to represent the discourse-practice and content of contemporary Western science. The teacher's awareness of and critical stance toward the relationships between schooling and social inequities can provide a personal and social context for the actualization of these dispositions. I would expect few beginning teachers to fill this tall order. Instead, I am proposing that teacher educators adopt a recommendation that has come from the work in teaching in diverse contexts, and look for the strengths that aspiring elementary teachers bring with them to science education courses. In doing so, we can model this aspect of teaching science for all as well as the more generic recommendations that have come from the science education literature and standards documents. As science educators become familiar with our own students' strengths, we can make connections to the educational content we have chosen (e.g., the dispositions and teaching expertise described above).

#### Research Method: Teacher Research as Praxis and Phenomenology

This study is based on a model of teacher research framed by the concept of "research as praxis" (Britzman, 1991; Lather, 1986a). Research as praxis attempts to effect change directly through research, rather than eschew interference with the aim of studying things as they are. Owing to this stance, the researcher's values are openly stated, both throughout the research process in any written or presented products. Therefore, the participants in this study knew that I was a proponent of science for all. In addition, my feminist convictions actively led me to value and place at the forefront women's ideas and experiences. This choice also makes sense in light of the fact that most elementary teachers are women.

I follow Lather (1986a) and van Manen (1990) in recognizing that themes do not arise purely from the data, but are influenced by the researcher's theories and values; the interaction between theory and data is reciprocal, and open for reinterpretation. The dangers of the researcher seeing only what she wants to see in this "openly ideological research" (Lather, 1986b) are mitigated by three factors: the researcher's explicit statement of ideology (here, an antideficit approach), the inclusion of data that allow the reader to judge the validity of the researcher's conclusions, and sharing of the analyses with the research participants.

A phenomenological perspective generated my analysis. When using a phenomenological writing approach, one favors a depth over breadth analytical process. Thus, I focused on a few students, and a few ideas, to develop particularized stories to exemplify large issues (Adan, 1991; Bogden & Biklen, 1992; van Manen, 1990). I named and developed themes through long-term analysis, with feedback from the participants during and after their participation in our interview-conversations. I also used their writing to see whether these developing themes were supported, contradicted, or complicated by the participants' words. I worked with a theme as long as it was productive and discarded or changed it when it ceased to be productive. In this process, a

productive theme was one that was fruitful for links to the literature and to experiences of myself and my students: it made sense (Richardson, 1994), reflecting a strong thread in the data. A nonproductive theme—on its way to being discarded—was one that oversimplified the data or led to so many contradictions that it became unworkable as an analytic lens. For example, early in the analysis, I believed that I could make connections between students' ideas and goals and Ladson-Billings' (1994) configuration of aspects of "culturally relevant teaching." As I created a written argument to share with others, I realized that the data fell far short of Ladson-Billings' description of culturally relevant teaching. I therefore let go of this framework for analysis and created themes that I thought better organized these participants' current positions in terms of teaching science for all.

Phenomenological analysis is inseparable from the writing process itself (Richardson, 1994; van Manen, 1990). In fact, "responsive-reflective writing and rewriting is the very activity of doing phenomenology" (van Manen, 1990, p. 132). This subjective process is one that creates different results with different researchers, even if they are working with the same data. However, it is hoped that my unique results will nonetheless ring true to readers, or at least trigger questions and ideas, as this, rather than scientific exposition, is the goal of phenomenological analysis.

### *Data Collection and Analysis*

Data sources for this study consisted of assignments that were part of the elementary science methods course that the participants took with me; "interview-conversations" (Howes, 2002), which were open-ended discussions about science and science teaching among myself and participants; e-mail communications; and written and spoken responses of participants to ongoing analyses. Seventeen interview-conversations were conducted, 12 during the fall semester and 5 late in the spring semester; 13 students were involved. Participants' attendance at these conversations varied. Some of the sessions were one-on-one with me; others were conducted with 2 or more participants (up to 5). They lasted from 1 hour up to 2.5 hours. This phase of the research reflects a type of collaborative teacher research Cochran-Smith and Lytle termed "oral inquiry" (1993, pp. 30–33), as the participants inquired into their own and each other's thinking about teaching science to all children, devoting especial attention to urban settings. It was during this phase of the research, which was unstructured to allow the students the freedom to discuss their immediate concerns, that I developed questions and tentative themes to structure my own inquiry.

My first attempt to comprehend the data took the form of a list of concerns that the research participants had shared during the interview-conversations (Table 1). Although this list served as a guide for further discussions with the research participants, it was lacking in particularity. In fact, when I shared this list with participating students, they did not seem intrigued with or interested in delving into this list in any more detail than I had provided. And as I reviewed this list from some distance, another reason occurred to me for my dissatisfaction. It is the very focus on concerns and problems that no longer fits these data as I have continued to examine them, nor does it represent the people who have produced the texts (McWilliam, 1994, p. 36) which I am calling *data*. These students are more than their concerns.

Some items on the list stand out as more positive than others: namely, the assumption that all students will do well in science, and the interest in creating and practicing science for all. These initially encouraged me to look for strengths that these people were bringing to their thinking about science teaching. I knew from years of teaching and a multitude of autobiographical accounts of science experiences read that the overwhelming majority of preservice elementary teachers have had unpleasant, negative, and even hurtful experiences as science students in school. However, as I looked more closely at the accounts (both written and oral) that these research

Table 1

*Initial themes: desires and concerns for science teaching with children*

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- A felt need for examples of ways to put what one wants to do into practice. Specifically, a strong desire for activities to pick and choose from as needed.
  - A desire to give children choice in what to study in science, and how.
  - Mandated curricula: Various perceived as useful and supportive (when one is in control of the daily implementation) or constraining (when one is required to follow the curriculum to the letter).
  - Limiting student teaching situations (mandated curricula; cooperating teacher's lack of interest in science) vs. supportive student teaching situations (mandated curricula; cooperating teacher's encouragement that one take over the classroom science teaching).
  - Importance of community building in the science classroom; respect, working together—"because that's what scientists do."
  - Idea of play connected to hands-on experiences—when is it good learning? How do we define it?
  - Assumption that "all of my students will do science." Beginning to come across difficulties, e.g. the lack of engagement of many girls in science.
  - Stumbling blocks in creating and practicing science for all: mandated curricula; short class periods; lack of access to materials and information (e.g., biographical resources about women and minorities in science); and high-stakes, standardized exams.
- 

participants were providing about their relationships with science, I discerned an equally powerful line of thought running up against the ubiquitous alienation from science stories. Upon delving into their autobiographies and philosophies of science (two required assignments in the course research participants had taken with me), I found descriptive and even passionate reports relating why these preservice teachers had decided to return to their love of inquiry, and or maintain their love of nature, even in the face of unpleasant experiences in school science. It was in this analytical encounter that I had my first inklings of love as a powerful strength that these students bring to teaching science for all. I was also taken with the poetry in their language when writing about their experiences with the natural world, as well as when writing about their students.

As I transcribed tapes of the interview-conversations I noted places where participants were recollecting their own science experiences, speaking of their relationships with and attitudes toward children and schooling, and indicating theories and plans related to teaching science. Based on the richness of the data in reference to these three concerns, I narrowed down the participants to four. I then examined these four students' coursework alongside the transcripts. After several iterations of written analysis (in close concert with the data) I eventually fixed on the three themes (strengths) upon which I expand, in the findings section.

*Research Participants*

The group with whom I conducted this research attended an elite private college in a cosmopolitan, multiracial and multiethnic city. The four students represented in this report each participated in at least two interview-conversations. In the process of writing this article, I asked these participants to provide feedback on my analysis of their thinking. Their responses have been incorporated into the final version. Each participant chose whether to use a pseudonym. Brief descriptions of these four participants follow.

Rebecca (a pseudonym), a White woman raised in a mid-Atlantic state, is a doctoral candidate who was pursuing certification concomitantly with her degree. She referred to herself as "a late bloomer" who had come to believe that there were "positive aspects of science which I have not yet explored in any depth, and so I am actively taking advantage of the opportunities when they arise." Rebecca's success in an 8-week-long substitute position persuaded her to consider

seriously becoming a science teacher in an elementary setting. Many of the students with whom she worked were English-language learners from Spanish-speaking homes; Rebecca's fluency in Spanish added to her confidence in this teaching situation. This first extensive science teaching experience was a very valuable one for Rebecca. She became "obsessed" with this "little substitute teaching job. . . . Everything we did, every place that I was, would inspire me with an idea to do in science."

Kathleen (real name) is an African American woman who grew up near a major metropolitan center on the East Coast. As an adolescent, she planned to become a chemical engineer, but she decided in 11th grade that "I don't get [math]; it does not click. . . . There [went] all hopes of . . . being a chemical engineer." Despite her misgivings about her mathematical talents, Kathleen, as Jane and Patricia (see below), has been successful in various stages of her scientific schooling. Nonetheless, she considered her felt lack of talent in math an unbreachable barrier to a career in professional science. For several years she has been a counselor and administrator for a girls' summer camp; she brought this experience to her talk about children and science education. Kathleen left the elementary preparation program in favor of the secondary preparation program in English education. She continues to express her interest in the natural world through both her role as a camp counselor and her literary interpretations of the environment (Howes, Jones, & Rosenthal, 2001).

Patricia (a pseudonym) is a White woman in her mid-twenties from the upper Midwest. She did well in high-school science and continued on in chemistry in college; she also considered becoming a chemical engineer. However, she decided that the rewards she received through grades were what were keeping her in science. She also stated, "When I started thinking about it, I was like, 'I enjoy the [chemistry] classes, but doing it for my life?' . . . It just sounded awful!" She changed her major to English, where she felt her creative needs were better met. On leaving college, Patricia did not intend to enter teaching immediately. However, an opportunity to teach at a Montessori preschool proved too hard to resist. Her father, himself an educator, told her that as a teacher, "You don't get any respect; you don't get any pay." This warning notwithstanding, Patricia chose teaching over a more lucrative and prestigious career, and is currently working in an urban public elementary school.

Jane (real name) is an African American woman whose family's several moves during her childhood offered her a variety of learning opportunities, both in school and out. She loved science as a child and had many positive school science experiences. She gave her parents considerable credit for their example as straight-A students through school (her mother considered becoming a chemist), for encouraging her questions, and for providing her with multiple experiences through vacations and different living situations. Similarly to Patricia, Jane became bored with her course of study in college: "I got into my second year of computer science and I realized: I am not doing this for the rest of my life." She had been tutoring her classmates since third grade and decided to make a profession of it. As with Patricia, both of Jane's parents were teachers. Jane is currently teaching in an urban Midwestern school with a majority African American population, in the same city in which her mother is an elementary teacher.

As were three of these research participants, many of the elementary education students I encounter were successful at school science in terms of grades. That does not mean, unfortunately, that they learned scientific concepts deeply or learned to view themselves with confidence as science learners or as having the potential to become professional scientists or competent science teachers. In addition, even when students feel that they have the ability and the background to pursue scientific careers, they often choose to leave science for work they see as more rewarding. Both Patricia and Jane lost interest in science in school—successful as they were, they decided that they did not want to make a career of what they perceived to be boring and repetitive work.

Kathleen decided to opt out of chemical engineering when she encountered mathematics that she felt was beyond her capabilities. All three of these participants, then, fit into a picture of women who have learned to distance themselves from science, particularly as it is conducted in academic settings. Rebecca had never thought of herself as a science person, yet she found herself rethinking her own attachment to science; the realization that questioning is a valuable trait for a scientist helped her to believe that she could conduct viable scientific instruction.

#### Findings and Interpretations: Strengths in Learning to Teach Science for All

The themes that organize my representation of these four preservice teachers' strengths in reference to learning science for all are presented in Table 2. Here I also summarize pertinent themes from relevant literature on teaching science for all, and indicate the direction in which I believe teacher educators can help preservice elementary science teachers move to better practice science teaching that supports the learning of all children. The table also includes generalized recommendations for making use of students' strengths in developing such a pedagogy. These recommendations in themselves are not original. My purpose is to employ the widely accepted egalitarian goals of science education by connecting them to a posited set of preservice teachers' strengths. In this section, I describe these strengths as inferred from the four participants and suggest ways to build on these strengths to support these and other aspiring teachers' growth toward inclusive teaching practices in elementary science.

Table 2  
*Linking preservice teachers' strengths to teaching science for all*

Strengths Categories	Links via Teacher Education	Teaching Science for All
Propensity for inquiry	<ul style="list-style-type: none"> <li>● Model inquiry teaching that interweaves scientific processes with content learning.</li> <li>● Focus on students' interests in natural phenomena.</li> <li>● Help students critique their own school science experiences.</li> </ul>	Appropriately represent the discourse and content of contemporary Western science.
Attention to children	<ul style="list-style-type: none"> <li>● Pay attention to our students' questions, knowledge, and lives and explicate them in our teaching.</li> <li>● Help students expand their interest in children to include children's thinking, families, and communities.</li> <li>● Help students compare different cultural ways of understanding and interacting with the natural world.</li> </ul>	Investigate and use children's cultures and knowledge in science teaching.
Awareness of school/society relationships	<ul style="list-style-type: none"> <li>● Help students expand their understandings of urban schools and school systems as political entities.</li> <li>● Help students critique their own school science experiences.</li> <li>● Engage with and nurture the knowledge that students of color bring to science and science teaching.</li> </ul>	Practice a critical and activist stance toward the relationships between schooling and social inequities.

The three strengths discussed below are: propensity for inquiry, attention to children, and awareness of school/society relationships. Propensity for inquiry involves curiosity and questions about the natural world, and a desire to base curriculum in students' questions. Attention to children involves an appreciation of children's fascination with the natural world, a respect for children's intellect and ability to wonder, and a recognition of children as individuals. The third strength is that of awareness of school/society relationships. These strengths are not end points that ensure the four women in this study will inevitably and automatically become good science teachers. They are strengths that I view as potentially productive aspects of their knowledge and dispositions about science and about teaching children that I could draw on to further their development as elementary science teachers.

### *Propensity for Inquiry*

Each of these participants described an interest in inquiry about natural phenomena. Rebecca carried this interest into her teaching; her propensity for inquiry-based pedagogy became evident through her recounting of a long-term substitute teaching experience in an urban school with a largely Spanish-speaking population. She herself had become open to questioning as a way to create science learning experiences; she became "aware of the fact that I was afraid of science . . . and found others who agreed and then got through that and moved on to, 'Okay, we knew we were afraid of science and we're not anymore. Now we realize that no one knows everything, now we realize that questioning is okay' . . . I was really confident going in to teach it to those kids." She began by asking the children, "What would you like to learn?" Rebecca stressed that focusing on students' questions gave her a structure for creating science curricula for all of the children in the school, Grades Kindergarten through 6, for whom she was responsible.

One class chose chemistry. They would research the chemicals in products at home, and come back to class with that. They would report . . . what was in which products. Then I would say, "Interesting. Look, there's sodium in these three things. But they're all used for different purposes. Why do you suppose that is?" I found the process of questioning to be a real safe haven for me, when it used to be an avenue of fear [and] an admission of ignorance. . . . Kids, after awhile, got used to the fact that I didn't necessarily have the answer. In fact, they wouldn't *come* to me for the answer; they would go to one another, or they would research it, but they kind of knew not to expect me to answer it. They began to come to me more with observations, and sort of a collegial question, "Wow, I wonder why it does this?"

Thus, Rebecca, who did not feel that she was strong in science, was able to create intriguing and open-ended science activities for her students by eliciting their interests, gathering examples of experiments connected to those interests—some of which she got from prepared curriculum, others of her own design—and, as she describes below, introducing the students to the scientific processes of observation, documentation, and replication:

Then I started introducing things like documenting what you'd done. How to make observations and chart what you've done. . . . A lot of them would come to me with these purple globs, you know, things that they wanted to do again! . . . We'd talk about how you document what you use, and then how you can alter it and compare it.

Rebecca removed herself as the sole authority for knowledge, creating a pedagogical position in which she felt comfortable and was able to use her knowledge of scientific discourse-practice to guide the children toward more systematic inquiry. She drew on the children's desire to share and duplicate their creations to support the development of their science process skills. In Rebecca's classroom the teacher did not control but guided the inquiry, introducing children to ways of scientific recording and written communication.

Kathleen's interest in inquiry is exemplified by a continual outpouring of her own questions. Although our class is long over, she continues to send me science questions over e-mail. In addition, she designed and conducted a lesson in which she asked middle-school students in an English class to write down things about which they wonder. She described to me her excitement about the questions the students came up with: for example, "Why are the planets round?" When I told her that in my analysis I had begun to think "Kathleen loves questions," she responded, "Your statement does make sense to me. I think that now I think more about why the world is the way it is. Partly because of class [elementary science course] and partly from my students." Kathleen considered herself capable of scientific thinking and activity. She said, "I'm not going to be high caliber; physics and chemistry are still basically *out* for me [but] I can still be scientific, in terms of method, how I look at the world, how I experience and deal with the world." She enjoyed the open-ended inquiry that was basic to the science methods course, and cited it as an important part of the course for her. She stated that she now "feel[s] free to go left, right, down the middle, there's not only one way. Which is actually rather refreshing . . . because science is about creation and whatever, so, obviously it can't just be one right answer." Kathleen links questions to her conception of inquiry, together with a recognition that there "can't just be one right answer." Informed by her belief that there *is* something called scientific method, her view of method is not rigid—not the mythical *the* scientific method—because the world is too complex for simple answers that can be perceived by simple procedures. Kathleen also argued that it is desirable for the teacher to be open about her lack of knowledge: "If we . . . say, 'I have no clue; we'll find out together,' that's different from . . . teachers [who are] not willing to go with you on the journey. They know it and they'll tell you and you get it or you don't. And they're not going to get dirty with you."

I claim Rebecca's and Kathleen's willingness to pursue questions in an open-ended fashion to be a strength in designing authentic inquiry opportunities for children. Kathleen and Rebecca stress the importance of scientific processes and a conviction that there is more to learning and teaching science than a single path or predetermined answer.

Patricia's relationship with scientific inquiry is demonstrated by a story about finding two skulls as a young child. She took the skulls to her mother, who helped her identify one as a dog's skull and the other as a gopher's. For show and tell time, she "took the dog skull in 4 weeks in a row, and was disappointed and upset every time I came home with it." She recalls her mother saying that Patricia "just didn't understand why people weren't as fascinated as I was and that I eventually decided not to take it in to school anymore." As successful as Patricia is in helping us feel her childhood hurt, this incident did not kill her affection for the natural world and the intellectual tales it inspires. As an adult, she wrote:

What I've discovered is that I love stories and logic—I love clear but complex explanations of interesting things. . . . I find our planet, our natural world fascinating and complex and mysterious and beautiful and inexplicable. I remember feeling a sense of satisfaction and glee to hear that there were species in the rainforest that scientists had never discovered and studied. . . . Those feelings of excitement and wonder have sometimes, but rarely, been triggered in one of my traditional science classes.

In contrast with Rebecca and Kathleen, Patricia's propensity for scientific inquiry is not directly linked to questioning. Her fascination with the world and the science that explains it is more diffuse and "wonder-ful." The intellectual satisfaction she feels when she learns a scientific concept does not dull her sense of ongoing mystery and the inexplicable. However, the excitement and wonder that was such a strong piece of her intellectual relationship with the world was rarely encountered in school. In Patricia's words I first noted a strong implication in my students' comparisons of science outside school and science inside school: The natural world is fascinating, but school science experiences do not generally encourage or reflect this fascination.

Jane's early recollections of science focused on her own childhood questions and her parents' positive response to them. She, as did Patricia, distinguished between her outside-of-school engagement with nature and her school science experiences. She described her adolescent years in California, where school science was not intriguing. Notably, her experiences with nature outside of school were—collecting rocks in the mountains and shells at the beach; figuring out "how to get a bird to trust you enough to eat food out of your hand"; and studying water conservation, smog, and earthquakes. As she wrote, "The in-school science was not memorable to me, but the surroundings were a feast of science." Her interest in school science was further muted as she proceeded to secondary school:

After the torturous experience of knowing in the eighth grade that the living, hopping frogs that were in the aquarium at the front of the room would soon be dead, with their guts open in front of me, I decided that I had no wish to study advanced level biology. . . . Mr. B. . . . required laborious lab reports which I hated and refused to complete. . . . The teacher also graded off points if the result was not what was intended according to his book. . . . Sadly, I realized that my teachers could have captured all of the things that I had with me . . . and developed a strong, enthusiastic scientist. Instead, now I struggle to attach words to knowledge, and relate experience to abstract concepts.

Jane's story about high school science demonstrates how her regard for "living, hopping frogs" clashed with the requirement that she dissect them, an activity that would require that she end their hopping and living. Her previously open-ended, question-grounded personal explorations of the world could not be squeezed into "laborious lab reports." As with Patricia, the distinction between science outside school and science inside school is clearly explicated. The physically grounded issues and phenomena that she studied on her own time and in her own ways are presented in contrast to school science, where form trumped content: A procedural script and a single right answer, not the questions or the exploration itself, had become the goal.

These four prospective teachers' representations of scientific inquiry focus on questions and explorations—their own and their students'. Their inquiries arise from interactions with the world both inside and outside the classroom. These new teachers are well placed to create open-ended inquiry opportunities for their own students. Science, of course, is about more than questions and explorations, and teachers can likely create better inquiry activities if they have a strong grasp of the applicable content. Nonetheless, Rebecca reflected the standards' recommendation that she remove the focus from herself and the right answer, to take advantage of children's curiosity and support their learning of inquiry processes. Kathleen, Patricia, and Jane are personally intrigued with wide-ranging explorations of the natural world. As their science education professor, I could capitalize on their captivation with scientific inquiry to encourage their own inquiries, and, through explicitly modeling the process, support their use of inquiry-based teaching in their own classrooms.

My expectations have been shaped by my teaching experience to view alienation from science as typical among prospective elementary teachers. Hence I was surprised to encounter strong

interest in the practices of science among these research participants. As I found here, however, these four students were disposed to explore the natural world through scientifically inflected empirical and intellectual methods. However, they did not experience this kind of exploration as students in the bulk of their formal schooling. Therefore, I do not believe their school experiences are mainly responsible for their professed interest in scientific inquiry. They speak warmly of out-of-school experiences—Jane’s seashore explorations, Patricia’s gopher and her discussions with knowledgeable friends about science, Kathleen’s camp experiences—and they contrast the artificiality of school science with the richness and complexity of nature. Importantly, they also noted a disjunction between what they believe is valuable and intriguing in science and what they normally experienced in school, even when they were successful in school science.

### *Attention to Children*

Preservice elementary teachers often claim their love of children as a motivating factor in their career choice. An important aspect of learning to teach is recognizing that children are intellectual beings, and that it is a main object of the science teacher to engage children in thinking about particular things (e.g., natural phenomena such as growth and light; humanly created artifacts such as measurement devices and microscopes) and particular ways of thinking (e.g., observing, predicting, hypothesizing, testing, and explaining). Studying students’ thinking is a vital part of this pedagogical challenge. The participants in this study do not explicitly propound this view. However, they see children’s conceptions as intriguing; they also assert the importance of respecting their students as learners and as individuals.

Kathleen is adept at noticing what children notice. In a story about science experiences in which she engaged with girls as their summer camp counselor, she included:

They’ll even notice the difference in say, color, of plants that are on the road and get a lot of sun as opposed to ones that are under the dining hall and don’t get as much sun and have a different color. How these two are similar and yet they’re different. They *notice* all of that stuff.

During a summer teaching experience in Washington, DC, Kathleen wrote me, “I had the best time today. My students were talking about really gross things like what’s inside of hot dogs and ‘secret’ ingredients in peanut butter. . . . Children are very fascinating creatures and they think about the weirdest stuff.” The delight that she takes in wondering about the world is mirrored in the delight she takes in seeing her students wonder.

Patricia indicates her attention to children through a reflection on her Montessori teaching. Here, her regard for children intersects with her fascination with the natural world:

Toddlers especially were children whose main tasks in life were to figure out what was going on, how this place worked, to observe and absorb everything around them. And my job was to observe them, maybe figure out how they worked. . . . The concentration, the curiosity, the *wonder* about everything. . . . It was a joyful experience to watch ants with them, to walk 10 feet through tall grass, to watch birds at a bird feeder, to just watch a thunderstorm. . . . We’d talk about the rain and the water and what was getting wet outside and where the birds go . . . and about puddles and wind and the noises, the thunder and the lightning and the dark clouds . . . and where the sun was and when we would see it again.

Her account of the activities in which she engaged the children (and herself) rings of an immediacy that reflects the joy found in experiencing nature directly. The skull-collecting child

Patricia seems re-enlivened as she accompanies her young charges in their own experiences with and thinking about nature. The adult Patricia, however, is conscious of her responsibility to attend to the children's learning, to "maybe figure out how they worked."

Rebecca enriched her relationships with her students by finding out about them as individuals through their families. She sent a letter home every Friday, in Spanish and English, describing what had gone on in the children's science classes that week; about these letters, she said, "Even though there was *plenty* of reason to be sending home bad news . . . I resisted the urge to mention it." Through phone calls home, she also maintained more direct contact. Here she benefited from her Spanish language skills:

Every weekend, I would randomly choose five parents and call them. . . . My first questions would be, "So, tell me about your kid. What are their strengths, what are their weaknesses? What are the things that I can't see?" They would tell me the most wonderful things. . . . The kids looked totally different the next day. I walk into the room and I'm, "I *know* you. I *know* you now! Now you're not this pain in the *ass* who comes in here every day with an attitude. . . . Because now I know all about you."

Although Rebecca taught in a progressive school, the setting was not ideal. She had over 30 students in some classes, for a total of over 200, in a small space with few materials. Despite the obstacles, Rebecca focused on the responsibility of getting to know her students, to teach them more effectively. She characterized this approach as a kind of love—a way of knowing the children as particular beings, with pasts, families, special talents, and problems. Rebecca explicitly refers to love of children as an important part of teaching. She does not mean a kind of universal or sentimental love, but, as she puts it,

You have to *love* the kids—not love *kids* but love *the* kids that are there with you, and you have to love them as if they were your own. . . . That has to be your feeling, as a teacher. Because they're not going to listen, they're not going to learn from you, they're not going to care what you have to share with them, if they don't feel like there's love.

In turn, Jane's love for her son did not mean that she could predict his scientific thinking; in fact, she noted that one of her most effective learning experiences grew out of an assignment in which she was required to interview a child about a specific scientific concept. She chose to interview her 8-year-old son and transferred what she learned from this experience to her thinking about planning science instruction. As she reported, "[I was] surprised by the fact that my own *son* has concepts that I didn't realize that he had about science. Really, that was sort of earth-shattering. . . . To know so clearly that you could go in there with the best intentions in the world and still not have a clue about what your students are thinking." She planned to address this issue, and try to learn what her students are thinking by "taking my lesson plans and making sure that there's time to *talk*, and time to understand what the students are thinking."

Attention to and intellectual understanding of particular children do not always go hand in hand. However, preservice elementary teachers often claim their interest in children as their reason for teaching. This generalized interest, or love (which, sadly, can turn into resentment in the face of the difficulties of teaching real children) may be replaced by an interest that is based in respect and particularity (Osborne, 1999). As Rebecca said, "You have to love the kids—not love kids but love *the* kids that are there with you, and you have to love them as if they were your own." A teacher's respect for and attention to her children's knowledge, beliefs, and ways of knowing play a vital part in teaching children well (Gallard, 1993; Gallas, 1995; Ladson-Billings, 1994;

Lee & Fradd, 1998). Might we use preservice students' love of children to draw them into the kind of intellectual attention required for good science teaching?

### *Awareness of School/Society Relationships*

The linguistic and cultural experiences of most preservice elementary teachers are different from those of children whom they will encounter in urban public school classrooms<sup>1</sup> (Haberman, 1996; Ladson-Billings, 1995b; Sleeter, 1993; Zeichner & Hoefft, 1996). Not all new teachers are cognizant of the importance of bridging the cultural distinctions between themselves and their students as a determinant of their teaching success. Patricia is at a stage in her teacher development in which she feels less than competent in teaching in all children. I see this recognition as an asset, as she has placed herself in a good position to learn about and from children different from herself. Although she was offered "several very good positions in [nearby suburbia]," Patricia chose to teach in the city, at a school that is a "wide mix of social-economic classes, about 40% White." Patricia and Rebecca both seem to believe that schools, as they have experienced them, will create more barriers than supports for the kind of teaching they want to practice. They do not bring an explicit political stance to this tension, but a personal understanding that if they find a school that nurtures their growth, they will be able to become good teachers for all children. As Patricia wrote,

I felt torn—first, I in many ways wanted to and felt obligated to use my knowledge as a teacher in a city school. On the other hand, I felt that it could be a selfish move, something to make myself a hero, but also could set me up for disaster as a poorly supported first-year teacher. It was more about the potential complexity of the whole situation, not simply about the *children* I would encounter. . . . As it turns out, I do work in . . . a progressive small public city school where I can work with a diverse and sometimes struggling student body but feel very supported in my teaching.

Patricia's awareness that most schools do not support new teachers allowed her to stick to her commitment to teach in the city. Her knowledge enabled her to seek out a school that would recognize her sensible desire for support in practicing the kind of teaching that matched her pedagogical beliefs and aspirations.

Rebecca had also hoped to work in the city, as an elementary science specialist. Her first interview was positive, and because the school embraced practices she valued, Rebecca was deeply disappointed not to be offered the job. Her other five interview experiences were uniformly dismal. These interviews were to fill floating positions, which meant that she would not have her own room, but had to spend her day "traveling around with a cart. . . . I had an entire laboratory on this cart!" Each of the six class periods would be 40 minutes long, which she thought was "ridiculous," not nearly long enough to "do anything significant in science, particularly when you want to have kids have quality time." As she put it,

The *structure* of the positions did not facilitate learning. And no one seemed to care about that. And no one was willing to change anything, to be risky, take a chance, and change the system. . . . I just feel . . . like I'm in the wrong tribe. . . . So I've decided that I really won't work in those kinds of environments.

Rebecca's rewarding urban public school teaching experience in the spring of 1998 provided her with confidence and the desire to continue practicing in ways that focused on children's interests and showed respect for each individual child and her or his family. I believe that when she entered the job market, Rebecca perceived that her teaching would be hopelessly

thwarted by the structures of the schools she encountered. Rather than suffer these limitations, she opted out.

Unlike Rebecca, Jane has headed enthusiastically into a personal and professional involvement with science education. Her enthusiasm is enriched by recognition of racism in U.S. society and of her responsibility as a teacher to reveal and challenge racist beliefs and practices. I asked Jane what she thought about multicultural education in science. Having recently conducted an independent study on historical frameworks of African American literacy, she was able to respond to this question quickly and at length (unlike her classmates or myself). She said that the history of African American education had had “a great impact” on her thinking concerning the implementation of multicultural thought in her classroom. She continued,

I had certain perspectives about African American access to education. . . . There’s a unique path, to educational literacy, that’s unique to African Americans because of how they came into the United States. . . . Because certain philosophies of education developed based on how people treated ex-slaves. DuBois believed in an education that included a New England curriculum, with a focus on the contributions of African Americans, or Africans more specifically. He believed that science and math were components of that education, and that there had been contributions made throughout history by Africans, and also later on by African Americans, to science. I think [that’s] something that we as teachers need to be aware of within the classroom.

For Jane, teaching is embedded in her knowledge of the history of African American education. She is positioning herself, and the teaching of science, inside what she named the “worthy struggle” for freedom in which African Americans have engaged for centuries. In fact, when I asked Jane what the most important part of the science methods course had been for her, she referred to an assignment titled “Becoming a Scientist.” This assignment required students to pick an atypical scientist, study that scientist’s life and work, and then take on the persona of that scientist to participate in a mock symposium centered on the question “What is science?” Jane chose Elijah McCoy, a child of escaped slaves who invented the automated lubricator for oiling train mechanisms. As Jane taught us while in her McCoy persona, despite his European education in engineering, racism prevented McCoy from working as an engineer in the United States. He eventually settled for a fireman’s job on the railroad, which meant that before inventing the automated lubricator, he spent his time shoveling coal and oiling the train’s moving parts. The following is a brief excerpt from her account of his life and work in which Jane speaks as McCoy.

To make money, I started appearing at conferences and lectures, and people would invite me, and they wanted to have “The Real McCoy” come and talk about this product. And I’d show up. And they’d cancel the engagement. Because they didn’t know that my skin was a different color. In fact, sometimes even though people needed to use my product, they said, “We’re not usin’ that. Not that, no way. A colored man did that.” So, one of the reasons I’m a little bit upset today is that in 1929, I died alone; no one knows about that product. But people still talk about “The Real McCoy.” And that’s because I, Elijah McCoy, developed this product; and it works so well, that if people got it from anyone else, they said, “I don’t want this, I want the real McCoy!”

Jane’s presentation of the scientist was dramatic and imbued with her consciousness of race prejudice and the role it has played in erasing the names of African American scientists and engineers from the school curriculum. Her reflection on the assignment underscores her passion

in this regard. She explained, “I think that [assignment] was most impactful for me because it led me to look at the contributions of all people in science and how important it is to really instill that within our students as we’re teaching. And it also was inclusive, which I think a lot of times, you know when I was growing up, science seemed more exclusive than inclusive.” Jane also commented, “I have always believed that [science is for everyone], but that has to do with my struggle as an African American, and a female, being *denied* access to things.” Jane insisted that she will engage her students, and herself, in the “worthy struggle” of successfully engaging with academic science.

Kathleen brought her strong concern about the unfairness of U.S. schooling to our conversations. She put forth an explanation for the structured unfairness of schools based on a core issue in our nation’s politics: equality versus fairness. When I asked her, “What role do you think the schools play in creating a more just society?” she responded,

I think they’re doing more to muck it up than anything. . . . Because we don’t have places where people learn because they want to. It’s more like, “All right, here’s the test, here’s the grade,” those are your ends. Lots of people just go to school to mark time. And so where’s the justice in that?

Another aspect of Kathleen’s understanding of the unfairness of schools in the United States had to do with tracking.

We take students who may be having learning difficulties . . . we stick them all together, in a classroom, pretty much in a basement. We don’t give them any supplies, and then, on top of that, we say that they must pass these tests. Some people were not born to be brain surgeons. Not everyone needs to take a Regents.<sup>2</sup> That’s just stupid and arbitrary. There’s no social justice.

There is an example in Kathleen’s talk here of a proposition with which I initially disagreed. When I think of science for all, I imagine all children as having strong capabilities for interacting with and theorizing about the natural world. In this, I may be falling into what Kathleen considers a fundamental trap of assuming that, as she says, “all men are created equal.” She goes on to explain that

when we start from that premise we sort of mess everything up. A better premise is “Everyone deserves respect.” We can work from there. Because regardless of who’s left-handed, who’s right-handed [when] we’re talking about social justice, we realize that everyone is not created equal. *But*, that does not mean that anyone’s *less*, they’re just different. And if we attend to everyone’s needs according to what their needs are, then we’re being just.

Kathleen seems to be arguing that the assumption that all are equal leads to the assumption that all is fair, when indeed our system of schooling is anything but fair.

As Jane and Kathleen speculate about and begin to implement their ideas in science teaching, they are also critiquing the structures of U.S. schooling. Because the kinds of science teaching that are advocated in the science for all movement will not happen within tracked and inequitably funded settings, I perceive this tendency as a strength. Patricia and Rebecca recognize that schools do not always support new teachers; Kathleen believes that schools do not do a good job of supporting students. Jane may recognize these issues but this does not dissuade her from engaging in the struggle.

A well-developed critical consciousness (Ladson-Billings, 1994) is evident in the words of Jane and Kathleen. Their critiques included recognition of social inequalities and the role of education in changing or reproducing these inequalities. This is not to say that their visions of science teaching were rigid in any way, or that their visions coincided because they are both African American women. I want to point out, however, that the critical consciousness aspect of teaching was a strong theme in their talk, and one that I do not see in that of the Patricia and Rebecca.<sup>3</sup> Kathleen decries the unfairness endemic in the current structure of schools. Jane speaks explicitly about her beliefs concerning African American education in math and science, thus exemplifying the need to bring in people who have been deleted from the history books. Jane is determined not to let her disillusionment with school science stifle her continuing struggle or to let her own experiences stand in the way of her students’ success in science. In fact, she is taking an active stance toward her students’ learning in science. As she puts it, “It is a worthy struggle. A journey that I can encourage my students to make.”

Table 3  
*Details and examples of evidence for strengths*

Strengths Category	Aspects of Strength	Examples from Research Participants
Propensity for inquiry	<ul style="list-style-type: none"> <li>• Curiosity and questions about the natural world</li> <li>• Desire to base curriculum on students’ interests</li> </ul>	<ul style="list-style-type: none"> <li>• Being an inquiring adult (Patricia)</li> <li>• Joining children in their inquiry (Patricia, Rebecca)</li> <li>• Valuing questions (Kathleen, Jane, Rebecca)</li> </ul>
Attention to children	<ul style="list-style-type: none"> <li>• Appreciation of children’s fascination with the natural world</li> <li>• Respect for children’s intellect and ability to wonder</li> <li>• Recognition of children as individuals</li> </ul>	<ul style="list-style-type: none"> <li>• Noticing what children notice (Kathleen)</li> <li>• “You have to love the kids . . . that are there with you, and you have to love them as if they were your own” (Rebecca).</li> <li>• “[I was] surprised by the fact that my own <i>son</i> has concepts that I didn’t realize that he had about science . . . To know so clearly that you could go in [to the classroom] with the best intentions in the world and still not have a clue about what your students are thinking” (Jane)</li> <li>• Speaking the children’s home language (Rebecca)</li> </ul>
Awareness of school/society relationships	<ul style="list-style-type: none"> <li>• Understanding that schooling and science are firmly based on inequitable social relations</li> <li>• Desire to use schooling to work for social justice</li> </ul>	<ul style="list-style-type: none"> <li>• Bringing historical examples of science and oppression into the classroom (Jane)</li> <li>• Belief that schooling works against social justice (Kathleen)</li> </ul>

### Discussion: Making Links to Science for All through Teacher Education

I do not believe that Rebecca, Kathleen, Patricia, and Jane are fully disposed to study and use their children's cultures and knowledge in their science teaching, create engaging and richly educative science inquiry teaching, or take a critical stance toward schooling and society. If they were, science teacher educators would be out of work. My goal, instead, is to indicate some strengths that I, as these women's teacher, could have used to help them move toward developing these requirements.

Interest in natural phenomena, coupled with a comfort with open-ended inquiry, may allow elementary teachers to create curriculum and enact instruction that take advantage of children's fascination with nature. The attitude that these participants portray toward exploring the world embodies a form of inquiry that models scientific curiosity absent the rigidity of predetermined truths and procedures. All else being equal, teachers whose content knowledge is strong will be more competent in guiding children in fruitful directions. Nonetheless, teaching that is based in inquiry processes and a let's find out together attitude is preferable to no science teaching at all, and preferable to that which is purely text- and worksheet-based. Some will argue that this approach will lead to a plethora of misconceptions in school children's understandings of scientific concepts. The jury is still out on this hypothesis, but it is clear that teacher educators need to balance the importance of understanding and teaching accepted scientific concepts and keeping the inquiry process open and welcoming. Although I am wary of separating scientific processes from content knowledge, these education students were more confident with open-ended inquiry than with their science content knowledge, and therefore I contend that such inquiry is a good place to start in supporting their learning to teach science.

Teacher educators can model the importance of all students' thinking in science by explicitly and reflectively attending to our own students' interactions with and ideas about the natural world. The kind of focused attention in which teachers study children's thinking, rejoice in their wondering, and get to know their families and communities is invaluable in the practice of science for all. This attention involves fascination with children's thinking processes and with the theories and questions that children bring to their relationship with the world. I propose that this kind of respect, rather than a love for science or a generic love for children, may bring a concentrated energy to new teachers' goals for teaching science for all in elementary classrooms. This requires that teacher educators draw on preservice students' interest in children, support them in developing a respect for children's intellect, curiosity, and questions concerning natural phenomena, and help them to base instruction on their own students' thinking.

The strengths described in this report indicate that these participants are inclined to attend to children's questions and observations. Their ability to use what they learn through this listening to help children make connections to scientific ideas is less apparent. Although I do not deny that these preservice elementary teachers lack certain canonical knowledge of science, the knowledge that they do bring is of a kind that finds excitement in exploration of the natural world and of the theories that have been created to explain it. Teachers who take joy in exploring the natural world with their students may succeed in portraying those habits of mind that encourage childhood connections to science.

New teachers, particularly in urban districts, are entering systems that often do not support the kind of teaching that contemporary pedagogical theories recommend. A supersaturated curriculum and isolationism versus collaboration among faculty and schools will mark their working conditions (Linn, Lewis, Tsuchida, & Songer, 2000; Weiner, 1999). Add to this, in urban settings, the pressures of high-stakes standardized tests, large class size, bureaucratic intrusion (Haberman, 1996), and high faculty turnover (Weiner, 1999), and the prospects diminish for support for

teachers who practice in urban public schools. Aiding and abetting critiques of the school system, the society it reflects and reproduces, and science education and science itself (Bianchini et al., 2000; Ladson-Billings, 1995b; Nieto, 1999; Rodriguez, 1998; Weiner, 1999; Zeichner, 1999) may help new teachers recognize, survive, and even alter the conditions under which they work.

The reformist claim that science must be taught well with all children implies “an ideological commitment to diminishing the inequities of American life” (Cochran-Smith, 1999, p. 116). Teachers who are aware of the role schools play in perpetuating inequitable social structures will be more disposed to challenge and change these structures. Without a critical approach, all else may well be for naught. In science, more perhaps than in other subject areas in which they have been more comfortable, preservice elementary students are usually capable of developing their own critiques of science education and willing to address the tensions between the liberatory and conservative aspects of science’s role in an inequitable society. Teachers aware of the role that social pressures have in fashioning school customs may be less disposed to accept current practices as inescapable, and less likely to reproduce the practices that they themselves did not benefit from as science students.

### Implications for Elementary Science Teacher Education

Preservice students’ dispositions will not directly translate into successful science teaching. Because of this challenge, attention to our own students’ experiences and perceptions is integral to our practice as teacher educators. This enterprise becomes even more challenging when we recognize the cultural and language differences between most urban elementary school teachers and their students, and indeed between most science teacher educators and researchers and the K–12 students we indirectly serve. Delving into students’ understandings and constructions of science education has helped me to see subtleties of personal experiences and interpretations that students bring to thinking about science education. As we learn about preservice teachers’ strengths, and think of these as resources in our teaching, we can support them in using these strengths in the creation of curricula and instruction, as well as in the development of the ongoing critical consciousness and activist stance for which science for all calls.

Teaching well in any context requires that teachers learn about and teach from their students’ strengths (Delpit, 1995; Ladson-Billings, 1994; Nieto, 1999; Valdés, 1996). This antideficit model intersects with the current focus in science education on children’s thinking: If one is to plan productively and assess authentically, one needs to know what students are thinking throughout instruction (Driver, 1989; Driver, Squires, Rushworth, & Wood-Robinson, 1994; Gallas, 1995; Shapiro, 1994). This study recommends teacher research as a powerful way to get to know (and love, in Rebecca’s terms) our own students. Knowing the students who participated in this study as individuals has allowed me to perceive distinct strengths that they bring to elementary science teaching. I want my own students to seek out and make use of their children’s strengths in their science teaching; it would be hypocritical for me to do otherwise in my teaching and teacher research with them. Although these students are just beginning to practice, they already have beliefs, attitudes, and skills that they will take with them into their future classrooms. What can we learn from these characteristics when we look at them as potentially leading to exemplary practice, rather than as barriers to such?

Understanding scientific concepts and understanding scientific practices as socially constructed do not take precedence one over the other, nor do they follow each other in a linear sequence. They are instead thoroughly intertwined and challenge teachers to develop not only science content knowledge but knowledge of the role of science in our society, and knowledge of the children and communities whom we serve. It is unlikely that many preservice elementary

teachers will come to teacher education courses capable of meeting these multiple challenges. It is the teacher educator's responsibility to figure out how to draw on what her or his students do bring to science teaching, to support them in meeting the complex challenges of teaching science well with all of their students.

This article was made possible with the support of the Spencer Research Training Grant at Teachers College, Columbia University. The author thanks Bill Rosenthal, Emily van Zee, Angela Calabrese Barton, Celia Oyler, the anonymous reviewers, and, of course, the research participants for their careful and critically important feedback at various stages of this work.

### Notes

<sup>1</sup>I do not mean to ignore issues concerning rural children in poverty. I choose here to focus on urban settings because the children with whom my students work are city children.

<sup>2</sup>The Regents are standardized tests that have recently become mandatory for all students in the state in which Kathleen lives.

<sup>3</sup>I wrote to Jane and Kathleen that I was concerned that this section might sound as though I was saying, "They're African American, therefore they have a critical consciousness." Kathleen responded, "Don't change this section. Maybe your next paper could investigate the difference between African American and White women."

### References

- Adan, J. (1991). *The children in our lives: Knowing and teaching them*. Albany: State University of New York Press.
- Akerson, V.L., Abd-El-Khalick, F., & Lederman, N.G. (2000). Influence of a reflective explicit activity-based approach on elementary teachers' conception of the nature of science. *Journal of Research in Science Teaching*, 37, 295–317.
- Akerson, V.L., Flick, L.B., & Lederman, N.G. (2000). The influence of primary children's ideas in science on teaching practice. *Journal of Research in Science Teaching*, 37, 363–387.
- American Association for the Advancement of Science. (1990). *Science for all Americans*. New York: Oxford University Press.
- American Association for the Advancement of Science. (1993). *Benchmarks for science literacy*. New York: Oxford University Press.
- American Association for the Advancement of Science. (1998). *Blueprints for reform: Science, mathematics, and technology education*. New York: Oxford University Press.
- Atwater, M.M. (1996). Social constructivism: Infusion into the multicultural science education research agenda. *Journal of Research in Science Teaching*, 33, 821–837.
- Atwater, M.M. & Riley, J.P. (1993). Multicultural science education: Perspectives, definitions, and research agenda. *Science Education*, 77, 661–668.
- Atwood, R.K. & Atwood, V.A. (1996). Preservice elementary teachers' conceptions of the causes of seasons. *Journal of Research in Science Teaching*, 33, 553–563.
- Ballenger, C. (1996). *Science talk in a bilingual classroom*. Cambridge, MA: TERC.
- Bianchini, J.A. & Colburn, A. (2000). Teaching the nature of science through inquiry to prospective elementary teachers: A tale of two researchers. *Journal of Research in Science Teaching*, 37, 177–209.
- Bogden, R. & Biklen, S. (1992). *Qualitative research for education: An introduction to theory and methods*. Boston: Allyn and Bacon.

Britzman, D. (1991). The structure of experience and the experience of structure in teacher education. In *Practice makes practice: A critical study of learning to teach* (pp. 28–60). Albany: State University of New York Press.

Bryan, L.A. & Abell, D.K. (1999). Development of professional knowledge in learning to teach elementary science. *Journal of Research in Science Teaching*, 36, 121–140.

Calabrese Barton, A. (1998a). *Feminist science education*. New York: Teachers College Press.

Calabrese Barton, A. (1998b). Teaching science with homeless children: Pedagogy, representation, and identity. *Journal of Research in Science Teaching*, 35, 379–394.

Collazo, T. (1999, April). Herbal remedies, fixing cars, and kitchen experiments: Coming to understand science knowledge among Latino families. Paper presented at the annual meeting of the American Educational Research Association, Montreal.

Cavazos, L. (1994). A search for missing voices: A narrative inquiry into the lives of women science teachers. Unpublished doctoral dissertation, College of Education, Michigan State University.

Cavazos, L., Bianchini, J.A., & Helms, J.V. (1998, April). From promoting awareness to changing practice: How do we teach teachers about gender, ethnicity, and science? Paper presented at the annual meeting of the National Association for Research in Science Teaching, San Diego, CA.

Cherryholmes, C.H. (1988). *Power and criticism: Poststructural investigations in education*. New York: Teachers College Press.

Cochran-Smith, M. (1999). Learning to teach for social justice. In Griffin, G.A. (Ed.), *The education of teachers: Ninety-eighth yearbook of the National Society for the Study of Education* (pp. 114–144). Chicago: University of Chicago Press.

Cochran-Smith, M. & Lytle, S.L. (1993). *Inside/outside: Teacher research and knowledge*. New York: Teachers College Press.

Delpit, L. (1995). *Other people's children: Cultural conflict in the classroom*. New York: New Press.

Dillard, C.B. (1997). Placing student language, literacy, and culture at the center of teacher education reform. In King, J.E., Hollins, E.R., & Hayman, W.C. (Eds.), *Preparing teachers for cultural diversity* (pp. 85–96). New York: Teachers College Press.

Driver, R. (1989). The construction of scientific knowledge in school classrooms. In Millar, R. (Ed.), *Doing science: Images of science in science education* (pp. 83–106). New York: Falmer Press.

Driver, R., Asoka, H., Leach, J., Mortimer, E., & Scott, P. (1994). Constructing scientific knowledge in the classroom. *Educational Researcher*, 23, 5–12.

Driver, R., Squires, A., Rushworth, P., & Wood-Robinson, V. (1994). *Making sense of secondary science: Research into children's ideas*. London: Routledge.

Fradd, S.H. & Lee, O. (1999). Teachers' roles in promoting science inquiry with students from diverse language backgrounds. *Educational Researcher*, 28, 14–20, 42.

Gallard, A.J. (1993). Learning science in multicultural environments. In Tobin, K. (Ed.), *The practice of constructivism in science education* (pp. 171–180). Hillsdale, NJ: Erlbaum.

Gallas, K. (1995). *Talking their way into science: Hearing children's questions and theories, responding with curricula*. New York: Teachers College Press.

Gins, I. & Watters, J. (1995). An analysis of scientific understandings of preservice elementary teacher education students. *Journal of Research in Science Teaching*, 32, 205–222.

Glaser, B. & Strauss, A. (1967). *The discovery of grounded theory*. Chicago: Aldine.

Haberman, M. (1996). Selecting and preparing culturally competent teachers for urban schools. In Sikula, J., Buttry, T.J., & Guyton, E. (Eds.), *Handbook of research on teacher education* (2nd ed.) (pp. 747–760). New York: Macmillan.

Hammond, L. (2001). Notes from California: An anthropological approach to urban science education for language minority families. *Journal of Research in Science Teaching*, 38, 983–999.

Harding, S. (1998). *Is science multicultural?: Postcolonialisms, feminisms, and epistemologies*. Bloomington: Indiana University Press.

Hollins, E.R., King, J.E., & Hayman, W.C. (1994). *Teaching diverse populations: Formulating a knowledge base*. New York: Teachers College Press.

Howard, G. (1999). *We can't teach what we don't know: White teachers, multiracial schools*. New York: Teachers College Press.

Howes, E.V. (1998). Connecting girls and science: A feminist teacher research study of a high-school prenatal testing unit. *Journal of Research in Science Teaching*, 35, 858–876.

Howes, E.V. (2002). *Connecting girls and science: Constructivism, feminism, and the science education standards*. New York: Teachers College Press.

Howes, E.V., Jones, K.M., & Rosenthal, B. (2001). *Out of the classroom: Collaborative research in science teacher education*. Paper presented at the 22nd Annual Ethnography in Education Forum, Philadelphia.

Huber, T., Kline, F.M., Bakken, L., & Clark, F.L. (1997). Transforming teacher education: Including culturally responsible pedagogy. In King, J.E., Hollins, E.R., & Hayman, W.C. (Eds.), *Preparing teachers for cultural diversity* (pp. 129–145). New York: Teachers College Press.

King, J.E., Hollins, E.R., & Hayman, W.C. (1997). *Preparing teachers for cultural diversity*. New York: Teachers College Press.

Kyle, W.C. (1998). Editorial: Viewing science in a different light: Making meaning of the science education goal “science for all.” *Journal of Research in Science Teaching*, 35, 835–836.

Ladson-Billings, G. (1994). *The dreamkeepers: Successful teachers of African American children*. San Francisco: Jossey-Bass.

Ladson-Billings, G. (1995a). But that's just good teaching! The case for culturally relevant pedagogy. *Theory into Practice*, 34, 159–165.

Ladson-Billings, G. (1995b). Multicultural teacher education: Research, practice, and policy. In Banks, J.A. & Banks, C.A.M. (Eds.), *Handbook of research on multicultural education* (pp. 747–759). New York: Macmillan.

Ladson-Billings, G. (1999). Preparing teachers for diverse student populations. In Iran-Nejad A. & Pearson, P.D. (Eds.), *Review of research in education Vol. 24*, (pp. 211–247). Washington, DC: American Educational Research Association.

Lather, P. (1986a). Research as praxis. *Harvard Educational Review*, 56, 257–277.

Lather, P. (1986b). Issues of validity in openly ideological research: Between a rock and a soft place. *Interchange*, 17, 63–84.

Lee, O. & Fradd, S.H. (1998). Science for all, including students from non-English-language backgrounds. *Educational Researcher*, 27, 12–21.

Linn, M.C., Lewis, C., Tsuchida, I., & Songer, N.B. (2000). Beyond fourth-grade science: Why do U.S. and Japanese students diverge? *Educational Researcher*, 29, 4–14.

Lynch, S. (2000). *Equity and science education reform*. Mahwah, NJ: Erlbaum.

McDevitt, T.M., Troyer, R., Ambrosio, A.L., Heikkinen, H.W., & Warren, E. (1995). Evaluating prospective elementary teachers' understanding of science and mathematics in a model preservice program. *Journal of Research in Science Teaching*, 32, 749–775.

McWilliam, E. (1994). *In broken images: Feminist tales for a different teacher education*. New York: Teachers College Press.

Moje, E.B., Collazo, T., Carrillow, R., & Marx, R.W. (2001). "Maestro, what is 'quality'?": Language, literacy, and discourse in project-based science. *Journal of Research in Science Teaching*, 28, 469–498.

Moll, L.C., Amanti, K., Neff, D., & Gonzalez, N. (1992). Funds of knowledge for teaching: Using a qualitative approach to connect homes and classrooms. *Theory into Practice*, 31, 132–141.

Mullholland, J. & Wallace, J. (1999). Learning and teaching elementary science in the transition from preservice to inservice teaching. Paper presented at the annual meeting of the American Educational Research Association, Montreal.

National Research Council. (1996). *National science education standards*. Washington, DC: National Academy Press.

Nieto, S. (1999). *The light in their eyes: Creating multicultural learning communities*. New York: Teachers College Press.

Norman, O. (1998). Marginalized discourses and scientific literacy. *Journal of Research in Science Teaching*, 35, 365–374.

Oakes, J. & Lipton, M. (1999). *Teaching to change the world*. Boston: McGraw-Hill College.

Osborne, M. (1999, April). Practicing elementary school teachers negotiating understandings of negotiated understandings. Paper presented at the annual meeting of the American Education Research Association, Montreal.

Richardson, L. (1994). Writing: A method of inquiry. In Denzin, N.K. & Lincoln, Y.S. (Eds.), *Handbook of qualitative research* (pp. 516–529). Thousand Oaks, CA: Sage.

Richmond, G., Howes, E., Kurth, L., & Hazelwood, C. (1998). Connections and critique: Feminist pedagogy and science teacher education. *Journal of Research in Science Teaching*, 35, 897–918.

Rodriguez, A. (1998). Strategies for counterresistance: Toward sociotransformative constructivism and learning to teach science for diversity and understanding. *Journal of Research in Science Teaching*, 35, 589–622.

Rodriquez, A.J. (1997). The dangerous discourse of invisibility: A critique of the National Research Council's National Science Education Standards. *Journal of Research in Science Teaching*, 34, 19–38.

Rosebery, A., McIntyre, E., & Gonzalez, N. (2001). Connecting students' cultures to instruction. In Rosebery, A., McIntyre, E., & Gonzalez, N. (Eds.), *Classroom diversity: Connecting curriculum to students' lives* (pp. 1–13). Portsmouth, NH: Heinemann.

Rosebery, A., Warren, B., & Conant, F. (1992). *Appropriating scientific discourse: Findings from language minority classrooms* (Working paper 1-92). Cambridge, MA: TERC.

Roth, K.J. (1991). Learning to be comfortable in the neighborhood of science: An analysis of three approaches to elementary science teaching. In Saul, W. & Jagusch, S.A. (Eds.), *Vital connections: Children, science, and books*. Washington, DC: Library of Congress.

Roth, K.J. (1996). Making learners and concepts central: A learner-centered, conceptual change approach to fifth-grade American history planning and teaching. In Brophy, J. (Ed.), *Advances in research on teaching*, Vol. 6: Teaching and learning history (pp. 115–182). Greenwich, CT: JAI Press.

Roychoudhury, A., Tippins, D., & Nichols, S. (1993–1994, Winter). An exploratory attempt toward a feminist pedagogy for science education. *Action in Teacher Research*, XV, 36–46.

Schiebinger, L. (1993). *Nature's body: Gender in the making of modern science*. Boston: Beacon Press.

Shapiro, B. (1994). *What children bring to light: A constructivist perspective on children's learning in science*. New York: Teachers College Press.

Sleeter, C.E. (1993). How white teachers construct race. In McCarthy, C. & Crichlow, W. (Eds.), *Race, identity, and representation in education* (pp. 157–171). New York: Routledge.

Sleeter, C.E. & Grant, C.A. (1993). *Making choices for multicultural education: Five approaches to race, class and gender* (2nd ed). New York: Merrill.

Smith, D.C. & Anderson, C.W. (1999). Appropriating scientific practices and discourses with future elementary teachers. *Journal of Research in Science Teaching*, 36, 755–776.

Smith, D.C., Conway, P., & Levine-Rose, S. (1995). The re-construction of preservice elementary teachers' conceptions of the nature of science. Paper presented at the annual meeting of the American Educational Research Association, San Francisco.

Stodolsky, S.S. & Grossman, P.L. (2000). Changing students, changing teaching. *Teachers College Record*, 102, 125–172.

Tobin, K., Tippins, D., & Gallard, A. (1993). Research on instructional strategies for teaching science. In Gabel, D.L. (Ed.), *Handbook of research on science teaching and learning* (pp. 45–62). New York: Macmillan.

Valdés, G. (1996). *Con respeto: Bridging the distances between culturally diverse families and schools: An ethnographic portrait*. New York: Teachers College Press.

van Manen, M. (1990). *Researching lived experience: Human science for an action sensitive pedagogy*. Albany: State University of New York Press.

van Zee, E.H. (1998). Fostering elementary teachers' research on their science teaching practices. *Journal of Teacher Education*, 49, 245–254.

van Zee, E.H. (1999, March). Facilitating reflective research in school settings: The science inquiry group. Paper presented at the 20th Annual Ethnography in Education Research Forum, University of Pennsylvania, Philadelphia.

van Zee, E.H. & Roberts, D. (2001). Using pedagogical inquiries as a basis for learning to teach: Prospective teachers' reflections upon positive science learning experiences. *Science Education*, 85, 733–757.

Vellom, R.P. & Anderson, C.W. (1999). Reasoning about data in middle school science. *Journal of Research in Science Teaching*, 36, 179–200.

Weiner, L. (1999). *Urban teaching: The essentials*. New York: Teachers College Press.

Zeichner, K. (1999). The new scholarship in teacher education. *Educational Researcher*, 28, 4–15.

Zeichner, K.M. & Hoefft, K. (1996). Teacher socialization for cultural diversity. In Sikula, J., Buttry, T.J., & Guyton, E. (Eds.), *Handbook of research on teacher education* (2nd ed.) (pp. 525–547). New York: Macmillan.

Zemal-Saul, C., Blumenfeld, P., & Krajcik, J. (2000). Influence of guided cycles of planning, teaching, and reflection on prospective elementary teachers' science content representations. *Journal of Research in Science Teaching*, 37, 318–339.