Beginning Teachers Moving Toward Effective Elementary Science Teaching

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ABSTRACT: We use a 10-year program of research centered on iterations of one elementary science methods course as a vehicle for exploring three important and interrelated goals for the learning of beginning elementary teachers. These include learning about inquiry-oriented science teaching, using science curriculum materials effectively, and anticipating and working with students' ideas in instruction. For each goal we discuss how the literature informs our thinking, describe relevant aspects of our design of the course, and present findings of our research with regard to preservice teachers' experiences in and learning from aspects of the course. For each goal, we also highlight examples from our longitudinal work following the preservice teachers into their early years as elementary teachers, to provide a glimpse of teachers' trajectories related to each of the themes. We close with a discussion of implications for research and practice in elementary science teacher education. © 2009 Wiley Periodicals, Inc. *Sci Ed* **93:**745–770, 2009

INTRODUCTION

Teaching science can be a challenge, especially for beginning elementary teachers. Most elementary teachers teach multiple subjects including language arts, mathematics, social studies, and science; some also teach other subjects such as art, music, and computer literacy. Within the subject of science, elementary teachers face further challenges, since at the elementary level teachers are responsible for life science, physical science, and earth science—and they are expected to teach these through engagement in authentic scientific practice. Beginning elementary teachers thus require many areas of mastery, yet generally

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lack both sufficient coursework and experience that would contribute to their knowledge base for helping children develop coherent knowledge of science concepts and practices and thus become scientifically literate citizens. A central tenet of our work in elementary science teacher education is that we must help teachers to develop a beginning repertoire of ideas, strategies, tools, and abilities—in other words, to help them be well-started beginners (Hollon, Roth, & Anderson, 1991).

The purpose of this paper is to further the discussion of research-based engagement in elementary science teacher education. We describe our program of research and teaching in an elementary science methods course for undergraduates, providing examples of approaches, and food for thought, for other elementary science teacher educators. Because we share a core belief that teacher education is not an end to itself but rather a step along the road to effective classroom teaching (Feiman-Nemser, 2001), we situate our discussions of the course within the context of the literature on both preservice and early career elementary teachers. In other words, we think about teaching preservice teachers within the broader context of who they will quickly become, which is early career teachers. As such, we also review highlights from our longitudinal study following some of the preservice teachers into their first few years of teaching.

Thus, by "beginning teachers" we mean to include both preservice and early career teachers. We argue that understanding both of these groups and their strengths and struggles helps us be better positioned to provide support within our methods courses. This understanding strengthens our knowledge of our learners—a part of our own pedagogical content knowledge (Shulman, 1986)—as elementary science teacher educators (Smith, 2000).

In this paper, then, we draw on a set of studies conducted over a 10-year period of time and the teacher education we engaged in concomitantly. Our design-based research informs our teaching, and our teaching informs our research. We show the bigger picture of what such a program of integrated research and teaching can illuminate: a better understanding of beginning elementary teachers who teach science, their strengths and their challenges, and how teacher educators' attempts to support them may succeed and fail.

Readers may take away different ideas from the paper. A new elementary science teacher educator may find useful the instructional approaches and description of beginning elementary teachers and their strengths and struggles, whereas perhaps a more experienced elementary science teacher educator may see points of contact with her or his own work. One researcher may benefit from the review of the literature and the synthesis of our program of work, and another can find a model here of using design-based research to inform teacher education practice, and vice versa. We hope that the paper fills these needs, and perhaps others, for science educators.

Introduction to Our Course and Connections to Problems of Practice

The introduction to this paper set (Mikeska, Anderson, & Schwarz, 2009, this issue) put forward three important problems of practice shared by preservice teachers and teacher educators: engaging students in scientific practices, organizing instruction, and understanding students. In our course, we support preservice teachers in achieving three interrelated goals, each of which closely connects to one of these problems of practice. We and our preservice teachers share an interest in these areas, giving us a starting place for our work together and leverage points as we move together toward effective elementary science teaching.

First, we want preservice teachers to develop an understanding of scientific inquiry and inquiry-oriented science teaching—for example, we want them to understand how to engage students in asking and answering scientific questions and constructing scientific explanations. This is related to the problem of practice of engaging students in scientific practices. We build on the preservice teachers' interest in promoting students' enthusiasm and maintaining their interest in a lesson, but we also help the preservice teachers come to recognize inquiry-oriented science teaching and its value in promoting meaningful science learning.

Second, we want preservice teachers to develop the ability to analyze, critique, and adapt science curriculum materials. We hope they move beyond simply "liking" or "disliking" a lesson plan and become able to engage in principled analysis of its characteristics. This is related to the problem of practice of organizing instruction. We help preservice teachers recognize how they can productively interact with science curriculum materials and use the materials to meet their needs. This should allow them to see how these materials can support them in achieving success in something that initially causes them anxiety: planning and carrying out science lessons.

Third, we want preservice teachers to learn to anticipate and work with students' ideas in instruction, with the ability to elicit and understand students' knowledge of scientific phenomena. This is related to the problem of practice of understanding students. We try to help preservice teachers recognize their students' ideas about science as intellectual resources on which to draw, thus moving beyond—but still valuing—an initial predilection toward emphasizing more affective aspects of understanding one's students.

We organize this paper around these goals, which we refer to as the *inquiry goal*, the *curriculum materials goal*, and the *students' ideas goal*. While we further justify our selection of these three goals throughout the paper, some of the reasoning behind our prioritization of these goals is discussed next.

Overcoming Challenges Through Addressing Goals

As noted above, beginning science teachers face challenges. To identify a research-base for characterizing these challenges, we reviewed the literature on beginning science teachers (Davis, Petish, & Smithey, 2006). We summarize some findings of our review, as related to beginning elementary teachers of science, to position the importance of our goals.

First, our review found—as is typically assumed—that preservice elementary teachers demonstrate unsophisticated knowledge of some specific science topics (e.g., Atwood & Atwood, 1996; Stofflett & Stoddart, 1994). Second, beginning elementary teachers tend to have unsophisticated beliefs about the nature of science (e.g., Abd-el-Khalick, 2001), again as is typically assumed, though we also noted some exceptions to this trend in the literature. Third, beginning elementary teachers seem initially to want to engage, interest, motivate, and/or manage their students, though they also experience change in this focus (e.g., Abell, Bryan, & Anderson, 1998; Howes, 2002). They recognize that knowing about their students' ideas and backgrounds is important, but do not know what to do with information they glean with regard to those ideas or backgrounds. Fourth, our review found that beginning elementary teachers tend to emphasize the use of hands-on activities (toward the goal of engagement, interest, and motivation, as noted above; e.g. Abell et al., 1998). They do not tend to emphasize the learning of science content. Fifth, beginning elementary teachers often avoid teaching science altogether, or focus on using science activities that are manageable and predictable (e.g., Appleton & Kindt, 2002). Sixth, however, beginning teachers sometimes have more sophisticated ideas about instruction than they are able to put into practice (e.g., Bryan & Abell, 1999)—indicating that beginning elementary teachers have strengths on which we can capitalize. Finally, our review identified personal characteristics such as reflectiveness, identity, personal history, and self-efficacy that seem to influence one's development as a teacher (e.g., Czerniak & Shriver, 1994). Our goals in the elementary science methods course—the goals related to inquiry, curriculum materials, and students' ideas—are intended to address some of these challenges.

Our review identified little exploration of the challenges faced by teachers around addressing the multitude of standards they are expected to cover in elementary science. We found little research on beginning elementary teachers' understanding of science inquiry. We found similarly minimal research on how beginning elementary teachers use curriculum materials—though one might imagine that curriculum materials could serve as a crucial support in overcoming some of the challenges beginning elementary teachers face. Our research allows us to help address these gaps in the current literature.

The Preservice Teachers, Teacher Education Program, and Early Career Teachers

Our elementary science methods course occurs during the third semester of an undergraduate teacher preparation program. The first author has taught at least one section of this course each year for several years; the second author has taught sections of the course three times and has worked with the preservice teachers in other capacities as well. Both of us view ourselves as still learning with regard to elementary science teacher education.

The four-semester teacher preparation program is aligned with recommendations of teacher education reform calls (e.g., Interstate New Teacher Assessment and Support Consortium, 1992; National Council for Accreditation of Teacher Education, 1987) and subject-matter standards documents (e.g., American Association for the Advancement of Science [AAAS], 1993; National Research Council [NRC], 1996), and emphasizes subject matter teaching. Each semester, the preservice teachers are placed in field classrooms for 6 hours per week, gradually taking on increased responsibilities. In the first two semesters, preservice teachers take courses in educational psychology, educational foundations, elementary schooling, and literacy and social studies methods. During the third semester, in addition to the science methods course that is the focus of this paper, the preservice teachers take a mathematics methods course. In this final semester before student teaching, preservice teachers are expected to connect their ideas about subject matter, inquiry, children, learning, and teaching as they engage in increasingly complex tasks of teaching. They have a significant role in their field classrooms.

The preservice teachers go through the program as a cohort. Each cohort (and thus each section of a methods class) typically includes 20–28 preservice teachers. Most are traditional fourth-year seniors (about 21 years old) in their final year of college. Typically, most are female and most are White; sometimes, we have a cohort in which all of the students are female. Although our students come from a wide range of social classes, most come from middle or upper middle class families. In other words, they are demographically typical of elementary teachers in the United States (U.S. Department of Education National Center for Education Statistics [NCES], 2003), though they also are attending a large, research-focused public university.

We followed a few of these preservice teachers as they moved into their own classrooms, in a longitudinal study (described more fully later) designed to explore beginning elementary teachers' learning about science teaching, with a particular focus on their learning with regard to inquiry-oriented science teaching. Each of these teachers is White and female. Table 1 lists these teachers, shows the years over which data were collected for each, and describes, briefly, the characteristics of each teacher's school context. Maggie and Tammy experienced early versions of the methods class; Whitney, Lisa, and Catie experienced a slightly later version (and Whitney and Catie were in the same class); and Brooke's and Kathleen's experiences were later still. These teachers are not necessarily representative of all of our graduates. For example, they each taught science as often as they can manage, in contrast to many elementary teachers, and agreed to participate in a project with a focus on their science teaching. Yet studying these teachers allowed us to get a sense of who some of our preservice teachers become.

Methods Used in Studies of Preservice and Early Career Teachers

While this synthesis of the program of design-based research cannot provide all the relevant details of the methodologies used in each individual study, here we describe some common characteristics across the studies.

The studies of the preservice teachers typically draw, as data sources, on the preservice teachers' written student work for the one-semester methods class, and/or transcripts of interviews with the preservice teachers. For most of the studies, the entire cohort of preservice teachers is included as participants—so typically the number of participants is around 20–25. Data analysis typically involves a form of content analysis, using some a priori codes informed by the research questions and the literature as well as some emergent codes. Sometimes, these studies of preservice teachers are smaller case studies, drawing on similar data sources but for one or a handful of preservice teachers purposefully selected to provide interesting and/or contrastive cases. On the other hand, sometimes these studies of preservice teachers incorporate larger scale quantitative analyses, for example of responses to a survey instrument administered to multiple sections of the methods course.

The longitudinal study, on the other hand, draws on different data sources. We interviewed each of the seven participating teachers three times each year, asking them to critique and reflect on science lesson plans, scenarios describing science teaching, and their own science instruction. We also tracked their use of our online learning environment (called CASES, for Curriculum Access System for Elementary Science; freely available at http://cases.soe.umich.edu) and read their reflective writings about their teaching of science over the years. Finally, we compiled data from an annual survey as well as their own descriptions of their science teaching within constrained response daily logs we developed. These data were collected for up to 5 years for each teacher, as shown in Table 1. While these data sources have important limitations—most notably the lack of focus on the teachers' actual classroom practice—they do allow us to characterize some salient features of the teachers' knowledge, ideas, and beliefs, as well as their change over time. Different studies within the overarching longitudinal study draw on different ones of these data sources, but all draw heavily on the interview data. Data analysis for the longitudinal study again draws on content analysis, with some a priori codes and some emergent. Some of these analyses were complemented by quantitative analysis of the numerical data obtained through surveys, CASES usage files, and/or daily logs.

Structure of the Paper

The rest of the paper is organized around discussions of the goals related to *inquiry*, *curriculum materials*, and *students' ideas*—which, again, are aligned with the problems of practice discussed in the Introduction (Mikeska et al., 2009, this issue) of engaging students in scientific practices, organizing instruction, and understanding students. For each goal, we first explore the importance of the goal and what we know about beginning elementary teachers with respect to it. We then briefly describe the design of our course with regard to the goal. We summarize the results of our research on preservice and early career teachers as related to the goal, including a few illustrative quotes typical

TABLE 1
Early Career Teachers in Longitudinal Study and Their Schools

Teacher	Year of Teaching Practice							
	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8
Maggie				Suburban private Catholic school; fourth grade		Urban public school; > 40% English as a second language; third grade (gets MA in special education)		
Tammy			Suburban private Catholic school; third grade					
Whitney	Rural/suburban public 4–8 school; near military base; highly transient; fourth grade							
Lisa	Suburban public school; fourth grade; wide range of SES							
Catie	Suburban private Catholic; sixth grade	Different suburban private Catholic school; second grade; large class sizes (gets MA in science education)						
Brooke	Highly diverse public school; low SES; highly transient; large ESL population; fifth grade							
Kathleen	Suburban public school; second grade	Same suburban public year-round school; third grade						

of the main findings of the study. These summaries are intended to give a sense of our program of research and to begin to show how the research informed our teaching, but the interested reader will need to turn to the papers cited to obtain details and see nuances. The paper closes with a discussion of implications of this work for elementary science teacher education.

THE INQUIRY GOAL

Effective science teaching helps students develop conceptual understandings and inquiry abilities necessary to be productive citizens and science learners (AAAS, 1993; NRC, 1996, 2007). Sense-making through scientific inquiry emphasizes learning conceptual knowledge and engaging in and learning about scientific practice (Anderson, 2001; Crawford, 2007; Scott, 1998). With support, young children can engage in sophisticated scientific practices and develop deep understandings of appropriate science concepts (Lehrer, Carpenter, Schauble, & Putz, 2000; Metz, 1995). Typical elementary science instruction, however, does not support students in achieving either of those outcomes (Weiss, Pasley, Smith, Banilower, & Heck, 2003).

Numerous perspectives on scientific inquiry exist (Anderson, 2007); for example, Schwarz (2009, this issue) explores modeling-centered scientific inquiry. Our definition builds on the "essential features" of inquiry (NRC, 2000). We distill these features into the notions of asking and answering scientific questions, constructing scientific explanations using evidence, and communicating and justifying findings. Over the years of engaging in design-based research, we have begun to emphasize constructing scientific explanations using evidence, as a way of promoting sense-making through scientific inquiry. Supporting students in explanation construction seems to be challenging for beginning elementary teachers, yet without this step, inquiry-oriented science has no substance. By constructing scientific explanations, we mean that children gather data (e.g., measurements, observations), organize and analyze data, and develop and support a claim using those data as evidence (McNeill, Lizotte, Krajcik, & Marx, 2006). Zembal-Saul (2009, this issue) explores scientific argumentation, a related scientific practice.

What works against the infusion of scientific inquiry in elementary classrooms? Typical elementary curriculum materials do not reflect current thinking in science education reforms. In addition, teachers may prioritize learning science content over scientific inquiry (Anderson, 2001; Beyer & Davis, 2008; Scott, 1998). Teaching for sense-making through scientific inquiry, furthermore, can be a challenge, especially for elementary teachers. Because elementary teachers can teach a dozen subjects, they require (but do not necessarily have) a rich, integrated, flexible knowledge base (Ball & Bass, 2000; Ma, 1999). Their knowledge base needs to include pedagogical knowledge, subject matter knowledge across numerous disciplines, and pedagogical content knowledge (PCK; Shulman, 1986) across that same range of disciplines. PCK refers to teachers' specialized knowledge for teaching specific subject matter, including knowledge of learners, instructional representations, and assessment (Grossman, 1990; Magnusson, Krajcik, & Borko, 1999). Teachers also need special PCK for supporting students in scientific practices like constructing scientific explanations (Davis & Krajcik, 2005; Zembal-Saul & Dana, 2000). Yet teachers often misunderstand inquiry, seeing it as linear and lockstep (Windschitl, 2003) or equating it with "hands-on" or "student-directed" (NRC, 2000)—despite the notions of the essential features of inquiry and the "inquiry continuum" that describes inquiry along a range from student directed to teacher directed (NRC, 2000).

The challenges are compounded for beginning elementary teachers (Davis et al., 2006). Beginning elementary teachers' knowledge of and beliefs about science tend to be limited and unsophisticated, including a limited understanding of scientific inquiry (e.g., Shapiro, 1996). Furthermore, due to their concerns about management, they may avoid teaching science or engage in only low-risk, non-inquiry-oriented science teaching (Appleton & Kindt, 2002). They may engage students in hands-on activities, with less concern for sense-making (Haefner & Zembal-Saul, 2004; Petish, 2004). On the other hand, some studies of how early career elementary teachers think about and support their students in constructing scientific arguments and explanations (Avraamidou & Zembal-Saul, 2005; Beyer & Davis, 2008; Rosebery & Puttick, 1998), as well as some work with preservice teachers (Schwarz, 2009, this issue; Zembal-Saul, 2009, this issue), provide evidence that beginning teachers can engage children in scientific practices related to sense-making through scientific inquiry.

How Do We Address the *Inquiry* Goal?

In our elementary science methods course, we engage the preservice teachers in considering and learning about inquiry-oriented science teaching through experiencing, developing, teaching, and reflecting on inquiry-oriented science lessons.

One in-class activity involves experiencing versions of inquiry (or counterexamples) in the context of an experiment on heat and temperature. It is intended to help preservice teachers understand the notion of the inquiry continuum, and, more generally, to promote consideration of the role of structure and a teacher's own comfort level with student-directed inquiry. It allows us to emphasize the idea of setting learning goals related to both science content and scientific inquiry. We print three versions of the instructions with each reflecting variations in the amount of structure and contextualization. Preservice teachers sit at tables with a single version of the instructions, and work with their tablemates to complete the activity—unaware that others in the class are working on a somewhat different task. Then, we ask each group to discuss the pedagogy behind the activity they did. We inform preservice teachers of the different versions, and they move into jigsaw groups to share ideas about the advantages and disadvantages of each version, considering, for example, each one's likely learning outcomes.

Another type of assignment involves experiencing inquiry as a teacher, from the standpoint of planning and enacting an inquiry-oriented science lesson. Referred to as the "reflective teaching" assignment, this assignment has evolved over the years but essentially involves planning a science lesson, enacting it, and reflecting on the enactment. In the current version, preservice teachers identify an existing lesson plan (typically received from their cooperating teacher), critique it informally, revise the lesson plan using our lesson plan guidelines, teach the revised lesson to the children in their field placement, then reflect on that enactment by responding to guiding questions. In part, this reflection entails analyzing some student work to help them consider changes to make if they were to teach the lesson again. The lesson plan guidelines support the preservice teachers in making their lessons inquiry oriented. In some situations, this is a natural fit; in others (e.g., when the given lesson centers around a read-aloud or coloring activity), they find this a very daunting challenge. In addition, as a part of the guidelines, the preservice teachers are asked to discuss how their lesson reflects the essential features of inquiry that we use to frame the course (based on NRC, 2000). The latter gives us a window into their current understanding of these complex ideas.

We also give a pair of assignments to help preservice teachers envision inquiry-oriented science teaching. We build on a feature of CASES, an online learning environment we developed providing educative science curriculum materials for beginning elementary teachers (see Davis, Smithey, & Petish, 2004). Educative curriculum materials are intended to promote teacher learning as well as student learning (Ball & Cohen, 1996; Davis & Krajcik, 2005). One educative feature of the materials in CASES is a set of short vignettes that we call "images of inquiry" (Smithey & Davis, 2004b). The vignettes serve as one of several types of representations of effective science teaching provided within CASES, thus potentially increasing the teachers' learning (Spiro, Feltovich, Jackson, & Coulson, 1991). While lacking the complexity of true cases, these vignettes incorporate some of their strengths (Lundeberg, Levin, & Harrington, 1999; Merseth, 1996). CASES briefly describes each fictional or real "image teacher," indicating what grade and unit the image teacher is teaching and how long he or she has taught. Each image teacher also has a focus that guides the issues he or she explores in the narratives, such as using students' ideas, establishing a culture of inquiry, or incorporating inquiry in a school that emphasizes standardized test scores. In the images of inquiry assignments, preservice teachers read a set of images of inquiry and the lessons in which they are embedded, and respond to a series of reflective questions. In the first assignment, they focus on the images from teachers focused on students' ideas. In the second assignment, they can choose any set of images. Asking preservice teachers to consider the choices that another teacher made can foster a strong image of themselves as teachers of science (Abell et al., 1998).

Finally, we use online and in-class discussions to promote understanding of inquiry. Conversations provide opportunities outside of class for preservice teachers to discuss ideas with one another. Teacher communities provide opportunities for intellectual and expertise development (Grossman, Wineburg, & Woolworth, 2001; Putnam & Borko, 2000) as well as identity development (Overbaugh, 2002). Preservice teachers who are placed in a cohort, as our preservice teachers are, show high levels of group participation and collaboration and are comfortable taking risks with one another (Beck & Kosnik, 2001). Therefore, social supports for preservice teachers in a cohorted program have a strong potential for fostering change. Because of these benefits, we sometimes have preservice teachers participate in online discussions of course topics (Smithey & Davis, 2002). A typical focus is inquiry-oriented science teaching.

Results of Our Research: The Inquiry Goal

Our research on preservice and early career elementary teachers yields some insight into these beginning teachers' ideas about inquiry-oriented science teaching. For example, one study analyzing 20 preservice teachers' written work in the methods class indicated that preservice elementary teachers typically believed that inquiry-oriented science teaching is important. Their reason, however, was different from that of science education researchers: they wanted to promote student interest, not engage students in authentic scientific activity (Davis, 2006b). For example, in describing how she would change a lesson to incorporate more inquiry, preservice teacher Jennie (all names are pseudonyms) stated:

> I would try to structure the lesson so that students design the experiments...I would want students to make their own predictions and find ways to test them...I think letting students design the experiment and how they want to test it gives them ownership which will naturally interest and engage them. (see Davis, 2006b, p. 361)

Jennie's response was typical of her peers' and other research has indicated a similar emphasis (e.g., Bryan & Abell, 1999).

In a study of how 27 preservice elementary teachers engaged in online discussion of science teaching, in which we analyzed the preservice teachers' posts to the online discussion, we found that when they responded to our prompts, their discussions typically centered around the course concepts and specifically around inquiry-oriented science teaching. For example, preservice teacher Erica wrote, in response to a scenario describing a teacher's dilemma related to inquiry-oriented science teaching,

> I do not think you can entirely plan for inquiry-oriented unit. I think that Mrs. W [the teacher in the scenario] can plan for inquiry by providing students with time/opportunities to explore and inquire about science. As [my partner] and I did, students can be given time to investigate freely while still being directed towards a specific idea. So, I think you can plan time for inquiry opportunities, however I do not think that you can plan follow up lessons prior to the time of inquiry. It is important I feel to look at what happens during inquiry explorations and plan lessons using the students' specific ideas, alternative ideas, and interests to further their scientific knowledge. (see Smithey & Davis, 2004a)

In discussions framed by the preservice teachers themselves, however, the responses were very different. Erica, again, provides an illustrative example:

> I was just reading through the responses to Dana's reply about under-resourced districts. It got me thinking. . . At this time next year we will be making all of the decisions. We will be the ones who parents, administrators, and students will want to sit down with and "talk" about what is and is not going right. We will have to wake up five days a week, instead of just two, to be at school by 8. We will have to do [all the planning] for every single subject for every single day. What are we going to do? (see Smithey & Davis, 2004a)

In these preservice teacher-initiated threads, there was evidence of teacher identity development but almost no mention of inquiry (Smithey & Davis, 2004a).

Findings like these—in which inquiry was valued but not fully understood, and not addressed when not prompted for—led us to design additional experiences to explicitly support preservice teachers in developing a more complete understanding of inquiry-oriented science teaching and to conduct more in-depth research on the preservice teachers' ideas about inquiry. For example, we started using our images of inquiry with the preservice teachers to help them envision inquiry-oriented science teaching. In a study analyzing 40 preservice teachers' written reflections about these images, we found that the preservice teachers productively explored issues of importance related to inquiry and curriculum materials (Dietz & Davis, in press). Some of the images of inquiry, for example, promoted consideration of the inquiry continuum. Some preservice teachers struggled with one depiction of teacher-directed inquiry. For example, preservice teacher Kelly wrote,

> In Brittany's MAGNET lesson, I agree with her that it posed a unique opportunity to teach the students to collect and review their data, but it seems to me that Brittany gave the students all the tools needed to complete this data study. Ideally, I would like to see the students create a useable and productive method of collecting, recording, and observing data. I do realize that this would pose a less organized product in the classroom, but I believe that it would be more effective for the students. (Kelly, Assignment 2; see Dietz & Davis, in press)

Kelly, like some of her peers, wanted to incorporate less guidance for the students. The images of inquiry, by providing multiple representations of inquiry and inquiry-oriented science teaching, promoted important reflection on the nature of inquiry. Responses like Kelly's opened the door for discussion of the role of scaffolding and support for students' inquiry.

How did the early career teachers participating in our longitudinal study think about inquiry-oriented science teaching? Early career teachers (see Table 1) emphasized a variety of aspects of inquiry. For example, interviews and other data sources from Whitney (including her reflective journal entries and daily logs describing her teaching) indicated that Whitney emphasized questioning in her classroom and continually wanted her fourth-grade students to ask and answer scientific questions (Forbes & Davis, 2007). Others emphasized evidence and/or explanation, though they differed in what they meant by these terms. Catie, for example, emphasized the use of detail, careful observation, and the organization of data (Beyer & Davis, 2008; Davis, Beyer, Forbes, & Stevens, 2007; Stevens & Davis, 2007). Catie saw these as important learning goals in their own right and did not always connect the use of evidence to the construction of scientific explanations; she attended more carefully to the accuracy of her second-grade students' claims (Beyer & Davis, 2008). Developing skill in supporting student explanation was especially hard (Beyer & Davis, 2008; Petish, 2004). Petish (2004), for example, observed that the three second-year teachers involved in her study (who had gone through versions of the science methods course but were not at that time a part of the longitudinal study) used hands-on activities in which students gathered data, but did not support the students in making sense of the data. An observational study of longitudinal teacher Catie during her third year of teaching demonstrated some development in her use of evidence-based explanations with her second graders (Beyer & Davis, 2008). Yet—based on analysis of interviews and drafts of her own images of inquiry—Catie's focus on explanation did not continue into her teaching the following year (Davis et al., 2007).

Our longitudinal study also indicated that the teachers experienced a tension between their use of expository text and first-hand data collection, struggling to find a balance (Forbes & Davis, 2007). Whitney, whose curriculum materials were oriented toward investigation, sought out supplementary textbooks and trade books. For example, in the fall of her first year of teaching, Whitney wrote in her journal,

> I also find it difficult at times to have only hands-on materials for science. I feel that textbooks with some information would help the students as well, as a reference as well as a starting point or a way to fill in the gaps of things we cannot experiment with in the classroom. (see Forbes & Davis, 2007)

By the end of her second year, she spoke of using subject matter text more often to complement her investigations. Lisa and Catie, on the other hand, pieced together investigations to supplement their use of their schools' texts (Forbes & Davis, 2007).

In sum, this research suggests, first, that some of our supports for learning about inquiry-oriented science teaching successfully support preservice teachers in their initial explorations of these ideas. Second, certain ideas, such as supporting students in explanation construction and integrating text with inquiry, may need additional support in the course. Third, ongoing support for engaging in inquiry-oriented science teaching as reflected in current science education reforms is necessary as teachers move into their own classrooms. Early career teachers continue to struggle with these complex ideas. Curriculum materials can provide one such form of support, and we turn to our curriculum materials goal next.

THE CURRICULUM MATERIALS GOAL

Existing science curriculum materials, while not perfect, are a starting point for teachers—and a very necessary one for beginning teachers (see Grossman & Thompson, 2004). Curriculum materials can serve as cognitive tools and may help elementary teachers develop confidence and competence in science teaching.

Teachers need to adapt even high-quality curriculum materials to better support their own students' learning (Barab & Luehmann, 2003; Baumgartner, 2004). Looking at how individual teachers use curriculum materials in their practice shows that teachers appropriate tasks (as-is), adapt tasks, or use the materials as a source of inspiration for developing new tasks (Brown & Edelson, 2003; Remillard, 1999). An experienced teacher might change a unit to allow students greater opportunity to design their own investigations; on the other hand, a beginning teacher may change the same unit to provide more structure. Another teacher might modify a lesson to incorporate experiences to capitalize on her students' language or cultural backgrounds.

Teachers must recognize the strengths and weaknesses of the materials they are using (Ben-Peretz, 1990). Teachers employ their personal resources (such as their knowledge and beliefs) as well as resources within the materials themselves in making changes; their ability to do so is referred to as their pedagogical design capacity (Brown, 2009; Brown & Edelson, 2003). When teachers change high-quality curriculum materials, ideally the changes are principled, maintain the integrity of the original design, and work toward attaining the same goals as the original (Ben-Peretz, 1990; Bridgham, 1971; Davis, 2006b; Pintó, 2005). Some teachers make productive changes to curriculum materials while others—for example, those who do not deeply understand the rationales behind reforms promoted in some materials—may make unproductive changes (Collopy, 2003; Remillard, 1999; Schneider & Krajcik, 2002). On the other hand, sometimes materials are not effective as written (Kesidou & Roseman, 2002), and teachers may need to make more significant changes.

Beginning elementary teachers may not be positioned to take best advantage of the existing science curriculum materials. Teachers are influenced—positively and negatively—in their curriculum use by their knowledge, beliefs, and context (Pintó, 2005). For example, teachers may not recognize adaptation of curriculum as a part of their job (Bullough, 1992; Eisenhart, Cuthbert, Shrum, & Harding, 1988). Furthermore, although many criteria exist along which teachers might critique existing curriculum materials (e.g., the AAAS Project 2061 criteria for evaluating textbooks; see Kesidou & Roseman, 2002), beginning elementary teachers may struggle to select appropriate criteria to use, or they may simply focus on whether they "like" or "don't like" the materials (Davis, 2006b). Furthermore, they may struggle with critiquing curriculum materials effectively (Lynch, 1997; Schwarz, 2009, this issue; Schwarz et al., 2008; Yerrick, Doster, Nugent, Parke, & Crawley, 2003).

Yet teacher educators lack models of instructional approaches for promoting these kinds of understandings. In a recent review of pedagogical approaches used in teacher education, for example, nothing is mentioned about supporting preservice teachers in learning to effectively use curriculum materials (Grossman, 2005). Our own work in this area is shaped by our ongoing conversation with colleagues in the Center for Curriculum Materials in Science about their approaches (e.g., Cartier & Sink, in preparation; Schwarz et al., 2008).

How Do We Address the *Curriculum Materials* Goal?

We use a series of experiences and assignments intended to promote preservice teachers' understanding of and abilities in analyzing, critiquing, adapting, and using existing elementary science curriculum materials. Most significantly, we have designed a series of in-class critique and adaptation assignments intended to promote the development of these skills. These assignments are described in some depth in Davis (2006b); we highlight a few key features here. First, these assignments are spread throughout the entire semester. As with all of our key goals for the course, we do not expect the preservice teachers to develop all the knowledge and skills they need from a single experience. Second, we use a range of curriculum materials, such as a lesson plan typical of those found on the Internet, a lesson plan from a commercially available science kit, and a hands-on activity not written as a lesson plan at all. (For simplicity, we here refer to all of these as either curriculum materials or lesson plans.) Third, these assignments emphasize the idea of using criteria along which one critiques curriculum materials. We try to move the preservice teachers into what we refer to as principled analysis of materials. Some assignments involve free development of criteria and some involve giving the preservice teachers criteria on which they are asked to focus. Fourth, we emphasize not just identifying weaknesses of the materials. In each assignment, we ask preservice teachers to use a criterion to identify strengths of the lesson plan related to that criterion, identify weaknesses related to that criterion, and describe changes they would make to address the weaknesses.

Over the years, one important change has been a move away from generating a set of class criteria driven by the ideas of the preservice teachers (as described in Davis, 2006b) to a more instructor-driven set of criteria. The rationale for the original design was a sound one, we think: We wanted to make sure that the teachers would buy in to the criteria we were asking them to use, so we synthesized their ideas to develop a manageable set of criteria. And in fact, those criteria reflected important issues, such as attending to students' ideas and accurately representing scientific ideas. They rarely, however, reflected the depth of understanding of scientific inquiry that we wanted to promote. As such, we moved to a different approach. We asked the preservice teachers to develop criteria in which one focused on students' ideas and three focused on the essential features of inquiry (NRC, 2000) around which our instruction is organized. We also changed one assignment to require the preservice teachers to use the criteria focused on evidence-based explanations and students' ideas. These decisions reflect design trade-offs. The revised design drew the preservice teachers' attention to the areas of focus of the course—but at the expense of the authenticity and buy-in reflected by the original approach.

We give the preservice teachers identical pre- and posttests that require many of the same skills, so we can measure changes in their knowledge and abilities (Davis, 2006b). Building on notions of professional role identity (e.g., Mahlios, 2002) and Remillard's (2005) framework for the relationship between teachers and curriculum materials, we also administer a survey that measures preservice teachers' curricular role identities, or their orientations toward the use of curriculum materials as a part of how a teacher defines herself (Forbes & Davis, 2008b).

We ask preservice teachers to make their own thinking visible as they use existing curriculum materials as the basis for lessons they develop. They turn in marked-up versions of their original lesson plans (typically received from their cooperating teachers) for the reflective teaching lessons they will teach to children.

Finally, we provide opportunities to explore a wide range of elementary science curriculum materials and resources. These include science kits and the teacher and student materials that accompany them, activity books, children's literature, science subject matter reference books for teachers or children, and a whole host of other materials.

Results of Our Research: The Curriculum Materials Goal

Our research analyzing the work on the critique assignments described above of 20 preservice teachers indicated that preservice teachers could engage in substantive critique and adaptation of curriculum materials with explicit support (Davis, 2006b). The preservice teachers experiencing the first version of the critique assignments held a sophisticated set of criteria for critiquing instructional materials; for example, they typically paid careful attention to scientific inquiry and learning goals. (Preservice teachers experiencing a later version of the course showed similar strengths; see Forbes & Davis, 2008a.) As noted above, and illustrated with a typical quote from Jennie, the preservice teachers valued inquiry but emphasized quite student-directed forms of it, perhaps not recognizing the role of guidance and scaffolding. Providing options of criteria from which they could select allowed them to engage in substantive critique of the instructional materials along criteria not prominent in their initial set. Even with explicit support, however, they did not engage in substantive critique about how scientific content is represented, such as what diagrams or models are used. These findings guided our redesigns of these critique assignments over the next few years.

We also investigated preservice elementary teachers' curricular role identities (Forbes & Davis, 2008b), or their orientations toward the use of science curriculum materials, as defined above. In particular, of course, we hope to promote a curricular role identity in which the active and analytic use of science curriculum materials is valued. By analyzing survey responses for 47 preservice teachers and interview and observational data for 8 of these, we found that the types of experiences described above, as well as positive interactions with their cooperating teachers around curriculum materials, influenced the preservice teachers' curricular role identities. In contrast to typical perspectives seen in the literature (e.g., see Ball & Feiman-Nemser, 1988), these preservice elementary teachers began to see curriculum materials as playing a foundational role in classroom teaching. For example, they started to recognize the active use of science curriculum materials as an important dimension of elementary teaching practice, account for the role of classroom and community context in using curriculum materials, and see the role curriculum materials could play in supporting teachers' learning.

Our longitudinal study indicated that supporting preservice teachers in developing knowledge, skills, abilities, orientations, and identities related to productive use of existing science curriculum materials is crucial. While a few of the early career elementary teachers with whom we worked (see Table 1) had high-quality, commercially available science kits with some orientation toward inquiry, others had less coherent materials and/or only textbooks; all spent enormous amounts of time drawing on a range of resources, as evidenced by analysis of interview transcripts and written reflections. As Catie noted at the end of her first year during which she was teaching sixth grade, "I can't say if there was one activity or experiment that I did this year that I wouldn't have some sort of modification to it" (see Forbes & Davis, 2007). The teachers relied heavily on curriculum materials to structure their practice and adapted them in light of their views of effective science teaching. Furthermore, the teachers' learning through their use of curriculum materials was influenced by their curriculum materials and their opportunities for iterative cycles of planning, enactment, and reflection. Whitney, for example, taught the same inquiry-oriented unit multiple times each year to all of her school's fourth graders and developed substantial PCK specific to that unit. Whitney was unusual in this regard. Other teachers experienced less consistency and were less able to develop relevant PCK (Forbes & Davis, 2007).

Our longitudinal research also explored, drawing mainly on analysis of interview transcripts, how three teachers critiqued and adapted instructional representations embedded in curriculum materials (Stevens & Davis, 2007), an area of struggle for preservice teachers (Davis, 2006b). Such representations include diagrams, models, analogies, and simulations. Lisa's statement here about her sense of using a particular representation with her third graders was typical of the teachers' responses to an instructional representation in their first year of teaching:

> I really think this could work. Third grade—sure. I figured, you know, you don't have to get too, too technical in third grade. (see Stevens & Davis, 2007)

The early career teachers came to critique instructional representations along important dimensions including how accurate and accessible they were as well as management issues. As they gained experience, the teachers started to integrate concerns about student learning in their reactions to instructional representations. For example, in year 3, Lisa said,

> But I don't really think if I was a kid I would be able to make that connection without having the teacher explain it and saying "this is why." Because I didn't get it until I read the teacher information. And unless the kids knew all that information about pressure and clouds, they might not be able to make the connection. (see Stevens & Davis, 2007)

The teachers became more sophisticated in their critiques over time, considering and integrating more factors (Stevens & Davis, 2007).

Two teachers, Maggie and Catie, wrote narratives about their use and modification of lesson plans, as images of inquiry for CASES (Davis et al., 2007). Maggie, the most experienced teacher in our longitudinal study and at the time a sixth-year teacher teaching third grade in a large urban district where her students represented a diverse group of languages and cultures, drew extensively on her knowledge of and experiences with students to make productive changes to lesson plans to account for her students' prior knowledge and abilities. For example, in describing the ways in which she changed a CASES weather observation lesson, Maggie wrote,

> I modified the worksheet so that students could easily record observations (something my students really needed to work on) of the weather in their environment. . . . Many of my students do not have computer access and language issues can get in the way of watching a weather report, so the only numerical data they collected each day was temperature, which they could get off the time/temperature in the corner of their television screen or preferably from the classroom thermometer. As our collective knowledge grew, students were required to include more specific weather vocabulary (e.g., types of precipitation, names for various clouds. . .). Overall, these modifications made daily observations less intimidating and more meaningful for my students. (Maggie, Images of Inquiry, Establishing Weather Observations Lesson)

Catie, on the other hand, based her curricular adaptations on her learning goals for students—but Catie's learning goals for her second graders were not always well aligned with the learning goals espoused by the CASES plants unit. Catie maintained the unit's emphasis on careful observation, but eliminated aspects that entailed using those observations as evidence to support claims (Davis et al., 2007).

Preservice teachers developed the propensity toward and some abilities related to principled analysis of curriculum materials. Our work also highlights aspects of preservice teachers' knowledge, beliefs, and identities to which we need to pay increased attention. For example, the preservice teachers struggled with critiquing the instructional representations in the curriculum materials. The early career teachers' reliance on and modification of curriculum materials leads us to suspect that the instructional time we spend on the curriculum materials goal is worthwhile. For example, Catie's focus on learning goals is consistent with our work in the course and the findings of our research with preservice teachers—but also suggests the importance of continued emphasis on inquiry. Maggie's integration of students' ideas and instructional decision making around modifying curriculum materials suggests the crucial importance of supporting beginning teachers in learning to anticipate and work with their students' ideas. We turn to this third goal next.

THE STUDENTS' IDEAS GOAL

Attending to learners' ideas is a critical aspect of PCK (Magnusson et al., 1999; Shulman, 1986). Most teacher educators seem to agree that preservice teachers are unlikely to develop PCK because they do not have much teaching experience (e.g., van Driel, De Jong, & Verloop, 2002). Even though teacher educators cannot easily provide extensive exposure to learners before student teaching, we hypothesize that they can provide experiences that prepare preservice teachers to develop PCK. We refer to this preparation to develop PCK as "PCK readiness" (Smithey, 2008). Kindergarten teachers spend most of their school year helping their students develop "reading readiness"—skills necessary for students to develop before they can read (for a review, see Farr & Anastasiow, 1969). For example, children need to know how to hold a book, which direction to turn the pages, the letters of the alphabet and the sounds each makes, and the general components of stories. None of these skills is technically "reading," but every reader has these skills. Similarly, a preservice teacher can learn about the content, how to represent content to learners, and common ideas their learners bring to science class. Even if this initial knowledge is in pieces, these pieces form necessary building blocks to well-developed PCK, and eventually, usable knowledge (Smithey, 2008). Our construct of PCK readiness guides us as teacher educators and researchers.

Because learning to teach is a difficult juggling act, it is not surprising that beginning teachers tend to focus on themselves rather than their students' learning (Fuller, 1969; LaBoskey, 1994), especially without scaffolding. Three issues may stand in the way.

First, as noted above, beginning teachers value interest and engagement in science. They want learners to enjoy science, often in contrast to their own experiences in school (Anderson, Smith, & Peasley, 2000; Bryan & Abell, 1999; Trumbull, 1999). As they engage with learners, however, they find that keeping students engaged as well as meeting science content goals is difficult. Some stop trying and focus only on engaging students (Anderson et al., 2000). Some do not understand the science and emphasize interest in science instead (Abell et al., 1998).

Second, beginning teachers struggle in dealing with students' ideas during instruction. Knowing strategies to help students overcome their difficulties is challenging (Magnusson et al., 1999; Smith & Neale, 1989). Weak subject matter knowledge can also limit teachers' ability to deal with students' ideas (Ball & Bass, 2000; Carlsen, 1992; Smith & Neale, 1989).

Finally, beginning teachers' view of knowledge impacts how they look at their students' ideas. Meyer (2004) found differences between how novice and expert teachers viewed students' ideas. Beginning teachers looked at knowledge as static, so they focused on finding out which bits students knew and did not know and then determining how to fill those gaps. Expert teachers held a more complex view of learning and brought that to their instructional decisions.

How Do We Address the *Students' Ideas* Goal?

We designed experiences to help preservice teachers consider characteristics of learners' ideas and how to deal with those ideas in instruction. Considering one's students and trying to anticipate their ideas, identify their actual ideas, and work with them in instruction all contribute to better understanding learners (Carpenter, Fennema, & Franke, 1996; Smith & Neale, 1989).

Smith (1999) advocated that interviewing children about content is crucial for preservice teachers, noting,

> Reading articles that describe research on children's thinking about how plants get their food is interesting. Having real children describe in their own words that "trees have long branches that touch the ground so that they can get the food from the soil" is much more compelling. (p. 182)

Smith argued that participating in these discussions develops preservice teachers' PCK. We ask the preservice teachers to interview a child about their understanding of the science concepts they plan to teach. They then reflect on the experience, describing their learners' science ideas and how they plan to use this information in their planning.

We also use three other activities that work toward our goal related to students' ideas: the assignments, described above, focused on images of inquiry, critique of lesson plans, and reflective teaching. Here, we briefly discuss how each relates to our goal of attending to students' ideas and how we use it in the course in relation to that goal. First, in the first images of inquiry assignment, as noted above, preservice teachers read images of inquiry focused on students' ideas, specifically on using students' ideas in instruction and planning. The preservice teachers respond to questions about these images. In the second images of inquiry assignment, the preservice teachers focus on any image teacher. Second, in one critique assignment preservice teachers evaluate a lesson based on criteria they generate for critiquing curriculum materials; in another, they use one of six class criteria that we generate based in part on our goals (including attention to student ideas). This activity, like the second images of inquiry assignment, does not force preservice teachers to focus on learners' ideas, but in each assignment, preservice teachers have the opportunity to do so. Third, preservice teachers teach two science lessons in their field placements for their reflective teaching assignments. For each, they turn in a lesson plan and a reflective journal entry. The lesson plan guidelines ask them to predict ideas their learners will have. The reflection instructions ask them to reflect about their students' ideas during the lesson. By using a framework for planning, enacting, and reflecting, preservice teachers can develop their PCK, especially when given multiple opportunities to do so (Zembal-Saul, Blumenfeld, & Krajcik, 2000).

Finally, one semester the preservice teachers did not seem engaged in the online discussions, and we decided to offer an option. The instructor provided a prompt related to learners' ideas, and preservice teachers could choose whether to participate in the discussion online or face to face. Those who chose to talk face to face, which included almost all of the preservice teachers, wrote a summary of and reflection on that conversation.

Results of Our Research: The Students' Ideas Goal

Our study of 25 preservice teachers' written reflections on their science teaching indicated that some preservice teachers integrated considerations of their learners with considerations of their own instruction, whereas others merely juxtaposed ideas about learners and instruction, as if they were unrelated to one another (Davis, 2006a). Preservice teacher Reyna's written reflection on her first science lesson was typical of her reflections in the course and illustrates the tendency of some preservice teachers to merely report on what students said or did in a lesson, rather than integrating ideas about learners, learning, instructional approaches, and assessment. For example, Reyna wrote,

> One child raised his hand and just said winter when I asked for questions. I asked if winter was a question or if he was telling me part of weather. He said part of weather. Then a few more questions and then someone else raised their hand and said rain. Again I said is that a question or part of weather. They said part of weather and I said right. (Reyna; see Davis, 2006a)

Other preservice teachers were much more analytic in their reflections, considering students' ideas and their relationship to instruction much more carefully. We extended this work in two studies related to the students' ideas goal (Smithey, 2008; Smithey & Davis, 2006, 2007), looking at how preservice teachers progress in their thinking about students' ideas and how the instructional opportunities we provide for them relate to their development of PCK readiness.

In one study focusing on selected written coursework of an entire class of 20 preservice teachers (Smithey, 2008; Smithey & Davis, 2007), we looked for the ways in which preservice teachers attended to two aspects of learners' ideas: *characteristics of those ideas* and *how to deal with ideas*. Preservice teachers emphasized aspects of dealing with students' ideas, focusing mainly on finding out what the ideas were. In contrast, preservice teachers almost never emphasized notions related to characteristics of learners' ideas, despite an emphasis on the course. The aspects of characteristics of ideas that were not emphasized—including factors that contribute to ideas, difficulty of ideas, resilience of ideas, and importance of ideas—seemed more abstract, whereas the two aspects of characteristics of ideas that preservice teachers did address—describing and anticipating learners' ideas—were more concrete.

Some assignments allowed preservice teachers to make choices about their focus. When given a choice, the preservice teachers tended not to focus on students' ideas. In the critique assignment with choice, the preservice teachers typically chose to evaluate the lesson plan based on criteria other than those focused on students' ideas. Similarly, in the second images of inquiry assignment, they typically chose to read about teachers with emphases other than students' ideas, and in the peer discussion, they typically considered other issues, as well (Smithey, 2008).

In a related study, eight preservice teachers were followed closely, to look at their trajectories related to their learners' ideas over the semester (Smithey, 2008; Smithey & Davis, 2006). For these teachers, we analyzed all of their written work for the course as well as transcripts from two interviews with each. Some changed the way they thought about their learners' ideas. Their experiences with their learners played an important role; the reflective teaching assignment seemed to facilitate the change. For example, after Riley taught a lesson using her cooperating teacher's strategy of having her first-grade students copy a sentence from the board to end a lesson, she wrote,

> I don't think I would use this [strategy] again because I don't think it gives a very accurate indication of what they have actually learned. Instead I would have them write as much as they can on their own, and allow time to go around and write down the ideas of each student. This way I can see who needs more scaffolding and what general ideas need to be revisited. (see Smithey, 2008)

These results suggest that even limited opportunities to teach science and reflect on the experience can be beneficial in developing PCK about how to attend to learners' science ideas.

Other preservice teachers did not change much in their thinking about learners' ideas (Smithey, 2008). Some engaged with thinking about learners' ideas when prompted but never did so on their own. Furthermore, some entered the semester with strong ideas related to learners' ideas that were in opposition to the ideas promoted in the course. Preservice teachers with these strong initial ideas changed little over the semester. Like the ideas of K-12 students, preservice teachers' ideas were resilient and not easy to change.

Our research on early career elementary teachers' consideration of students' ideas is ongoing. Some of our analyses with other emphases, however, point to the importance of students' ideas for these teachers. These analyses are mostly based on interview data and written reflections. Whitney (see Table 1), for example, drew on her students' ideas extensively as she elicited scientific questions from them and used those questions to frame her instruction (Forbes & Davis, 2007). Lisa thought carefully about how she could scaffold her students' understandings of complex science content, identifying ways to align her instruction with her students' understandings (Stevens & Davis, 2007). And Maggie used her students' backgrounds, prior knowledge, and experiences to inform her modification of curriculum materials, saying, for example, "You really need to know your kids" (see Davis et al., 2007). Each moved along a trajectory as she gained experience in the classroom (Anderson et al., 2000).

In sum, our research reinforces the importance of working on the student ideas goal in an elementary science methods course. Some assignments do help promote our goal, whereas others are less consistently successful. Some dimensions—including aspects of how teachers can identify and work with learners' ideas—are easier to promote than other more abstract notions. For example, further support is needed to help preservice teachers consider the factors that may contribute to students' ideas or the resilience of those ideas, as well as to connect ideas about their learners to the instructional experiences the learners have. Finally, we highlight the role of individual differences among preservice teachers. These differences appear to continue to play out as the teachers move into their own classrooms.

DISCUSSION

Ideally, preservice teachers integrate their knowledge to become able to use their knowledge flexibly in authentic teaching situations (Davis, 2004; Linn & Hsi, 2000). We hope that the preservice teachers with whom we work do not come away with isolated knowledge and abilities related to each of the goals, but rather that they are able to tie them together in a meaningful way. This ability to connect ideas would allow them to develop flexibility (Spiro et al., 1991). We see this integration as a hallmark of a well-started beginner.

Given this assumption, talking about the three goals of our course separately may seem inadequate. We have separated the three goals for two reasons. First, from an instructional standpoint, it helps us in our teaching. We can explicitly draw preservice teachers' attention to the handwritten list of goals hanging in our classroom, and we can point to instances of when we are working on one, two, or all three of the goals—or when they are recounting instances from their own teaching in which they are drawing on issues related to one or more of the goals. Second, separating the goals is necessary analytically. For us to get a sense of the progress we are making on these issues, we need to—at least some of the time—consider them separately.

Most of our assignments work toward multiple goals. Consider, for example, the series of critique assignments in which preservice teachers critique and adapt curriculum materials. Most centrally, of course, the critique assignments work toward the curriculum materials goal. Some teachers do not see curriculum adaptation as a part of their professional role (Bullough, 1992; Eisenhart et al., 1988), and preservice teachers sometimes see this as outside the realm of what they should do (Ball & Feiman-Nemser, 1988; Schwarz et al., 2008). Yet effective teachers engage in constant analysis and adaptation (Ben-Peretz, 1990; Brown, 2009; Remillard, 2005). Our preservice teachers come to see the use of curriculum materials as an important aspect of their job (Forbes & Davis, 2008b). They recognize that it is not sufficient merely to like or dislike a set of materials. Equally important, the assignments help the preservice teachers develop knowledge and abilities related to the analysis and productive adaptation of materials (Davis, 2006b; Forbes & Davis, 2008a)—skills with which they may otherwise struggle (Lynch, 1997).

Yet the critique assignments also support the inquiry goal. Engaging in the assignments helps preservice teachers see how inquiry can be instantiated in an instructional plan and think about how lessons can be adapted along the inquiry continuum (NRC, 2000). Focusing on inquiry-oriented science teaching within these assignments and elsewhere should promote understanding that the goal of science teaching is to engage children in scientific practices toward the goal of learning science content (NRC, 2007).

Finally, the critique assignments support the students' ideas goal, for example, by helping the preservice teachers recognize that as they use curriculum materials, they need to look for how seriously the materials take students' ideas. Furthermore, these assignments can help preservice teachers recognize that children *can* learn complex science ideas and engage in authentic scientific practices, when scaffolded (Metz, 1995).

Thus, the same series of assignments allows preservice teachers to simultaneously address all three of the goals. The images of inquiry assignments are another example of meeting multiple goals at once. Working on the three goals throughout the entire course, using a range of assignments and experiences, helps us address all of the problems of practice identified in the Introduction (Mikeska et al., 2009, this issue).

Consider the work presented here using the lens of some of the main findings of our review of the challenges facing beginning science teachers (Davis et al., 2006), as summarized above in the section Overcoming challenges through addressing goals. To recap, beginning elementary teachers often struggle with understanding science content and the nature of science; they tend to focus on students' engagement, interest, or motivation; they do not know what to do with information they learn about their students' backgrounds or ideas; they emphasize the use of hands-on activities but not learning from these activities; they avoid teaching science; they struggle to put their ideas into practice; and their personal characteristics influence their development. Developing an understanding of scientific inquiry should contribute to our beginning teachers' improved understanding of science and the nature of science, though we have not yet researched such improvement. The beginning teachers with whom we work do move beyond a focus on engaging, managing, and/or motivating their students, toward prioritizing learning goals. While they are not yet expert at using their students' ideas, most do develop some PCK readiness while they are in our classes, and some of the early career teachers in our longitudinal study reflect sophisticated expertise with regard to finding out and working with their students' ideas. The participants in our longitudinal study, at least, actively work to incorporate more science into their students' school days, sometimes working to subvert explicit directives from their school administrators. They do have less sophisticated practice than ideas, to be sure—but many seem positioned to blossom into very effective science teachers, especially if supported by high-quality curriculum materials. Finally, we see evidence of reflectiveness and identity development—science teacher identity and curricular role identity—that may promote that blossoming sooner rather than later.

Despite the ways in which we see our course as supporting preservice teachers in becoming well-started beginners who are poised to overcome some of the challenges facing them, we always want to improve our course. We discuss our future instructional work next, to set the stage for considerations for science teacher education more generally. Some of these design implications grow directly out of our research, while others are less direct.

FUTURE INSTRUCTIONAL DIRECTIONS: DESIGN IMPLICATIONS

Our research indicates that we need to continue to support preservice teachers in understanding characteristics of students' ideas, such as the resilience of those ideas and the factors that contribute to their development (Smithey, 2008), and elementary science teacher educators should continue to explore ways of doing so. Learners have a repertoire of connected ideas, and simply telling them that one idea is right and another is wrong is unlikely to change their thinking (Linn & Hsi, 2000; Smith, diSessa, & Roschelle, 1994). If teachers view learners' ideas as easy to change, then their instruction is less likely to be effective.

Furthermore, we do not yet do enough to help our preservice teachers understand learners who are different from themselves. Most of the preservice teachers in our classes are White females, like most of the elementary teachers in the United States (NCES, 2003), and they have been successful in school—yet these teachers will teach children who are different from one another in many ways. These differences manifest themselves in terms of race, ethnicity, class, language, special needs, gender, family structure, and religious background, to name just a few. We need to prepare the teachers to work effectively with all children and to recognize their funds of knowledge (Bianchini, Johnston, Oram, & Cavazos, 2003; Fradd & Lee, 1999; Southerland & Gess-Newsome, 1999; see Mikeska et al., 2009, this issue). Elementary science teacher education research needs extensive, purposeful focus here.

A more general instructional issue that has emerged from our findings is the tension between freedom and structure (Davis, 2006b; Smithey, 2008; Smithey & Davis, 2004a). Our studies suggest that without specific prompting to focus on a particular issue, preservice teachers may choose to focus on other areas. This suggests that methods instructors should—to the extent possible—carefully scaffold a focus on those concepts that are most important. However, we suspect that giving preservice teachers freedom to choose their focus is also an important aspect of building preservice teachers' identities as science teachers. Elementary science teacher education needs to continue to explore ways of supporting conceptual growth without stifling other development.

We continue to work on improving the characteristics of the field placements in which the preservice teachers are placed. If preservice teachers can see their cooperating teachers working with curriculum materials, have more extensive experiences with the children in their classrooms, and see inquiry-oriented science teaching being enacted—rather than just learning about these ideas in our methods class—they can make better progress on our goals. All of these are tall orders. Given what is known, however, about the resistance of preservice teachers even to coherent visions of practice (Clift & Brady, 2005), it seems crucial to work to improve the field experiences in these ways (Schwarz et al., 2008; Zembal-Saul, 2009, this issue).

Most importantly, we continue to press on developing preservice teachers' abilities directly related to instructional practice. We prepare preservice teachers with some of the knowledge and analytic skills they need to be well-started beginners. Yet we do too little to support the preservice teachers in moving their lesson plans into the classrooms, and developing the instructional moves that will make their plans a success as they interact in real time with children. Doing so would support the preservice teachers in moving from PCK readiness to developing usable PCK. Elementary science teacher education needs to explore effective approaches for fostering these shifts.

CONCLUSION

We reiterate that we have chosen to focus on three goals in our elementary science methods course and in this paper, related to inquiry-oriented science teaching, the use of curriculum materials, and students' ideas. These align with the problems of practice identified in the Introduction (Mikeska et al., 2009, this issue) and are crucial areas of focus for elementary science teacher education. We do not argue, however, that these are the only goals of value. Other science methods courses reflect different and equally important choices. Zembal-Saul (2009, this issue) and Schwarz (2009, this issue) both take on the task of seriously supporting preservice teachers in learning to engage students in authentic scientific practices—a goal we aspire to with our work on scientific explanation and inquiry more generally. Cartier and Sink (in preparation) emphasize supporting preservice teachers in learning to engage children in learning about and with "big ideas" in science—an emphasis that deserves more attention in our own course. Other teacher educators focus on other important goals, as well. Any set of goals that drive design decisions inherently reflects a set of design trade-offs (Mikeska et al., 2009, this issue); balance, of course, is key.

We hope we have provided a sense of what these beginning teachers are like—who they are, what they struggle with, and how they grow over time and with support. Some of these characteristics, struggles, and areas of growth are likely similar across contexts, and may inform other elementary science teacher educators. The joy of integrating our research with our teaching is that we can always directly connect our findings to something tangible—the activity in tomorrow's class, the scaffolding provided in next month's assignment, or the supports provided in the curriculum materials we develop with the intention of supporting teacher learning.

We also hope we have persuaded readers of the importance of the particular goals discussed here, but more significantly, we encourage other elementary science teacher educators to identify their own goals, based on the field's understanding of beginning elementary science teachers. The work of teacher education is to develop not expert teachers, but well-started beginners, with the knowledge, strategies, tools, and abilities they need. We encourage elementary science teacher educators to measure success systematically in terms of the important outcomes related to elementary science teacher education, and then to iteratively refine instruction, through design-based research, to better achieve the goals.

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