

Preservice Elementary Teachers' Critique of Instructional Materials for Science

ELIZABETH A. DAVIS

School of Education, University of Michigan, Ann Arbor, MI 48109-1259, USA

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ABSTRACT: Science teachers must adapt curriculum materials, so preservice teachers must develop beginning proficiency with this authentic task of teaching. What criteria do they use when they critique these materials in preparation for adapting them, when they develop the criteria themselves and when they are given a set of criteria from which to choose? These results indicate that the 20 participating preservice elementary teachers held a sophisticated set of criteria for critiquing instructional materials; for example, they paid attention to scientific inquiry and instructional goals. In some cases, providing options from which they could select as a part of the instructional approach taken in the class allowed the preservice teachers to engage in substantive critique of the instructional materials along criteria not prominent in their initial set. Even with explicit support, however, the preservice teachers did not engage in substantive critique about how scientific content is represented. Furthermore, they typically describe inquiry as important to incorporate to promote student interest, not to engage students in genuine scientific activity. It is concluded that critique activities used in science methods courses should be authentic and scaffolded to be optimally effective. Critique along especially challenging dimensions needs systematic, explicit, and perhaps more consistent support. © 2006 Wiley Periodicals, Inc. *Sci Ed* **90**:348–375, 2006

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Correspondence to: Elizabeth A. Davis; e-mail: betsyd@umich.edu

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INTRODUCTION

Effective teachers use curriculum materials as a guide. Adapting curriculum materials is especially important when teachers face the challenges of meeting crucial content and inquiry standards and teaching an increasingly diverse population of learners. Expert teachers, therefore, refine curriculum materials to be appropriate for their own students, contexts, objectives, and styles. New teachers need to learn to make the same kinds of adaptations, both while planning and during enactment, so preservice teachers need to be supported in developing beginning levels of proficiency with this task of teaching.

What kinds of adaptations do teachers need to make during their planning? Consider an example. A set of curriculum materials for elementary science might include hands-on activities but fall short in suggesting how to help students make sense of the science or connect activities to their real-world experiences. Teachers using the curriculum materials should be able to notice these characteristics—hence the importance of critique—and then make appropriate changes to develop learning experiences that are more likely to be productive for their students.

This study explores how preservice teachers in an elementary science methods class critiqued and adapted instructional materials over time, with a primary focus on critique, which is the first step of critique and adaptation. The primary question is *what is the basis for preservice elementary teachers' critique of instructional materials in science?* Because we know little about how preservice teachers approach this task, the study is largely descriptive. To better understand the preservice elementary teachers' use of criteria for critiquing curriculum materials, the description is broken into two pieces, corresponding to two types of assignments the preservice teachers were given. One type asked the preservice teachers to *develop* criteria for critiquing curriculum materials on their own and the other asked them to *select* from a set of criteria. Thus, the study also investigates questions about providing different levels and types of scaffolding in the assignments: *what criteria do preservice elementary teachers use for critiquing instructional materials when they develop the criteria themselves, and what criteria do they use when they are given a set of criteria from which to choose?* Since the study takes place within the context of an elementary science methods course in which a major goal was the development of their knowledge and ability with regard to critiquing instructional materials, all the assignments incorporated support for the preservice teachers' success, though the specifics differed.

I use the term *instructional materials* in these research questions to capture a range of resources including activities, lesson plans, unit plans, and assessments. The term is intended to signal that not all of the materials that the preservice teachers investigated were part of a coherent curriculum (as *curriculum materials* might imply, though in keeping with standard usage I use *curriculum materials* in my discussion of the literature). Furthermore, although the course involved some informal critique of all of these types of instructional materials, this study focuses on critique of activities and lesson plans. I distinguish between activities and lesson plans; *lesson plan* is intended to imply more pedagogical information for the teacher than *activity*. For example, an activity might describe how to use a tennis ball and a flashlight to model the phases of the moon, while a lesson plan would also provide recommendations for a teacher who wanted to use such a model with her students, perhaps including discussion questions, assessment ideas, or other features a teacher might need.

Adapting instructional materials can refer to changes made during one's planning or real-time during one's enactment. The preservice teachers in this study identified strengths and weaknesses of the instructional materials and suggested changes for the written plans. In reality, the critique and adaptation were intertwined for the preservice teachers here, and so when I discuss what the preservice teachers did in my class, I use *critique* to signal this

amalgam of critiquing and adapting in planning. This study does not investigate, however, the preservice teachers' enactment of lessons. In my discussion here of the importance of critiquing and adapting instructional materials, I distinguish between the critique and adaptation at the planning stage and the real-time adaptation in which practicing teachers must also engage.

A goal of this study is to inform the design of science teacher education to promote preservice elementary teachers' productive use of instructional materials. Toward that end, the study is intended to determine what aspects of science curriculum materials preservice elementary teachers pay attention to or ignore, what aspects of curriculum they can critique well, and where they need support. The study also investigates how different supports for critiquing help the preservice elementary teachers engage in this authentic task of teaching.

TEACHERS AND CURRICULUM MATERIALS

Teaching is difficult, especially for beginning elementary science teachers. For example, because of the high demands put on them, elementary teachers often demonstrate weak subject matter knowledge in science (Anderson & Mitchener, 1994). Teaching inquiry-oriented science is especially complex (Crawford, 2000; Metz, 1995) and typically requires teachers to teach in a way that is different from how they were taught (Windschitl, 2003). In addition, recent reviews of science curriculum materials indicate that they may not help teachers much; many textbooks do a poor job of representing scientific content and inquiry (Kesidou & Roseman, 2002) and include numerous scientific inaccuracies (Hubisz, 2003). Finally, learners, far from being a homogeneous group, are becoming ever more diverse, with different needs and strengths (Lee, 1997). How can teachers using curriculum materials overcome these and other challenges?

The answer depends on one's view of the roles of teachers and curriculum materials. Historically, researchers have taken one of three views of the role of curriculum materials vis-à-vis teachers. The first perspective is that curriculum materials should be implemented as written—the “remote control” (Brown & Edelson, 2003, p. 2; see also Shulman, 1983) or “teacher-proof” (see Krajcik, Mamlok, & Hug, 2000; Rudolph, 2002) approach to shaping instruction or school reform through curriculum materials. The second perspective, at the other extreme, is that teachers should do mainly curriculum *development*, rather than using curriculum materials developed by others (see, e.g., Prawat, 1993). Karplus (1971) described teacher development of curriculum as the ideal, given the context-specific nature of classrooms and enactment. (As a developer of curriculum materials himself, though, he acknowledged the impracticalities of adopting this perspective on a large scale and pointed to the practical need for high-quality, readily available curriculum materials.) The third perspective, which grounds the current study, represents an important and more flexible middle ground: that teachers should be able to *adapt* curriculum materials developed by others, such as commercial curriculum writers or other teachers. This perspective is described next.

Why and How Do Teachers Critique and Adapt Curriculum Materials?

Pragmatically, teachers often need to adapt even high-quality curriculum materials to better support their own students' learning (Barab & Luehmann, 2003; Baumgartner, 2004; Squire et al., 2003). This adaptation, at both the planning and enactment stages of teaching, is especially important when one takes as a goal the promotion of current educational reforms that recommend engaging students in meaningful learning activities and helping them connect ideas to their real-world experiences. For example, an experienced teacher

might adapt a unit to allow students greater opportunity to design their own investigations; on the other hand, a beginning teacher may adapt the same unit to provide more structure. Another teacher might adapt a unit to incorporate experiences to capitalize on her students' language or cultural backgrounds. Some teachers make productive changes to curriculum materials toward these ends 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).

The results of the curriculum development and implementation efforts of the 1950s and 1960s in the United States indicate that curriculum developers and researchers must account for the role of teachers in order to promote reform through curriculum (e.g., Bolin, 1987; Krajcik et al., 2000; Welch, 1979). Indeed, in the efforts following (and reacting to) those efforts, teachers started to be referred to as curriculum makers (Clandinin & Connelly, 1991) and as agents, rather than targets, of reform (Prawat, 1993). Curriculum developers started to consider teachers as individuals who would make individual decisions about their use of curriculum materials. Looking at how individual teachers use curriculum materials in their practice, rather than looking at groups of teachers investigating curriculum materials as part of their curriculum deliberation (Harris, 1986; Johnston, 1993; Roby, 1985), shows that teachers appropriate tasks (as-is) from curriculum materials, adapt tasks included in the curriculum materials, or use the curriculum materials as a source of inspiration for developing new tasks (Brown & Edelson, 2003; Remillard, 1999). *Curriculum development* itself began to take on a broader, more expansive meaning. For example, Bolin (1987) wrote

Curriculum development should be seen as a continuum from development of a document—which may be begun by one group—through implementation of the document by the teacher. The teacher is an active participant in the process. This participation begins with the teacher's intellectual engagement with the document, in which its substance is analyzed, modified, and supplemented in light of the realities of the teacher's own classroom. (p. 97)

This broader view of curriculum development is grounded in an assumption that teachers must recognize the strengths and weaknesses of the written curriculum materials they are using (Ben-Peretz, 1990). Researchers, developers, and practitioners who hold this perspective emphasize that when teachers change high-quality curriculum materials, the changes must be principled, maintain the integrity of the original design, and work toward attaining the same goals as were the goals of the original (Ben-Peretz, 1990; Bridgham, 1971; Brown & Edelson, 2003; Pintó, 2005).

In the midst of these shifts in perspective, Shulman (1983) argued eloquently in favor of allowing teachers the autonomy to make decisions in their own classrooms. Rather than recommending that instructional designers, administrators, or others “help” teachers by prescribing all aspects of their practice, Shulman instead described teachers as professionals whose actions are bounded—in both positive and negative ways—by a multitude of policy and bureaucratic structures. Curriculum materials can act as a set of useful constraints. In Japanese lesson study, for example, lessons are collaboratively and painstakingly designed by teachers, and these lessons are intended as “examples of a particular goal or vision in action”; other teachers “feel free to draw on them as appropriate to their own philosophy and classroom” (Lewis & Tsuchida, 1998, p. 14). Allowing teachers the autonomy to make decisions about curriculum materials' classroom use is crucial—and so is helping teachers to learn the skills that they need in doing so effectively (Lloyd, 1999). Providing this support for beginning teachers is especially important.

Learning to Critique and Adapt Curriculum Materials

Science teacher educators, however, face challenges in providing support for preservice teachers learning to critique and adapt curriculum materials in their planning and enactment. First, teachers (including preservice teachers) may not recognize adaptation or development of curriculum as a part of their job or may not value it as they make decisions about their priorities (Bullough, 1992; Eisenhart et al., 1988). Second, there is not consensus about what criteria to use for making curricular adaptations (Barab & Luehmann, 2003), though some criteria exist (e.g., Ben-Peretz, 1990; Kesidou & Roseman, 2002). Third, how teachers adopt and adapt any curricular innovation is influenced by a complex constellation of factors including the teachers' knowledge and beliefs about content, teaching, and learning as well as their contextual constraints (Pintó, 2005). Fourth, it is difficult for preservice teachers, in particular, to critique curriculum materials effectively (see, e.g., Lynch, 1997). For example, preservice teachers may not understand the analogies that are used in curriculum materials to represent scientific ideas (Yerrick et al., 2003) and thus they may have trouble critiquing the representations effectively. Fifth, teacher educators lack models of instructional approaches for engaging preservice teachers in critique and adaptation of curriculum materials. Recent reviews illustrate the lack of focus on this area in science teacher education as well as in teacher education more generally (Davis, Petish, & Smithey, accepted pending revisions; Grossman, 2005). Finally, science curriculum materials are not of consistent quality (Kesidou & Roseman, 2002), and so may present additional challenges as teachers try to adapt them.

Given the challenges beginning elementary teachers face in general, as well as these challenges faced by science teacher educators, why should teacher educators even try? In sum, two reasons for introducing critique and adaptation of curriculum materials during teacher education are most salient here. First, new teachers must be supported in recognizing that adapting curriculum materials is, indeed, a crucial part of their job (Bullough, 1992). Second, new teachers need to develop some initial skills and knowledge in this arena to help them be better prepared for this aspect of their job when they become practicing teachers, though of course they will continue to learn through their experience, as well. Teacher educators have an obligation to help preservice teachers be well-started beginners.

Toward these ends, preservice teachers in an elementary science methods course were engaged in this study in a series of activities intended to help them learn about critiquing instructional materials. The preservice teachers were provided with scaffolding to help draw out their own criteria for critiquing and apply those criteria in systematic ways. They critiqued multiple types of instructional materials, and so gained familiarity with a wide range of resources (and their varying levels of quality) while they gained beginning-level skills in critiquing.

METHODS

This study took place during the third semester of an undergraduate teacher preparation program in the United States. The preservice teachers in the elementary science methods course studied here went through the program as a cohort. All were female and most were white; in other words, these preservice elementary teachers were typical of elementary teachers in the United States (NCES, 2003). Most were traditional fourth-year seniors (about 21-years old) in their final year of college. The author taught the science methods course. At the start of the course, 20 of the 24 preservice teachers in the course consented to later analysis of their work from the course, so data were collected on 20 individuals. The preservice teachers were reassured that they could withdraw their consent for participation at any time, though none of them opted to do so.

The four-semester teacher preparation program was aligned with recommendations of teacher education reform calls (e.g., INTASC, 1992; NCATE, 1987) and subject-matter standards documents (e.g., AAAS, 1993; NCSS, 1994; NCTM, 1991; NRC, 1996). At a fundamental level, the program attempted to help preservice teachers understand a few key aspects of teaching including learners, learning, knowledge, knowing, and instruction. Each semester in the program, the preservice teachers were placed in field classrooms for 6 h per week, gradually taking on increased responsibilities. The first semester of the program also involved an introductory course in which preservice teachers carefully investigated the learning of a single student, an educational psychology course, and a literacy methods course. The overarching emphasis was on *learners and learning*. In the second semester of the program, the preservice teachers took a second literacy course, an educational foundations course emphasizing multiculturalism, and a social studies methods course in which the preservice teachers engaged in curriculum development and refinement with a focus on history content and ways of knowing history. This second semester emphasized *knowledge and knowing* and *instruction*. During the third semester, in addition to the science methods course that is the focus of this study, the preservice teachers took a mathematics methods course, in which they focused on representations of mathematical ideas and on children's ideas about mathematical concepts. The emphasis of the third semester as a whole, and of the science methods course in particular, was on *integrating* concerns about *knowledge and knowing*, on the one hand, and *learners and learning*, on the other hand, into one's thinking about *instruction*.

Specifically, three main conceptual themes characterized the elementary science methods course. The first focused on anticipating, recognizing, and dealing with students' ideas. The second emphasized inquiry-oriented science teaching. The third theme—most salient to the current study—involved critiquing instructional materials.

Critique Activities in the Science Methods Course

The assignments relating to the critique of instructional materials were integrated into the fabric of the elementary science methods course studied here, rather than forming the course's sole focus. The goal of researching and reporting on the preservice teachers' critique of instructional materials in the context of this course is to show what can happen with regard to preservice teachers' critique of instructional materials in a regular elementary science methods course covering multiple areas of interest to science educators. Although the critique assignments were integrated into the rest of the course, the preservice teachers' work on these assignments can be pulled out and analyzed separately, as a distinct site for attention.

Some of the critique assignments were completed individually. Assignments #1 and #5 served as individual pre- and post-course assessments; I designed Assignment #2A as an individual activity to encourage independent thinking about critique before moving to a collaborative endeavor in Assignment #2B. The preservice teachers completed Assignments #1, #2A, and #5 without my input either during their work or in response to it. For the other assignments (i.e., #2B, #3, and #4), I talked with pairs of preservice teachers as they worked. I designed these assignments to be completed in pairs to take advantage of the benefits of collaborative learning.

Each critique assignment involves one lesson or activity plan to review. As the course instructor, I wanted the preservice teachers to explore a range of instructional materials—including commercial materials, materials freely available on the Web, and their own plans. Within the first two of these categories, I selected materials I thought would be especially productive for my students to review. For example, two of the plans I used—in Assignments #1, #2, and #5—involved problematic instructional representations because I hoped to foster

discussion of the use of representations in science teaching. (I use “instructional representation” to mean any analogy, diagram, graph, or other form that a teacher might use to “represent” a scientific idea to students.) Of course, my selection of the materials to critique necessarily influenced about what preservice teachers were likely or even able to comment.

Toward the goal of providing a rich description of the work in which the preservice teachers were engaged (Grossman, 2005; Zeichner, 2005), I describe these assignments and how they were used in the methods course in more detail next. I provide abbreviated versions of each assignment in the Appendix.

The first critique activity, Assignment #1, was assigned during the first week of the class. The preservice teachers completed this short-answer pretest as homework individually before the next class session. The preservice teachers were given a commercially available activity plan that included two superficially related hands-on activities and two potentially conflicting instructional goals (making secondary colors and understanding the conversion of light energy to heat energy). According to the activity plan, children were to mix primary colors of paint to create secondary colors, paint the insides of several cups different colors, add water to the cups, place the cups in sunshine, and measure the temperature change for each cup. The activity included confusing or nonsalient “thought questions” (e.g., “Can a person get sunburned on a cloudy day?”) and a problematic instructional representation (i.e., red is a “warm” color). Assignment #1 asked the preservice teachers to state their specific goal or goals for students’ learning, describe what they would do to foster that learning, and explain why they would make the changes they described.

Assignment #2A, “Developing My Criteria,” was completed individually in the middle of the semester. As homework, each preservice teacher wrote three criteria she would use for critiquing instructional materials. By *criteria* I mean principles that could be used as lenses with which to critique instructional materials, such as “the lesson supports students in engaging in scientific inquiry.” Then, in class, they were given a lesson plan typical of many found on the Web, and were told to apply their criteria to the lesson plan. This process took approximately 15 min. The lesson touched on the topics of condensation, precipitation, and saturation, and was described as being a part of an inquiry-oriented unit on weather. It involved multiple hands-on activities and teacher demonstrations. The lesson plan included numerous instructional goals and a misleading instructional representation that used a sponge as a model for a cloud; the sponge becomes saturated when a teacher adds water to the top, spoonful by spoonful. After the preservice teachers used their own criteria to critique the lesson plan, they were to select one or more of their own criteria to list in a public list of criteria. This task generated a public class list of 21 criteria used in Assignment #2B, which took place the same day during the rest of the class session.

In Assignment #2B, “Selecting from Our Public Class List,” the preservice teachers worked in pairs. Each pair selected three of the criteria from the public class list of 21 criteria. For each criterion, they critiqued the lesson plan described above (i.e., used in Assignment #2A) using an instructional support that was also used in Assignments #3 and #4; the preservice teachers were provided a table that included spaces to note “aspect(s) of the lesson plan that meet the criterion,” “aspect(s) of the lesson plan that do not meet the criterion,” and “for aspects that don’t meet a criterion, how would you change this aspect of the lesson plan to better meet the criterion?” (See the Appendix.) This process took approximately 50 min.

As part of my instruction for the course, after Assignment #2B, I conducted a content analysis to distill the 21 criteria for critiquing from the public list in Assignment #2B into a smaller set by clustering the criteria written by the preservice teachers into categories iteratively until the major themes were accounted for. The resulting six class criteria included *student ownership and engagement, questioning, instructional goals, real-world*

applications, instructional representations, and communication. (See the top portion of Table 1.) These six class criteria were used throughout the rest of the course and were provided on Assignments #3 and #4. The examples provided in those assignments are exemplars developed for the purpose of instruction. The preservice teachers' own written criteria tended to be somewhat less clear and complete.

TABLE 1
All Codes for Criteria for Critiquing. These Examples for Class Criteria Were Provided on Assignments #3 and #4

Category	Example
<i>Class Criteria</i>	
Student ownership and engagement	The lesson engages students in science learning that is meaningful and engaging to them.
Questioning	The lesson expects students to [ask or] ^a answer challenging questions.
Instructional goals	The lesson sets a limited number of worthwhile science-learning goals. The goals include goals for learning science concepts and scientific inquiry.
Real-world applications and connections ^b	The lesson makes connections to real-world examples of the scientific ideas [or other connections such as to other lessons]. ^b
Instructional representations	The lesson represents the science content in scientifically accurate ways, and will not promote alternative ideas.
Communication	The lesson supports students in productively discussing ideas with each other and with the teacher.
<i>Inquiry Criteria</i>	
Inquiry and investigations	The lesson supports students in engaging in scientific inquiry.
Specific aspects of inquiry	Combines messing about, finding information, making predictions, making observations, making sense of data, and planning and designing.
Messing about	The lesson allows for students to explore, make initial observations, manipulate objects, and play with materials (Krajcik et al., 1999, p. 93).
Finding information	The lesson allows for students to ask others, read purposefully, and evaluate information (Krajcik et al., 1999, p. 93).
Making predictions	The lesson allows for students to ask and answer questions like, What would happen if. . . ? (building from Krajcik et al., 1999, p. 93).
Making observations	The lesson allows for students to assemble experimental apparatus and gather data (Krajcik et al., 1999, p. 93).
Making sense of data	The lesson allows for students to analyze, transform data, and make inferences (Krajcik et al., 1999, p. 93).
Planning and designing	The lesson allows students to consider how they might answer their questions (Krajcik et al., 1999, p. 93).

^a The bracketed phrase was added to the questioning criterion for coding purposes.

^b The real-world applications and connections criterion was provided to the class as just real-world applications; in later analysis, this criterion was expanded to include other types of connections as well.

In Assignment #3, “Selecting One Criterion,” the preservice teachers again worked in pairs. This assignment took place in the second half of the semester and involved a commercial balls-and-ramps lesson that was part of a unit on motion and typical of many elementary science kits. The preservice teachers first worked with the lesson informally as students and teachers, exploring the scientific phenomena and the lesson design. Then, they selected one of the six class criteria on which they would critique the lesson plan. I asked the preservice teachers to focus on one criterion because I wanted them to consider a single criterion in depth. They again identified aspects of the lesson plan that met and did not meet the criterion and changes that they would make to better meet the criterion. They worked on the assignment for a whole class session (approximately 80 min).

Assignment #4, “Selecting Criteria for Our Own Lessons,” occurred near the end of the semester. Pairs of preservice teachers critiqued one of their own lesson plans. They selected one or more of the six class criteria. They again identified aspects of the lesson plan that met and did not meet each chosen criterion as well as changes that they would make. They worked on this assignment for an entire class session, though the assignment also included optional components, including a peer critique, that some of the preservice teachers worked on for a part of that total time.

Assignment #5, a posttest identical to Assignment #1, took place in the second-to-last class. Preservice teachers worked individually for as long as they needed, approximately 45 min.

Data Sources

In sum, I gave two types of assignments in which preservice teachers were expected to critique activity and lesson plans. These assignments serve as the data sources for the study. In one type of assignment the preservice teachers worked *individually to develop and apply* criteria. The criteria development could be implicit or explicit. Assignments #1, #2A, and #5 were the three *criteria-development assignments*. As data sources, these assignments serve to illuminate the preservice teachers’ own criteria for critiquing.¹ In the second type of assignment, pairs worked *together to select* criteria from a set provided and then *apply* those selected criteria. Assignments #2B, #3, and #4 were the three *criteria-selection assignments*. These *criteria-selection assignments* serve to demonstrate how preservice teachers use a limited set of possible criteria.

Although these two types of assignments are referred to here as *criteria-development* and *criteria-selection* assignments, respectively, note that in both cases they also involve *applying* the criteria to a lesson or activity plan and (except in Assignment #2A) *adapting* that plan based on the critique. The study’s research questions focus on the preservice teachers’ criteria for critiquing, but understanding what the preservice teachers were asked to do in terms of adapting the instructional materials is also important as part of the broader instructional context in which they were working.

¹ Project 2061 has developed an extensive, comprehensive, and principled set of criteria for critiquing instructional materials (see Kesidou & Roseman, 2002). I had the preservice teachers develop their own criteria for three main reasons. First, the Project 2061 criteria, as written, are designed for the analysis of textbooks, not activity or lesson plans. Second, to learn to use the Project 2061 criteria effectively requires several full days of training—quite difficult in a one-semester course. I feared that to fail to provide adequate training would reduce the effectiveness of the criteria. Finally, I believed that the criteria would be more meaningful for the preservice teachers if they developed them themselves, building on the work they had done in the science methods course and earlier in their program. As indicated by the six class criteria, their criteria covered some of the same aspects as are covered by the Project 2061 criteria for textbook analysis (e.g., encouraging curiosity and questioning), though certainly in less depth. Other important criteria were ignored altogether, as is discussed in the Implications and Conclusions section.

Coding and Analysis

To answer the research questions, the analysis focuses on the basis for the preservice teachers' critiques (i.e., their criteria for critiquing). These criteria were identified through data segmentation and coding. In Assignment #2A, for example, the criteria the preservice teachers wrote were segmented into one or more pieces with distinct foci, and each segment was coded separately. Some of the descriptive codes emerged from the data from Assignment #2A and were provided to the class as the class criteria in Assignments #3 and #4, as described above. Other descriptive codes for criteria (e.g., making predictions, making sense of data) were developed a priori on the basis of the model of scientific inquiry used in the course textbook (Krajcik, Czerniak, & Berger, 1999). Thus, the coding process combines codes that were predefined on the basis of the conceptual focus of the course context with codes that emerged based on the content of the participants' actual written work in the course (Miles & Huberman, 1994). Table 1 provides all descriptive codes for criteria, which were pilot tested in an earlier analysis of the preservice teachers' work on Assignments #2A and #2B, as well (Davis, 2002). Two other researchers participated in the development of the coding key and coded subsets of the data. The infrequent differences in coding were discussed and resolved collaboratively, and the coding key was iteratively refined as a result of this process.

What did the data being coded look like? One preservice teacher wrote "the lesson plan is 'real world' " as a criterion for critiquing in Assignment #2A, and the statement was coded as *real-world applications and connections*. Another preservice teacher wrote "the lesson plan is tied to a question that the students asked"; this statement was coded as *questioning*. A third preservice teacher wrote "to what extent did it allow children to analyze data?" and the statement was coded as the *specific aspect of inquiry* about *making sense of data*. Any given criterion written by a preservice teacher might include multiple components and thus receive multiple codes, one for each segment. For example, one preservice teacher wrote "the lesson plan supports [a] scientific investigation cycle, built on previous experiences", and the statement was coded as both *inquiry and investigations* (because of the mention of a "scientific investigation cycle") and *real-world applications and connections* ("built on previous experiences"). Another preservice teacher wrote "the materials allow students to gather evidence to support their claims," and the statement was coded as getting at two *specific aspects of inquiry: making observations* ("gather evidence") and *making sense of data* ("to support their claims").

The *inquiry and investigations* category is a purposefully broad code that captures general statements about inquiry, whereas the other predetermined categories represent specific aspects of inquiry. To make the analysis more meaningful by making trends more apparent, the specific aspects of inquiry are collapsed to create a single code (called *specific aspects of inquiry*) referring to any of these specific aspects. (See Table 1.) At times in the analyses that follow, I refer to *specific aspects of inquiry* to illustrate trends in the data about any of these specific aspects as compared to the other descriptive codes. I also, however, distinguish among these specific aspects where appropriate, to elucidate the preservice teachers' thinking about inquiry. The data indicate that in most cases, the *inquiry and investigations* code co-occurred with at least one mention of a *specific aspect of inquiry*. (This is the only instance of co-occurrence apparent in the data.)

To synthesize the data for the basis for the critiques, I determined which criteria were most or least prevalent for each assignment through quantifying the qualitative data. A criterion code was considered *most prevalent* if it was used in at least 15% of the responses for an assignment. A criterion code was considered *least prevalent* if it was used in 3% or fewer of the responses for an assignment. The cutoff for *most prevalent* was selected

because it allowed identification of 2–4 criteria as most prevalent for each assignment, making these descriptors more meaningful and comparable across assignment contexts. A similar rationale guided the cutoff for *least prevalent*, but then codes were combined if they consistently yielded least prevalent characterizations, except in the case of *instructional representations* which was one of the class criteria. Furthermore, a code called *connections* was folded into the *real-world applications* code due to conceptual overlap in the two codes. This process results in depiction of the coded data to allow patterns to be more easily identified and examined (Chi, 1997; Miles & Huberman, 1994); that is, identification of most and least prevalent criteria in turn allows for determination of themes to explore further.

All of the written data from all 20 participating preservice teachers were coded and analyzed. To illustrate the findings about use and prevalence of criteria, representative examples are drawn from several preservice teachers selected as being representative of the larger group. The examples from their work were selected as also being representative of other examples. I draw several of the examples from three individuals, whose pseudonyms are Jennie, May, and Whitney. This technique allows the reader to gain a better perspective on how preservice teachers experienced the course. To broaden that perspective, I also draw (though less heavily) on examples from other preservice teachers. None of the preservice teachers quoted were partners for assignments. All of the examples, taken together, are intended to provide more insight into how the preservice teachers critiqued instructional materials at different points in time and with different types of support.

RESULTS

Recall that the research questions ask about the basis for the preservice teachers' critiques. Table 2 summarizes how the preservice teachers used the critique criteria and indicates which criteria were most prevalent in each assignment. Preservice teachers often used the *specific aspects of inquiry* and *real-world applications and connections* criteria, across several of the assignments. Table 3 summarizes how the preservice teachers used the specific aspects of inquiry in each assignment; *making predictions*, *making observations*, and *making sense of data* were all used fairly consistently. Preservice teachers almost never focused on *instructional representations* or on *messing about* or *finding information*.²

The following sections elaborate on these results, characterizing the preservice teachers' uses of criteria in the context of the criteria-development and criteria-selection assignments.

Criteria Developed and Used by Individuals

As described in the Methods section, when the preservice teachers worked individually, they had three opportunities to critique instructional materials using criteria they developed themselves: Assignments #1 (the pretest), #2A (in which they explicitly developed and applied their own criteria), and #5 (the posttest). Examining the criteria the preservice teachers used in these assignments illuminates what criteria they use for critiquing when given free choice. Individuals tended to develop criteria for critiquing having to do

² This study was not designed to investigate change over time in the preservice teachers' critique, because I was especially interested in better understanding the preservice teachers' thinking about the ways in which instructional materials could be critiqued when taking all the data as a whole and when comparing the two types of assignments. Inspection of the data resulting from the preservice teachers' critiques on Assignments #1 and #5 indicates that the preservice teachers' choice of criteria did not change much. The exception is that the preservice teachers did mention the *planning and designing investigations* aspect of inquiry more often at the end of the term. Furthermore, the preservice teachers did, generally, get more specific in their critiques and recommendations.

TABLE 2
Instances of Critique Criteria Used Across All Assignments

	Criteria-Development Assignments			Criteria-Selection Assignments		
	Pretest #1	Developing My Criteria #2A	Posttest #5	Selecting from Our Public Class List #2B	Selecting One Criterion #3	Selecting Criteria for Our Own Lessons #4
Student ownership and engagement	9%	13%	8%	4%	20%	24%
Questioning	12%	18%	9%	4%	20%	13%
Instructional goals	15%	14%	17%	11%	10%	11%
Real-world applications and connections	12%	8%	13%	28%	50%	19%
Instructional representations	0%	1%	0%	0%	0%	11%
Communication	10%	4%	11%	11%	0%	21%
Inquiry and investigation	3%	21%	2%	9%	n/a	n/a
Specific aspects of inquiry	26%	19%	33%	26%	n/a	n/a
Other	14%	2%	7%	7%	n/a	n/a
Total instances	78	95	88	46	10	62

Percentages are computed using the number of instances a code for an assignment divided by the total codes made for an assignment.

Assignments #3 and #4 involved only the class set of six criteria, so percentages for these columns should not be directly compared to percentages for other columns.

"Most prevalent" is denoted by bold print and indicates that a code was used in at least 15% of the instances for a given assignment.

with *specific aspects of inquiry*, *inquiry and investigation*, *instructional goals*, and *questioning*. (See Table 2.) In sum, the data indicate that the preservice teachers focus on the instructional materials' use of scientific inquiry and questioning. They perceive these to be ways of promoting student interest in science, which in turn would help students achieve the teachers' substantive instructional goals. I explore the preservice teachers' ideas about inquiry, instructional goals, and questioning next.

Only *specific aspects of inquiry* was most prevalent on all three of the individual criteria-development tasks. (See Table 2.) Recall that specific aspects of inquiry include multiple criteria codes for a range of inquiry-oriented practices. The practices identified most often on these assignments included *making predictions*, *making observations*, *making sense of data*, and—to a lesser extent—*planning and designing investigations*. (See Table 3.) The preservice teachers almost never developed criteria having to do with *messing about* or *finding information*.

To illustrate some of these findings, consider what preservice teacher Jennie writes on Assignment #1 (pretest) about specific aspects of inquiry such as making predictions and performing experiments or making observations.

TABLE 3
Instances of Specific Aspects of Inquiry Critique Criteria Used Across All Assignments

	Criteria-Development Assignments			Criteria-Selection Assignments
	Pretest #1	Developing My Criteria #2A	Posttest #5	Selecting from Our Public Class List #2B
Messing about	0%	0%	3%	0%
Finding information	0%	0%	0%	17%
Making predictions	40%	17%	34%	17%
Making observations	30%	22%	24%	33%
Making sense of data	25%	44%	17%	33%
Planning and designing	5%	17%	21%	0%
Total instances of specific aspects of inquiry	20	18	29	12

Percentages are computed using the number of instances a code for an assignment divided by the total number of *specific aspects of inquiry* codes made for an assignment.

Assignments #3 and #4 involved only the class set of six criteria and so are not included here.

Jennie, Assignment #1: Once we've established [that lighter colors get warm more slowly than darker colors], I would ask students to predict what primary colors would get warm faster. I would then have them experiment to find out if their predictions were correct. . .

After describing a series of changes that would further engage students in experimentation, Jennie continues:

Jennie, Assignment #1: I think this progression of activities is more logical and provides the students with adequate experimentation to learn the correlation between heat and darker colors.

Similarly, preservice teacher May writes:

May, Assignment #1: To foster their learning I would have the students make hypotheses by drawing on their background knowledge. . . After the students conduct the experiments, I would have them reflect and self-assess their hypotheses based on the results obtained.

On Assignment #2A ("Developing My Criteria"), May develops two criteria about *inquiry and investigation*, one of that assignment's most prevalent criteria (21%; see Table 2). She writes:

May, Assignment #2A, criterion 2: The lesson plan supports scientific investigation cycle, built upon previous experiences.

May, Assignment #2A, criterion 3: The lesson plan invites the students to be engaged in progressive cycles of inquiry and evidence (also design).

In critiquing the lesson plan, she unpacks her meaning of inquiry and makes connections to several specific aspects of inquiry:

May, Assignment #2A, critique using criteria 2 and 3: The lesson plan does attempt to provide information about the students' background (knowledge). The lesson plan does incorporate previous experiences—from outside the classroom [and] from day 1 to day 2. The lesson plan is progressive from day 1 to day 2. The lesson plan does have the students investigate and record observations. The lesson plan does not seem to tie into the larger picture or engage the students in investigating their curiosities (questions). The lesson plan does not allow the students to voice their inquiry.

Similar to many of her peers and in keeping with what she and Jennie both recommended in their pretest responses, May mentions making observations and designing investigations. At the same time, she wants students to investigate their own “curiosities” and to “voice their inquiry.”

On their posttests (Assignment #5), Jennie and May both recommend infusing more of the planning-and-designing aspect of inquiry into the lesson plan:

Jennie, Assignment #5: 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.

May, Assignment #5: I would. . . have the students decide how often we should take the temperatures of the water, to give them control of the lab a bit more.

This change parallels a general shift among the preservice teachers in the class toward increased emphasis on planning and designing investigations. (See Table 3.) Note, though, that Jennie and May both want to increase students' opportunity for planning and designing an investigation to increase students' ownership, not to more closely model authentic practices of scientists. This was typical of the preservice teachers' rationales for increasing opportunities to design investigations; while some preservice teachers connect the increased engagement to increased learning of *content*, almost none recommend using inquiry practices because of their authenticity to science as an intellectual endeavor.

In fact, the preservice teachers worry a lot about their students' learning of science content, especially when they perceived multiple goals to be at odds. *Instructional goals* is most prevalent on Assignment #1 (15%) and Assignment #5 (17%); see Table 2. Recall that the activity plan critiqued for these assignments presents two distinct instructional goals. May and Jennie both describe the need to focus on just one main content goal. On Assignment #5, May writes:

May, Assignment #5: The specific goal for the students' learning would be for the students to observe how and why temperature is related to color.

Jennie is even more specific about focusing on only one of the activity's two goals:

Jennie, Assignment #5: I would want to focus on colors absorbing more light than other colors and therefore becoming warmer. The lesson also deals with mixing paint and the colors that result. I would try to steer the emphasis away from colors.

Jennie continues, “I think students could get caught up in mixing colors and miss the point of the lesson. I would want to provide most colors premixed so they can concentrate on the science concepts.” Both Jennie and May describe instructional goals for their students' learning of substantive science content, and both of them plan to limit the number of

instructional goals as compared to the multiple goals included in the original plan. This, too, is typical of the preservice teachers' comments at the end of the semester.

The preservice teachers focus much of their attention on *questioning* in Assignment #2A, in which 18% of the criteria developed have to do with questioning. (See Table 2.) For example, preservice teacher Catie develops a criterion about questioning:

Catie, Assignment #2A, criterion 2: The lesson plan demands that students constantly ask questions about concepts and principles.

In critiquing the lesson plan (i.e., applying this criterion), she comments:

Catie, Assignment #2A, critique using criterion 2: The students do ask questions, but most of them are premade for them. They aren't asking questions that are necessarily important to them.

Catie's concern here is typical of other preservice teachers' critiques. Catie does seem to recognize the importance of content (the questions are "about concepts and principles"), but rather than focusing on, for example, how scientifically meaningful the questions are, she and the other preservice teachers emphasize who asks and answers the questions, again demonstrating a student-centered perspective rather than a focus on the process of science itself. The preservice teachers connect—sometimes implicitly, sometimes explicitly—what they consider to be student-centered teaching practices to student learning of content.

Whitney makes a more explicit connection. She writes two criteria involving questioning:

Whitney, Assignment #2A, criterion 1: The lesson plan has students answer how and why questions.

Whitney, Assignment #2A, criterion 2: The lesson plan continues and has a cycle of learning and questioning.

In her critiques using these two criteria, Whitney writes:

Whitney, Assignment #2A, critique using criterion 1: The assessment asks students to answer how and why questions, as well as connect the experiment in the classroom to what happens outside with weather. During the lesson there are not as many how and why questions, so some students may not know at the end.

Whitney, Assignment #2A, critique using criterion 2: The start of the lesson uses a demo which could create questions, and tries to evolve from that.

Whitney's emphasis on "how and why questions" focuses on the science. She also connects learning explicitly and directly to questioning (referring to "a cycle of learning and questioning" and saying that a lack of how and why questions may lead to students not learning the science).

These examples indicate that individual preservice teachers are able to articulate important focuses for their critiques of instructional materials (including about inquiry, instructional goals, and questioning), and that they can successfully apply those criteria in some instances. Their emphasis on inquiry, while demonstrating a novice level of understanding, indicates their developing recognition of inquiry-oriented science teaching as valuable. The preservice teachers often demonstrate a student-centered perspective; they want students to be interested and engaged, and they view inquiry, experimentation, and questioning as ways

to promote that interest. At the same time, their emphasis on instructional goals indicates that they see the importance of setting learning goals. The preservice teachers talk about the involvement of students as likely to promote their engagement, and some preservice teachers connect this to students' substantive learning of content. Science education researchers, on the other hand, might emphasize the ways in which the students would be engaged in more authentic scientific practices of, for example, making observations or predictions. Thus, the preservice teachers' *rationales* for instructional decisions seem, in some cases, to be different than the rationales that would be espoused by science education researchers. I return to this point in the Discussion.

Criteria Selected and Used by Pairs

In addition to developing criteria on their own, the preservice teachers also had the opportunity to select from lists of criteria, on Assignments #2B ("Selecting from Our Public Class List"), #3 ("Selecting One Criterion"), and #4 ("Selecting Criteria for Our Own Lessons"). Analyzing their selections provides insight into what criteria they deem important (e.g., in justifying the choice she and her partner to use one criterion, Whitney writes, "So important—stressed by our practicum teacher") or what they feel capable of addressing when they have a proscribed and explicit set of criteria to consider. Recall that Assignments #3 and #4 presented the preservice teachers with the set of six class criteria. As a result, the *inquiry and investigation* and *specific aspects of inquiry* criteria were not available on those two assignments. To foreshadow the results, the preservice teachers draw on *specific aspects of inquiry* when they can (i.e., in Assignment #2B). Of the six class criteria, the preservice teachers most prevalently use *student ownership and engagement* (on two of the criteria-selection assignments) and *real-world applications and connections* (on all three of these assignments). Again, the preservice teachers' use of criteria indicates their integration of a student-centered perspective with a learner-centered one, though these perspectives manifest themselves differently in this set of assignments.

As they did when they individually developed criteria (in Assignments #1, #2A, and #5), pairs of preservice teachers use *specific aspects of inquiry* as they critique in Assignment #2B (see Table 3). In particular, four pairs apply the *making observations* criterion, four apply *making sense of data*, two apply *finding information*, and two apply *making predictions*. No pairs apply the *messing about* or *planning and designing investigations* criteria on this assignment.

Jennie and her partner, for example, select the following criterion about *making sense of data* from the public class list of 21 criteria:

Jennie, Assignment #2B, criterion 1: Lesson allows [students] to gather evidence and use it in explanations.

Jennie's reason for selecting this criterion is "explaining how and why in their answers allows for a deeper understanding—not just memorization." She does not connect the use of explanation to scientific inquiry, but she does clearly connect it to students' learning.

In reporting on their critique of the lesson plan along this criterion, Jennie writes:

Jennie, Assignment #2B, critique using criterion 1: Some evidence [is] gather[ed] (plate and water activity). Does not allow students to gather a lot of evidence to formulate explanations. [We recommend] more experiments to relate to their predictions and to support or refute their claims.

Here, Jennie comments on the limited number of opportunities for students to form explanations based on evidence, and she and her partner recommend increasing students' opportunities for experimentation (which Jennie connects to making sense of data).

Whitney selects a criterion about *making observations* from the public list of 21 criteria:

Whitney, Assignment #2B, criterion 2: Lesson requires self-generated evidence.

Whitney writes, to the side of her criterion, "kids feel more ownership." Then, in her critique of the lesson plan along this criterion, Whitney writes:

Whitney, Assignment #2B, critique using criterion 2: Observe and record of data gives good self-gen[erated] evidence. Demo— good. [But] sponge demo is not student generated. [We recommend] Question. Ask students to come up with an example and ways to test to make it more engaging?

Note Whitney's emphasis on ownership and engagement. Unlike her connection between questioning and student learning in Assignment #2A, reported above, and unlike Jennie's direct connection between explanation and learning, here Whitney wants students to make observations mainly to promote their engagement.

Student ownership and engagement is most prevalent for two of the criteria-selection tasks, Assignments #3 and #4. (See Table 2.) For example, on Assignment #3 ("Selecting One Criterion"), preservice teacher Terri and her partner select "student ownership and engagement" from the class set of six criteria available for that assignment. Among the aspects of the lesson plan that they identify as meeting the criterion are "[when we worked as students experiencing the lesson] we were able to design our own experiment" and "allows students to work wherever they want to." They recommend that the lesson be changed to "allow [the students] to pick their own materials." These examples provide further evidence for a student-centered perspective. But why is student ownership and engagement only most prevalent on these two assignments, if preservice teachers so often hold a student-centered perspective? It seems that when student ownership and engagement is listed clearly as a criterion to select, preservice teachers do tend to select and use it. At other times, they make changes to plans that address other major issues—such as how inquiry practices are incorporated into the lessons—but only in their rationales for these changes do they emphasize student engagement.

The *real-world applications and connections* criterion is most prevalent for all three of the criteria-selection tasks. (See Table 2.) Conceptually, this too seems in keeping with a student-centered perspective on science teaching, in that the preservice teachers want to be sure their lessons connect to their students' lives. For example, on Assignment #2B, Jennie and her partner select a criterion focused on real-world applications. Jennie writes:

Jennie, Assignment #2B, criterion 2: Lesson must be meaningful/allows students to investigate real science/events in the natural world.

Their reason for selecting this criterion is twofold. Jennie writes, "A lesson must be meaningful for students to sustain interest and for understanding the world around them." Again, we see a link between promoting interest and engagement, on the one hand, and understanding, on the other. Jennie, like several of the preservice teachers, sometimes focuses on motivation, sometimes on learning, and sometimes connects the two.

When they critique the lesson plan along this criterion, Jennie writes:

Jennie, Assignment #2B, critique using criterion 2: The lesson is aimed at investigating the world around them and things they personally experience (hanging things out to dry). [But, one aspect of the lesson plan that does not meet the criterion is] the sponge/saturation demonstration. [We recommend] saturation needs to be connected to their own lives—perhaps connect it to a dripping swimsuit, or walking through a puddle and having dripping shoes.

Here Jennie and her partner's comment about the "sponge/saturation demonstration" may indicate an inadequate or possibly idealized perspective on childhood—they appear not to realize that even preschool age children have likely experienced a dripping sponge. Despite their naivety, Jennie and her partner do cite the importance of making connections to children's real-world experiences and develop two of their own possibilities for including a real-world application that they perceive would be more relevant.

Similarly, preservice teacher May and her partner select another criterion focused on real-world applications from the public list of 21 criteria. May writes:

May, Assignment #2B, criterion 1: The lesson makes connections to previous lessons and real-world examples.

In their critique, May writes:

May, Assignment #2B, critique using criterion 1: [The lesson] draws on [the] real-world [and] asks [students] to consider their experiences, i.e., hanging clothes: where does the H₂O go? (etc.). Sponge, cloud. [But, one aspect of the lesson plan that does not meet the criterion is] the puddle experiment. Forced activity, relevance of results is lost, not clearly connected to real world. Activities aren't based on students' questions nor do they allow for their "design." [We recommend that the lesson be changed to] finish the puddle experiment with realistic features—measure humidity in room, discuss environmental conditions, take it outside (and repeat). Do activities that are based on students' questions and curiosities.

May and her partner comment on a different aspect of the lesson plan than Jennie and her partner had focused on—the puddle experiment on evaporation as opposed to the sponge demonstration on the saturation of clouds. May and her partner identify the lesson's connection to hanging clothes as a way of making the puddle experiment relevant to students' lives. As with Jennie and her partner, and as is typical in the class' work throughout this assignment, these preservice teachers highlight the importance of connecting to students' lives and suggest how such connections could be made.

In sum, the pairs of preservice teachers selecting criteria for critiquing tend to focus on specific aspects of inquiry, when they could, as well as on real-world applications and student ownership and engagement. On these assignments too, then, the preservice teachers blend student-centered and learning-centered perspectives. The specific criteria on which they draw, however, are somewhat different than those used in the criteria-selection assignments.

SYNTHESIS AND DISCUSSION

The critique assignments in the elementary science methods class provided the preservice teachers with the opportunity to engage in an authentic task of teaching—the critique of instructional materials—and to work toward the adaptation of those materials. Specifically, this study asks, what is the basis for preservice elementary teachers' critique of instructional materials for science? What criteria do they use when they develop the criteria themselves,

and what criteria do they use when they are given a set of criteria from which to choose? Four main findings stand out in answering these questions:

1. The participating preservice teachers entered the class with a strong set of criteria for critiquing instructional materials.
2. The preservice teachers blended student-centered and learning-centered perspectives in their critiques and rationales.
3. The preservice teachers' critiques depended on the scaffolding present or absent in the critique assignments and on the features of the instructional materials being critiqued.
4. The preservice teachers did not focus on instructional representations despite being supported in doing so through the assignment scaffolding and the features of the instructional materials being critiqued.

I discuss each of these findings next.

First, in considering the basis for preservice elementary teachers' critique of instructional materials, this study shows that the participating preservice teachers entered the class with an impressive repertoire of criteria for critiquing, as indicated by the analysis of their pretests (Assignment #1). There they used a range of criteria including student ownership and engagement, questioning, instructional goals, real-world applications and connections, communication, and specific aspects of inquiry. (Given that this study occurred after the preservice teachers had experienced two semesters of a coherent program emphasizing making connections among ideas about learners, learning, knowledge, knowing, and instruction, some of these strengths are not especially surprising, and serve simply as indicators of the strength of the program in which they are enrolled. Their earlier coursework did not, however, emphasize critique *per se*, and did not emphasize connections to science.) The preservice teachers entered the course with some tools to help them critique instructional materials, and they continued to be able to use those tools (i.e., apply their criteria) in meaningful (though of course still novice) ways throughout the course.

Second, this study illustrates the centrality of children and their learning in some of these preservice elementary teachers' critiques of instructional materials. This finding is consistent with—and may provide additional insight about—other research indicating the child-centered perspective of many preservice elementary teachers (e.g., Abell, Bryan, & Anderson, 1998; Davis, *in press*; Howes, 2002). Here, even when preservice teachers point to the same strengths or weaknesses of instructional materials that science education researchers would, their rationales for their critiques are often quite different. These preservice teachers want to have students ask and answer questions or plan and design investigations, for example, largely because they think students will be more interested and engaged and thus will learn more science content if they do so—not because these are authentic scientific practices that are valuable in their own right (see also Davis, 2002, for further exploration of this point). This finding highlights the importance of designing teacher education experiences that capitalize on these productive inclinations toward incorporating inquiry-oriented science teaching into their classroom instruction while promoting understanding of the additional rationales for engaging students in scientific inquiry practices.

How, though, do the preservice elementary teachers understand these inquiry practices? Not surprisingly, the preservice teachers emphasize the experimentation aspects of inquiry (e.g., making predictions, making observations) while downplaying other aspects that may seem (to them) at odds with a student-centered perspective (e.g., finding information). Furthermore, the preservice teachers' interest in having children plan and design investigations, in particular, may represent a naïve perspective on young students' ability to do so. The

preservice teachers here rarely, if ever, discuss a teacher's role in scaffolding children to be successful in this endeavor. They should be supported in recognizing the important role teachers play in ensuring children's success in engaging in scientific inquiry. We know that young children can successfully engage in scientific inquiry (Metz, 1995; Schauble et al., 1995) but that they need support to do so.

Third, the substance of the critiques depended to a degree on the scaffolds that were present or absent in the critique assignments and the features of the instructional materials being critiqued. Specifically, *real-world applications and connections* appeared as a prevalent code when it was explicitly scaffolded by the assignment (as in the criteria-selection Assignments #2B, #3, and #4). But the criterion was not used as frequently when the assignment did not explicitly scaffold its use (as for Assignments #1 and #5). This criterion may be one for which reminders to consider the criterion can be especially effective; the preservice teachers may feel that they have some facility with making connections to their students' lives—and so they focus on this when they are reminded to do so—but they may not (yet) think to make these connections on their own, without such reminders. On the other hand, the activity plan used for the critiques in Assignments #1 and #5 afforded a focus on *instructional goals* not afforded to the same degree by the other plans the preservice teachers critiqued. Even having the criterion of *instructional goals* explicitly prompted in the criteria-selection assignments did not promote as much use of the criterion when critiquing instructional materials where it was somewhat less obvious.

Teacher educators, then, must consider the interactions between the scaffolding they provide and the substance of the critiqued instructional materials. For example, beginning elementary teachers may value setting important instructional goals for their students but may have trouble identifying weaknesses related to instructional goals in ambiguous cases. Teacher educators may need to provide additional support to consider instructional goals in such cases.

Furthermore, though fading is a critical aspect of the classical definition of scaffolding (Stone, 1998; Wood, Bruner, & Ross, 1976), determining when and how to fade is difficult (Bell & Davis, 2000; Pea, 2004). In fact, beginning teachers likely need some ongoing system of scaffolding-without-fading (Pea, 2004)—perhaps implicit features of the context itself or perhaps more explicit features of curriculum materials—to help them effectively critique materials (Lemke, personal communication, July 7, 2003). Educative curriculum materials designed to promote teacher learning as well as student learning could provide such ongoing scaffolding (Davis & Krajcik, 2005).

This ongoing scaffolding may be especially important for supporting preservice teachers in using particular criteria. Specifically, a final finding of the study is that the class and the preservice teachers' other experiences did *not* promote a focus on instructional representations despite its being highlighted as a class criterion for critiquing instructional materials and despite such representations being prominent in two of the lesson plans critiqued. *Instructional representations* was never a most prevalent code. In fact it was almost never used at all.

Why might this be the case? The literature points to three possible factors. One factor may be that elementary teachers often do not have the sophisticated understandings of science content their secondary counterparts have (Anderson & Mitchener, 1994). Without deeply understanding the content, they are unlikely to identify representations as either successful or problematic (Yerrick et al., 2003). A second factor may be that instructional representations can be evaluated (see, e.g., McDiarmid, Ball, & Anderson, 1989; Treagust & Harrison, 2000)—but preservice teachers may not recognize that these representations vary in their effectiveness, much less how to evaluate them. A third factor may be that preservice teachers may assume that an instructional representation is high quality simply by virtue of the fact

that it has been published, as the preservice teachers in Ball and Feiman-Nemser's (1988) study did before instruction. Despite these issues, empirical work indicates that preservice elementary teachers *can* develop and enact effective instructional representations for science when provided with programmatic support (Zemal-Saul, Blumenfeld, & Krajcik, 2000). Providing such support more consistently than was the case in the study here seems critical. More generally, this finding provides additional evidence that preservice teachers have more difficulty looking at instructional materials through some lenses than through others. Their decisions about which criteria to use indicate their abilities as well as their priorities.

IMPLICATIONS AND CONCLUSIONS

Preservice and new teachers often believe that they must develop their own curriculum materials (Ball & Feiman-Nemser, 1988; Trumbull, 1999). Alternatively, they sometimes think they must adopt as-is the materials they receive from their districts or mentors, or they view curriculum adaptation as irrelevant to their role as teachers (Bullough, 1992; Eisenhart et al., 1988). Instead, new teachers should be encouraged to critique instructional materials and then adapt them (on paper and in the classroom) so the resulting instruction is aligned with the teacher's own philosophy, students, school context, strengths, and interests, as experienced teachers do (e.g., Baumgartner, 2004). This research indicates that preservice elementary teachers can engage in such work and have strengths on which they can build. Yet they need support to learn to apply their ideas well.

What, then, are the implications for science teacher education? First, a focus on critique can help preservice teachers (or, for that matter, inservice teachers) develop knowledge, beliefs, and skills they will need as professionals. Just as students learn more from activities grounded in their lived experiences (Bransford et al., 1990; Krajcik et al., 2000; Linn & Hsi, 2000), teachers benefit from learning experiences grounded in the authentic work of teaching (Putnam & Borko, 2000), and critiquing and adapting instructional materials is one authentic task of teaching (Ben-Peretz, 1990; Bolin, 1987; Lloyd, 1999). Teacher education, however, does not always engage preservice teachers in such authentic activities (Grossman, 2005). Criteria-development assignments, such as Assignments #1 and #5 used here, are inherently more authentic to teachers' typical work. But criteria-selection activities narrow the preservice teachers' range of options; forcing some attention on criteria likely to prove difficult (e.g., instructional representations, instructional goals) should improve on the approach used here. The set of critique experiences should be as authentic as possible while still providing guidance and direction.

Second, preservice teachers need to consider criteria that were ignored by the class criteria generated here. For example, preservice teachers should critique instructional materials from the standpoints of equity (e.g., Bazler & Simonis, 1991; Bryan & Atwater, 2002; Lee, 1997) and the nature of science (e.g., Davis, 2003; Lederman, 1992). If teachers cannot adapt curriculum materials to help diverse learners understand authentic science, they will fail. Yet preservice teachers' ideas about diverse learners and authentic science lack sophistication (Cobern & Loving, 2002; Lederman, 1992). Supplementing the teachers' own criteria with criteria focusing on known areas of need could help preservice teachers move along these and other important dimensions. Again, teacher educators will need to provide support to help make their critiques effective.

This study points to important avenues for research in science teacher education. For example, is a commercially published curriculum taken as an authority while one found on the Web is considered more adaptable? Does it matter if the teacher is new or experienced? Research should also compare preservice teachers' critiques in planning with their adaptations of lessons in practice. We know relatively little about how preservice and new teachers

make these real-time changes (for important studies looking at experienced teachers' classroom use of curriculum materials, see Collopy, 2003; Lloyd, 1999; Remillard, 1999). Future research should also investigate the quality of preservice teachers' critiques and adaptations. Do the changes they suggest undermine the designers' rationale, or are they aligned with the intent of the designers (Pintó, 2005; Stylianidou, Boohan, & Ogborn, 2005)? Do the skills continue to develop over time? Finally, research should further investigate the reasons for the changes preservice teachers make to instructional materials.

In sum, this research indicates that preservice teachers must be supported as they learn to critique, adapt, and use curriculum materials effectively. Teacher education opportunities should build on preservice teachers' strengths while addressing their weaknesses. Curriculum materials themselves could also be designed to promote productive changes (Davis & Krajcik, 2005). Providing such support will help these new teachers as they enter the crucial early years of their teaching careers.

CODA

Two of the participants in this study, Catie and Whitney, participate in a longitudinal study following elementary teachers into their first several years of practice. What are Catie and Whitney like now? Do we see any lasting effects of the instruction described here?

Catie and Whitney both seem to be successful elementary science teachers. After 1 year of teaching sixth-grade math and science, Catie has taught second grade for the past 2 years. Whitney has taught fourth grade in the same school for the past 3 years. Both are dedicated to their jobs and both seem to identify themselves as science teachers or at least science enthusiasts.

In the elementary science methods class, Catie consistently focused on *student ownership and engagement, questioning, and instructional goals*. One of these criteria, instructional goals, shows up very clearly in her talk about her practice as a teacher now; Catie wants to ensure that her second graders are learning substantive science, not just participating in fun activities. In fact, Catie critiques her school's textbooks for not supporting substantive science learning. She focuses in particular on the instructional representations used by the textbook. As a second-year teacher, for example, she says with frustration:

One of the animals [unit] experiments that they had in [the textbook] . . . was stringing beads onto a string and then wiggling it around to see what a snake might move like. [And] another one of them was building your own creature out of art supplies.

Catie now focuses very heavily on having her students make observations and make sense of data. She clearly views these inquiry practices as helping students learn content, but she also describes these as "part of being a scientist." During the methods class, though, she only addressed making observations once (in Assignment #5) and never discussed making sense of data. Clearly Catie has come a long way in her thinking about science teaching and instructional materials. A strong student in the science methods class, she has turned into an even stronger science teacher.

Like Catie, during the methods class Whitney showed a consistent focus on *instructional goals*; she also focused consistently on *real-world applications and connections*. The most notable trend in Whitney's talk about her practice now, on the other hand, is a focus on *questioning*. Whitney clearly sees the importance of having students ask and answer scientific questions. Recall that Whitney provided the counterexample to the emphasis many of the preservice teachers put on using questioning mainly as a way to promote student engagement; instead, Whitney emphasized the connections between questions and

learning. On the other hand, she, too, sometimes now uses questioning to promote student engagement. Whitney seems to recognize the power of questions as a tool for promoting and maintaining her students' interest while also closely connecting the use of questions to foster and assess student learning. Whitney continues to blend—in productive ways—a student-centered perspective with a learning-centered perspective.

These teachers illustrate some ways in which the emphasis on critique of instructional materials seems to have stuck with them. More importantly, perhaps, they continue to use some of the criteria they used in the methods class as they improve all aspects of their teaching—not only their use of instructional materials.

APPENDIX

This appendix contains abbreviated versions of each critique assignment's questions related to critique of lesson plans and activities. The most salient questions are bolded here for emphasis. The activity plans and lesson plans being critiqued for each assignment are described in the text.

Assignment #1: Pretest

... Now imagine that it is later in the unit and you have been given the activity xeroxed on the back of this page to use in your placement classroom. You may modify it however you like before you teach it. Again, your [cooperating/supervising] teacher wants to see your plans in advance. Consider and reflect on the following questions:

Q1. What would be your specific goal for the students' learning?

Q2. What would you do to foster their learning? What would you have the students do?

Q3. If you have made changes, why would you make the changes you have described?

Assignment #2A: Developing My Criteria

Part 1: Individual Critique. **Q1. Write down the three criteria you came up with for critiquing instructional materials.** (You will use these numbers to refer to your criteria for the rest of Part 1.) Phrase your criteria as statements (e.g., "the lesson plan supports inquiry" or "the lesson plan brings closure by supporting students in tying the ideas together").

#1:

#2:

#3:

Q2. Use your criteria to review the lesson plan provided. For each criterion, explain how the lesson plan meets or does not meet the criterion. Try to find positive as well as negative things, and focus on deep (rather than superficial) aspects of the lesson. Some big areas you may want to focus on include the learning objectives, the students' learning activities, the ways the activities map on to the objectives, the ways the content is represented, the way the lesson is brought to closure, and how students' ideas are assessed.

#1:

#2:

#3:

Assignment #2B: Selecting from Our Public Class List

Part 3: Critiquing With a Partner. **Q1. As a pair, decide on the three criteria from the class list [i.e., the 21 criteria listed on chart paper at the front of the room] that**

you did like to focus on today. (Pick at least two that neither of you had thought of on your own.)

Q2. Our criteria (use these numbers to refer to your criteria for the rest of Part 3)

#1:

#2:

#3:

Q3. As a pair, apply the three class criteria you are focusing on to the lesson plan. For each criterion, describe how the lesson plan meets or does not meet the criterion. Again, identify both positives and negatives, and focus on crucial aspects of the lesson, not superficial ones. Then, describe how you might change the lesson plan to better meet the criteria. Be as *specific* as you can be.

Criterion	Aspect(s) of the lesson plan that meet the criterion	Aspect(s) of the lesson plan that do not meet the criterion	For the aspects that do not meet a criterion, how would you change this aspect of the lesson plan to better meet the criterion?
#1			
#2			
#3			

Assignment #3: Selecting One Criterion

We have talked about different criteria for critiquing instructional materials. Some of the criteria you have identified have included:

Student Ownership: The lesson engages students in science learning that is meaningful and engaging to them.

Questioning: The lesson expects students to answer challenging questions.

Instructional Goals: The lesson sets a limited number of worthwhile science-learning goals. The goals include goals for learning science concepts and scientific inquiry.

Real-World Applications: The lesson makes connections to real-world examples of the scientific ideas.

Representations: The lesson represents the science content in scientifically accurate ways, and will not promote alternative ideas.

Communication: The lesson supports students in productively discussing ideas with each other and with the teacher.

Part 1: Critiquing a Lesson Plan. Q1. Based on what you see in the lesson plan, as a pair, decide on one criterion that you did like to focus on today. You may choose something from the list above, or a different one.

(Select a criterion that you think this lesson plan will allow you to go into depth on.)

Our criterion:

Q2. As a pair, apply the criterion you are focusing on to the lesson plan. Describe how the lesson plan meets or does not meet the criterion. Identify both positives and negatives, and focus on crucial aspects of the lesson, not superficial ones. Then, describe

how you might change the lesson plan to better meet the criterion. Be as *specific* as you can be.

Aspect(s) of the lesson plan that meet the criterion	Aspect(s) of the lesson plan that do not meet the criterion	For the aspects that do not meet the criterion, how would you change this aspect of the lesson plan to better meet the criterion?
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Assignment #4: Selecting Criteria for Our Own Lessons

Some of the criteria for critiquing instructional materials you have identified have included:

- Student Ownership:* The lesson engages students in science learning that is meaningful and engaging to them.
- Questioning:* The lesson expects students to answer challenging questions.
- Instructional Goals:* The lesson sets a limited number of worthwhile science-learning goals. The goals include goals for learning science concepts and scientific inquiry.
- Real-World Applications:* The lesson makes connections to real-world examples of the scientific ideas.
- Representations:* The lesson represents the science content in scientifically accurate ways, and will not promote alternative ideas.
- Communication:* The lesson supports students in productively discussing ideas with each other and with the teacher.

Part 1: Critiquing Your Own Lesson Plan. Q1. Apply the criteria to your lesson plan. Describe how the lesson plan meets or does not meet the criteria. Identify both positives and negatives, and focus on crucial aspects of the lesson, not superficial ones. Then, describe how you might change the lesson plan to better meet the criteria. Be as *specific* as you can be. Put a star by the most crucial change you want to make.

Criterion	Aspect(s) of the lesson plan that meet the criterion	Aspect(s) of the lesson plan that do not meet the criterion	For the aspects that do not meet the criterion, how would you change this aspect of the LP to better meet the criterion?
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Assignment #5: Posttest

... Now imagine that it is later in the unit and you have been given the activity xeroxed on the back of this page to use in your placement classroom. You may modify it however

you like before you teach it. Again, your [cooperating/supervising] teacher wants to see your plans in advance. Consider and reflect on the following questions:

Q1. What would be your specific goal for the students' learning?

Q2. What would you do to foster their learning? What would you have the students do?

Q3. If you have made changes, why would you make the changes you have described?

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