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Curriculum Design for Inquiry: Preservice Elementary Teachers' Mobilization and Adaptation of Science Curriculum Materials

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Abstract: Curriculum materials are crucial tools with which teachers engage students in science as inquiry. In order to use curriculum materials effectively, however, teachers must develop a robust capacity for pedagogical design, or the ability to mobilize a variety of personal and curricular resources to promote student learning. The purpose of this study was to develop a better understanding of the ways in which preservice elementary teachers mobilize and adapt existing science curriculum materials to plan inquiry-oriented science lessons. Using quantitative methods, we investigated preservice teachers' curriculum design decision-making and how their decisions influenced the inquiry orientations of their planned science lessons. Findings indicate that preservice elementary teachers were able to accurately assess how inquiry-based existing curriculum materials are and to adapt them to make them more inquiry-based. However, the inquiry orientations of their planned lessons were in large part determined by how inquiry-oriented curriculum materials they used to plan their lessons were to begin with. These findings have important implications for the design of teacher education experiences that foster preservice elementary teachers' pedagogical design capacities for inquiry, as well as the development of inquiry-based science curriculum materials that support preservice and beginning elementary teachers to engage in effective science teaching practice. © 2010 Wiley Periodicals, Inc. J Res Sci Teach 47: 820–839, 2010
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Curriculum materials, which include instructional resources such as textbooks, lesson plans, and student artifact templates (i.e., worksheets), are important resources upon which teachers rely to structure both their planned and enacted instruction. Recent research has fostered novel perspectives on the teacher–curriculum relationship grounded in the assumption that teachers actively engage with curriculum materials (e.g., Remillard, 2005). Science teachers, through a process of curriculum design for inquiry, actively mobilize, evaluate, and adapt science curriculum materials to engage students in inquiry-based science as advocated within contemporary science education reform (American Association for the Advancement of Science (AAAS), 1993; National Research Council (NRC), 1996, 2000, 2007). Essential features of inquiry-based classroom science, which include engaging students in scientifically oriented questions; gathering, organizing, and analyzing data; formulating explanations from evidence to address scientifically oriented questions; evaluating their explanations in light of alternative explanations; and communicating and justifying their explanations; best promote students' science learning (NRC, 2000).

However, to engage students in science as inquiry, teachers must learn to use curriculum materials effectively. Even when using inquiry-based science curriculum materials, elementary teachers may not always effectively engage students in science as inquiry (Appleton, 2002; Pine et al., 2006). They must therefore learn to mobilize their personal characteristics (i.e., knowledge, beliefs, identities, and orientations), as well as science curriculum materials, to make pedagogical decisions that accomplish particular instructional goals in light of affordances and constraints of their professional contexts. This

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particular perspective on teachers' use of curriculum materials, as well as teaching expertise more generally, is encapsulated as *pedagogical design capacity* (PDC; Brown, 2009). We draw upon PDC in this study to investigate teachers' PDC specifically for inquiry-based elementary science teaching and learning.

Teachers' capacities for pedagogical design evolve over time and across contexts along the teacher professional continuum (Feiman-Nemser, 2001; Putnam & Borko, 2000). As such, preservice teachers need to be supported to begin developing their PDC for inquiry. This is particularly important since beginning teachers tend to rely heavily on curriculum materials to which they have access and often articulate understandings of inquiry-based science that are inconsistent with instructional frameworks advocated in science education reform (Abell, 2007; Forbes & Davis, 2010; Davis, Petish, & Smithey, 2006; Grossman & Thompson, 2004; Kauffman, Johnson, Kardos, Liu, & Peske, 2002). Focusing on the development of preservice teachers' PDC for inquiry in teacher education, specifically their learning to use science curriculum materials, can help insure that they enter teaching as ''well-started beginners'' who are prepared to maximize opportunities to learn in and from professional practice.

In recent years, a body of research has emerged focused on preservice elementary teachers' use of and learning from science curriculum materials (e.g., Beyer & Davis, 2009; Dietz & Davis, 2009; Forbes & Davis, 2008; Schwarz et al., 2008). This is an important strand of research that helps science teacher educators and science curriculum developers better understand the needs of preservice elementary teachers and how to support their developing PDCs for inquiry. To maximize these learning experiences for preservice teachers, however, more research is needed to better understand preservice teachers' PDC for inquiry.

In this study, we investigate the curriculum design decisions that preservice teachers make as part of their curriculum design efforts, as well as the outcomes of those decisions, specifically in regard to inquiry. Teachers' PDCs for inquiry depend on their personal characteristics (knowledge, beliefs, identities, and orientations) and features of their professional contexts. Before the development of preservice teachers' PDCs for inquiry can be fully characterized, though, the field must first better understand the curriculum design decisions these novice teachers make, as well as the outcomes of those decisions. Rather than addressing PDC for inquiry in its totality, in this study we foreground (a) the nature of the teacher–curriculum interactions (i.e., how preservice elementary teachers mobilize and adapt existing science curriculum materials to plan and construct inquiry-oriented science lesson plans) and (b) how those interactions, as well as the inquiry orientations of the science curriculum materials the preservice teachers use, impact the overall quality of the science lessons the preservice teachers plan (i.e., how inquiry-oriented their planned science lessons are). In regard to the preservice teachers' lesson planning, we ask the following research questions:

(1) How many and what types of curriculum materials do preservice elementary teachers use and what adaptations do they make?
(2) How inquiry-oriented are their lessons before and after adaptation?
(3) How do the preservice teachers' curriculum design decisions and inquiry orientations of the curriculum materials they use influence the inquiry orientations of their revised, post-adaptation planned science lessons?

This study addresses critical gaps in the corpus of research focused on preservice teachers' use of science curriculum materials. First, whereas previous research has focused primarily on preservice elementary teachers' critique and evaluation of science curriculum materials, in this study we focus on their adaptation of science curriculum materials. Second, we highlight the preservice teachers' curriculum adaptation specifically for inquiry-based science as articulated in science education reform (NRC, 2000). Finally, this study design affords a sufficient sample size to employ quantitative analytical methods to most effectively address our research questions. Findings from this research will provide an important foundation upon which to engage in follow-up studies employing both quantitative and qualitative research methods.

Theoretical Framework

Broadly defined, PDC for inquiry entails a synergistic relationship between teachers' personal characteristics (knowledge, beliefs, identities, and orientations) related to science teaching, the science curriculum materials they use, and features of their professional contexts that best promote students' science

learning, including relevant instructional goals. Ultimately, the PDC for inquiry afforded a given teacher is evidenced in specific teacher–curriculum interactions through which teachers use curriculum materials to shape planned science instruction, as well as the outcomes of those interactions. These interactions and their outcomes are foregrounded in this study. To more fully position this work, we next discuss existing research on preservice teachers' learning to teach science as inquiry and use of science curriculum materials, as well as a model of teachers' curriculum design for inquiry.

Preservice Teachers, Inquiry, and Science Curriculum Materials

In order to engage students in standard-based, inquiry-oriented science, teachers must develop a thorough understanding of scientific inquiry and inquiry-oriented science teaching and learning, as well as orientations toward science teaching that are congruent with inquiry teaching and learning (AAAS, 1993; NRC, 1996, 2000, 2007). However, supporting preservice teachers in developing requisite knowledge and abilities to engage students in science as inquiry remains a challenge. Preservice teachers generally possess less well-developed understandings of inquiry-based science (Davis, 2006; Windschitl, 2004). For example, preservice elementary teachers typically exhibit child-centered perspectives on teaching and emphasize active, hands-on science experiences for students (Abell, 2007; Howes, 2002). They often view the nature of science as a body of facts rather than as negotiated and constructed through scientific practices (Gess-Newsome, 2002) and, even when they do acknowledge the epistemic practices of science, often perceive these practices as linear and lockstep rather than dynamic and iterative (Windschitl, 2003). However, preservice elementary teachers' generally positive orientations toward active, hands-on, investigation-based science can serve as a productive foundation upon which to support their developing understanding of scientific inquiry (Howes, 2002) and, through teacher education, they can begin to develop more robust knowledge of scientific inquiry (Bryan, 2003; Gess-Newsome, 2002; Haefner & Zembal-Saul, 2004; Windschitl, 2003).

Even if preservice teachers develop better understandings of inquiry-based teaching and learning, translating that knowledge into science teaching practice remains a daunting challenge (Bryan & Abell, 1999; Crawford, 1999, 2007; Southerland & Gess-Newsome, 1999; Zembal-Saul, Blumenfeld, & Krajcik, 2000). Preservice teachers often lack substantial opportunities to enact science lessons in elementary classrooms and, when they do, may face resistance in engaging students in inquiry-oriented science. In the face of such obstacles, science curriculum materials, particularly lesson plans, can serve as highly accessible records of science teaching practice that preservice teachers can apply their knowledge of inquiry to evaluate, critique, and adapt. The rationale for such an instructional approach is supported by a growing body of research that suggests teachers very often actively engage in codesign with curriculum materials rather than use them ''as-is'' (Brown, 2009; Enyedy & Goldberg, 2004; Nye, Hedges, & Konstantopoulos, 2004; Pine et al., 2006; Pintó, 2004; Remillard, 2005; Schneider, Krajcik, & Blumenfeld, 2005). It is particularly important for preservice teachers to learn to use science curriculum materials to promote inquiry since the curricular resources to which they have access may not be highly inquiry-based (Beyer, Delgado, Davis, & Krajcik, 2009; Ford, 2006; Kesidou & Roseman, 2002) even when beginning teachers tend to rely heavily on them (Forbes & Davis, 2010; Grossman & Thompson, 2004; Kauffman et al., 2002). The process of curriculum planning is a crucial component of teachers' practice, including the use of curriculum materials (Remillard, 2005). As such, foregrounding the use of science curriculum materials in teacher education can provide preservice teachers with valuable opportunities to begin to develop their abilities to use both their knowledge of classroom inquiry and curricular resources to engage in inquiry-oriented science, or their PDCs for inquiry.

Unfortunately, there is little existing research that illustrates how preservice elementary teachers learn to use science curriculum materials. Findings from previous research suggest that preservice elementary teachers prioritize the investigative dimensions of inquiry at the expense of explanation-construction, a crucial component of scientific inquiry (Davis, 2006) and often prioritize other relevant criteria over inquiry and inquiry-oriented science teaching (Schwarz et al., 2008). However, scaffolded opportunities for learning in science methods courses can help preservice teachers first develop awareness of particular criteria and then learn to apply them over time in their use of curriculum materials (Davis, 2006; Schwarz et al., 2008). Additionally, while preservice teachers can learn to use educative features of curriculum materials to support their learning (Dietz & Davis, 2009), they also acknowledge that more experienced teachers can learn from

curriculum materials in two cases: when using new curriculum materials and when teaching new content (Forbes & Davis, 2008). These studies also provide evidence that preservice teachers' learning to use curriculum materials is fundamentally intertwined with their developing identities as teachers (Dietz & Davis, 2009; Forbes & Davis, 2008).

An Expanded Model of Teachers' Curriculum Design for Inquiry

The relationship between teachers and curriculum materials lies at the core of notions of PDC. To better understand and operationalize teacher–curriculum interactions, others have proposed models that have focused primarily on teachers' adaptations of the curriculum materials they use (Brown, 2009; Remillard, 1999, 2005). Some teachers use curriculum materials in ways that closely mirror those intended by the curriculum developers. In this case, teachers *appropriate* existing curriculum materials (Remillard, 1999) and use them as designed. In doing so, teachers *offload* (Brown, 2009) much of the responsibility for pedagogical design to the curriculum materials. However, even when teachers believe that they are using curriculum materials as intended, they often enact them differently. Rather than using curriculum materials "as-is," teachers more commonly modify them through a process of *invention* (Remillard, 1999) or *adaptation* and *improvization* (Brown, 2009).

The continuum from more to less curriculum adaptation highlighted in existing models of the teacher–curriculum relationship is an important dimension of teachers' use of curriculum materials. However, we expand upon Brown's (2009) and Remillard's (1999, 2005) frameworks for teachers' use of curriculum materials in our proposed three-dimensional model of teachers' curriculum design for inquiry shown in Figure 1.

In the model in Figure 1, the continuum from more to less adaptation of curriculum materials described by Brown (2009) and Remillard (1999, 2005) is retained in the horizontal axis. However, we include two additional dimensions that more robustly represent teachers' curriculum design for inquiry. First, teachers not only adapt curriculum materials but also often mobilize a variety of different curricular resources, particularly when they do not have access to full, coherent sets of curriculum materials. In the model in Figure 1, this dimension is represented by the vertical axis. At one end of this continuum is what has thus far been emphasized in teacher–curriculum research (Brown, 2009; Remillard, 2005)—situations in which teachers modify a single set of curriculum materials that was already available (less mobilization). The other end of this continuum involves more curriculum mobilization and represents situations in which teachers mobilize multiple curricular resources. Using this continuum, we can more fully account for the diversity and frequency of curriculum materials teachers use as well as the modifications they make to them.

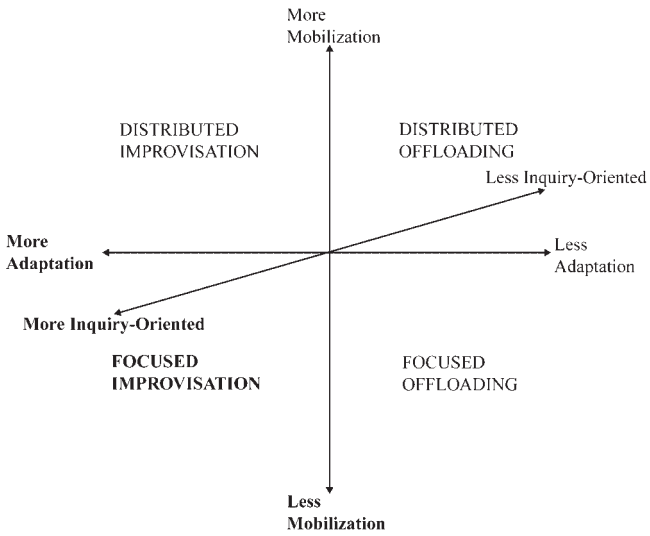

Figure 1. Framework for teachers' curriculum design for inquiry.

These two dimensions of curriculum materials use—curriculum mobilization and curriculum adaptation—capture four constituent patterns of teacher–curriculum interactions represented by the four quadrants in Figure 1. For any instance in which teachers use curriculum materials to engage in instruction, the curriculum design process can be characterized as distributed or focused improvization or offloading. Teachers who engage in *distributed improvization* mobilize a wider variety of curriculum materials and actively adapt them. Teachers who engage in *distributed offloading* similarly use many different curricular resources but make fewer adaptations to them. Teachers who engage in *focused improvization* use fewer curriculum materials but heavily modify and adapt those they do use. Finally, teachers who exhibit *focused offloading* use few curriculum materials and make few to no changes to them.

Finally, and perhaps most importantly, teacher–curriculum interactions result in particular outcomes. The curriculum design decisions that teachers make can be productive, unproductive, or neutral (Pine et al., 2006; Pintó, 2004; Remillard, 1999; Schneider et al., 2005). To provide a measure of the effectiveness of teachers' curriculum design decisions, we include a third dimension to model in Figure 1 that characterizes the inquiry-orientation of the teachers' developed lesson plans. This third dimension provides a standard by which to assess how productive or unproductive teachers' curriculum design decisions are in respect to inquiry-oriented science instruction. The primary goal of this study is to investigate relationships between patterns of preservice elementary teachers' curriculum design decision-making (interactions) and the inquiry orientations of the science lessons they construct (outcomes).

Methods

This study involved 46 preservice elementary teachers enrolled in two sections of an undergraduate elementary science teaching methods course. As part of the course, the preservice teachers completed two assignments in which they used existing science curriculum materials to plan inquiry-based science lessons and enact them in elementary classrooms. Using artifacts associated with those lessons, we analyzed the types and frequencies of curriculum materials the preservice teachers used and the adaptations they made, how inquiry-based their pre- and post-adaptation lessons were, as well as how these decisions helped explain how inquiry-based their adapted lessons were.

Participants and Context

This study took place during the third semester of a four-semester undergraduate elementary teacher preparation program at a large, Midwestern University in the United States. During the third semester, the preservice teachers were enrolled in an elementary science teaching methods designed around two broad domains for preservice teacher learning: inquiry-oriented science teaching and the use of science curriculum materials. Between the two sections of the course, there were 46 preservice elementary teachers who agreed to participate in this research ($n_1 = 22, n_2 = 24$). All were traditional fourth-year seniors (about 21 years old) in their final year of college. Most were female and Caucasian, thus making them representative of the population of elementary teachers in the U.S. (National Center for Education Statistics, 2003).

The science methods course builds on current research and practice to prepare preservice teachers to promote elementary school students' science learning (see Davis & Smithey, 2009, for a description of the course and its foundations). Through a variety of course-specific learning activities, the preservice teachers developed familiarity with current science standards documents, constructivist learning theory, the five essential features of science as inquiry (NRC, 2000), and numerous elementary science curricular programs. They also engaged in investigations involving asking questions, making predictions, conducting experiments, collecting data, making observations, developing explanations, and communicating findings. As part of the teacher education program, the preservice teachers were also placed individually in local elementary school classrooms for 6 hours each week during the three pre-student teaching semesters in which they completed university coursework, including the semester in which this course occurred. These field placements provided the preservice teachers a consistent and highly valuable context in which to apply ideas and strategies promoted in the methods course, as well as to analyze and reflect on their own and others' professional teaching practice.

Data Sources and Collection

During the methods semester, the preservice teachers were asked to plan, develop, teach, and reflect upon two science lessons. These assignments were called *reflective teaching (RT) assignments* and were the two most substantial assignments in the elementary science methods course. Prior to beginning their RT assignments, the preservice teachers were afforded opportunities to learn about the five essential features of inquiry and features of effective science lessons, as well as critique and adapt sample science lessons in collaborative, in-class activities. The purpose of the RT assignments was to afford the preservice teachers an opportunity to implement these ideas and strategies in authentic elementary classroom settings and, in doing so, gain experience not only planning but also enacting and reflecting upon inquiry-oriented science teaching using a variety of science curriculum materials.

A primary goal of the methods course was to support the preservice teachers' learning to use science curriculum materials effectively. As such, for the RT assignments, the preservice teachers were not asked to develop a science lesson from the ground up. Rather, they were asked to critique and adapt an existing science lesson or set of science curriculum materials to produce a more inquiry-based, revised science lesson. The instructional goals and curricular topics in their placement classrooms largely determined what science lessons the preservice teachers planned and enacted. They most often used science lessons and associated materials from the science curriculum materials in their placement classrooms (e.g., FOSS, Science Companion, STC), which were typically provided or recommended by their cooperating teacher. However, some mobilized science lessons from other sources. Time was allotted in the methods class for collaborative lesson planning and feedback from peers and the course instructors, though the preservice teachers planned their lessons primarily outside of class. The preservice teachers enacted their lessons in their placement classrooms and wrote post-enactment reflective journals. In completion of each RT assignment for the methods course, the preservice teachers submitted the original science lesson and/or curriculum materials they used, the lesson plan and associated documents they developed, the reflective journal, and a small sample of student work.

Data Coding and Analysis

We analyzed lesson plans and other instructional artifacts from the two RT assignments completed by the preservice teachers. The purpose of the quantitative analyses was to characterize the types and frequencies of curriculum materials the preservice teachers used, the types and frequencies of adaptations the preservice teachers made, and how inquiry-oriented their initial and revised science lesson plans were.

Data Coding. Three coding keys or rubrics were developed for this study. In order to characterize the types of science curriculum materials the preservice teachers used, we employed a coding key to distinguish between lesson plans, textbooks, student worksheets, and other types of curriculum materials the preservice teachers mobilized to plan their lessons. This coding key is shown in Table 1.

Building on previous studies of teachers' use of curriculum materials (e.g., Drake & Sherin, 2006), we used another coding key to characterize the types of adaptations preservice teachers made to these curriculum materials. This coding scheme allowed us to characterize the nature of the changes they made at a structural level, thus supporting our goal of describing their curriculum design for inquiry. This coding key helped distinguish between additions to or deletions of portions of existing curriculum materials, as well as their rearrangement (relocations, substitutions, inversions, and duplications). This coding key is shown in Table 2.

In using the coding keys in Tables 1 and 2, we sought to describe patterns in the preservice teachers' curriculum design decision-making and relationships between these patterns and curriculum design outcomes. However, in order to assess the inquiry orientations of the preservice teachers' pre- and post-enactment science lesson plans, we used the inquiry scoring rubric included in the Appendix. This scoring rubric is informed by existing rubrics for the evaluation of science curriculum materials (Kesidou & Roseman, 2002) and science teaching (Bodzin & Beerer, 2003; Luft, 1999). It was explicitly designed to capture the five essential features of inquiry as defined in current science education reform (NRC, 1996, 2000, 2007). These include engaging students in scientifically oriented questions; gathering, organizing, and analyzing data; formulating explanations from evidence to address scientifically oriented questions; evaluating their explanations in light of alternative explanations; and communicating and justifying their

Table 1
Coding key for types and frequencies of curriculum materials

Type of Curriculum Materials	Description
Existing lesson plan (LP)	Preservice teacher uses an existing lesson plan to develop the science lesson he/she enacts
Stand-alone investigation, experiment, or activity (AIE)	Preservice teacher uses stand-alone investigation, experiment, or activity to develop the science lesson he/she enacts
Textbook (T)	Preservice teacher uses a textbook to develop the science lesson he/she enacts
Content resource (science background information) (CR)	Preservice teacher uses a content resource to develop the science lesson he/she enacts
Video/DVD (VD)	Preservice teacher uses video or DVD to develop the science lesson he/she enacts
Models, graphs, or images (MGI)	Preservice teacher uses a separate model, graph, or image to develop the science lesson he/she enacts
Trade book (story) (TB)	Preservice teacher uses a trade book to develop the science lesson he/she enacts
Computer software (CS)	Preservice teacher uses computer software to develop the science lesson he/she enacts
Student worksheet (SW)	Preservice teacher uses a student worksheet to develop the science lesson he/she enacts
Other (O)	Preservice teacher uses a curricular resource not captured in the other categories to develop the science lesson he/she enacts

explanations. This is an important contribution of this study since many previous studies of preservice teachers' knowledge, beliefs, and orientations regarding scientific inquiry and inquiry-oriented practice have not explicitly operationalized elements of scientific inquiry and inquiry-oriented science teaching as defined in current reform documents (Davis et al., 2006).

Data Analysis. Our analyses were based on numerical and categorical data provided directly by the preservice teachers in their lesson artifacts, as well as the quantification of qualitative data (Chi, 1997). Coding reports were produced for each preservice teacher's RT assignment documents. These reports summarized the types and frequencies of curriculum materials used and adaptations made, as well as an inquiry score for both their existing and revised lesson plans. For this coding, inter-rater reliability was performed with a colleague. For the codes in Tables 1 and 2, and the Appendix, coding consistency for the preservice teachers' RT assignments ranged from 65% to 100%, averaging 82% agreement prior to discussion. After discussion, 100% agreement was reached. These quantified data were imported into SPSS for statistical analysis.

Quantitative analysis involved a number of steps. The first set of quantitative analyses focused on providing descriptive statistics and establishing statistically significant relationships between variables. Using *t*-tests, chi-square tests, and ANOVA, we investigated relationships between individual teacher characteristics. Then, we generated descriptive statistics for the types and frequencies of both curriculum materials used and adaptations made to them for the preservice teachers' two RT assignments. Additionally, we investigated relationships between patterns of curriculum materials use in the first and second RT assignments using Pearson correlations. Next, we investigated the inquiry scores of the preservice teachers' science lessons, both before and after adaptation. We used *t*-tests, ANOVA, and Pearson correlations to compare these inquiry scores within and across the two RT assignments. For all statistical tests, measures of

Table 2
Coding key for types and frequencies of adaptations to curriculum materials

Types of Changes	Description
Insertions (Ins)	Adds a new element to the lesson plan
Deletions (Del)	Deletes an element of the existing lesson plan
Substitutions (Sub)	Substitutes a new element for an existing element of a lesson plan
Duplications (Dup)	Includes an existing element from the lesson plan in another part of the lesson plan
Inversions (Inv)	Switches the order or placement of 2 or more existing elements of a lesson plan
Relocations (Rel)	Moves an existing element in the lesson plan to a different location in lesson

statistical significance have been provided. Also, consistent with the recent emphasis on reporting statistical power as well as significance (e.g., Zientek, Capraro, & Capraro, 2008), we report effect sizes for statistical results. Additionally, we performed independent samples *t*-tests to determine if there are any significant differences between the two sections of the course.

Second, we constructed a hierarchical linear regression model to provide explanatory power for trends in the preservice teachers' curriculum design for inquiry. The dependent or outcome variable was the post-adaptation inquiry scores of the preservice teachers' revised science lessons in the first and second RT assignments. In this regression model, three predictor variables were used: the inquiry score of the curriculum materials the preservice teachers initially used to develop their lesson, a composite variable for the types and frequencies of curriculum materials they used, and a composite variable for the types and frequencies of adaptations they made to the curriculum materials. These groups of variables are consistent with theoretical models of the teacher–curriculum relationship that foreground dynamic interactions teachers have with curriculum materials based on their own views and features of the curriculum materials themselves (Remillard, 2005). We used a hierarchical regression model because the variables are added to the model one at a time such that the cumulative effect of independent variables on the outcome variable can be ascertained. This model met the requirements of linearity, independence, homoscedasticity, and normality (Osborne & Waters, 2002) and was therefore suitable for analysis.

Results

In the sections that follow, we present results from the preservice teachers' first and second RT assignments (RT1 and RT2). We first provide descriptive statistics for the types and frequencies of science curriculum materials the preservice teachers used and the adaptations they made to them. Next, we present results that show how the preservice teachers' curriculum design efforts resulted in more inquiry-oriented planned science lessons and explore relationships between these variables. Finally, we present findings from hierarchical linear regression analyses to explore the influence of science curriculum materials and the preservice teachers' curriculum design decisions on the inquiry scores of their revised science lessons.

Preservice Teachers' Curriculum-Design Decisions

In our first research question, we asked, ''how many and what types of curriculum materials do they use and adaptations do they make?'' We first discuss the types and frequencies of science curriculum materials the preservice teachers used and then the types and frequencies of adaptations they made to them.

Types and Frequencies of Curriculum Materials Used

Trends in the types and frequencies of curriculum materials used by the preservice teachers were similar across the two RT assignments. In both RT assignments, the preservice teachers overwhelmingly used existing lesson plans ($M_{RT1} = 1.04$, $SD_{RT1} = 0.42$; $M_{RT2} = 0.91$, $SD_{RT2} = 0.56$) and student worksheets ($M_{RT1} = 0.91$, $SD_{RT1} = 0.63$; $M_{RT2} = 1.13$, $SD_{RT2} = 0.92$). There was no statistically significant difference between the mean number of existing lesson plans and student worksheets used by the preservice teachers in either RT1, $t(45) = 1.29$, $p = 0.22$, $d = 0.24$ or RT2, $t(45) = -1.7$, $p = 0.096$, $d = 0.29$. The next most frequently used type of curriculum material was models, graphs, or images, which were used by just under 25% of the preservice teachers in RT1 ($M_{RT1} = 0.5$, $SD_{RT1} = 1.38$) and 15% of the preservice teachers in RT2 ($M_{RT2} = 0.29$, $SD_{RT2} = 1.82$). The remaining types of curriculum materials were used by preservice teachers in only a few instances.

Frequencies of Curriculum Materials Used. In each of their RT assignments, the preservice teachers mobilized a number of existing curriculum materials to plan and develop their science lessons. To plan their science lessons, the preservice teachers used an average of 2.89 ($SD_{RT1} = 1.67$) and 2.96 ($SD_{RT2} = 1.49$) unique curriculum materials to plan their RT1 and RT2 science lessons, respectively. Though the preservice teachers used slightly more curriculum materials in the second RT assignment, the difference between the number of curriculum materials used in RT assignments 1 and 2 was not statistically significant, $t(45) = -0.23$, $p = 0.82$, $d = 0.04$. Additionally, the number of curriculum materials used in RT1 and RT2 was only weakly and insignificantly correlated, $r(45) = 0.27$, $p = 0.07$, suggesting that the preservice

teachers did not necessarily tend to use the same number of curriculum materials in their second RT assignment as in their first.

Types of Curriculum Materials Used. In addition to analyzing the total number of curriculum materials the preservice teachers used, we also investigated the number of unique *types* of curriculum materials they used.[1] To plan their science lessons, the preservice teachers used an average of 2.36 ($SD_{RT1} = 0.93$, $SD_{RT2} = 0.61$) unique types of curriculum materials to plan their science lessons for both RT1 and RT2. As with the total number of curriculum materials previously, the number of types of curriculum materials used in RT1 and RT2 was weakly and insignificantly correlated, $r(45) = 0.29$, $p = 0.051$, suggesting that the preservice teachers did not necessarily tend to use the same number of types of curriculum materials in their second RT assignment as in their first.

Comparing Frequencies and Types of Curriculum Materials Used. The preservice teachers used a greater total number of curriculum materials than they did unique types of curriculum materials in both RT1, $t(45) = -2.77$, $p = 0.008$, $d = 0.53$, and RT2, $t(44) = -3.01$, $p = 0.004$, $d = 0.39$. This suggests that preservice teachers often used more than one curricular resource of a particular type in a given RT assignment. For example, many preservice teachers used multiple student worksheets in a single lesson. Additionally, preservice teachers who used more curriculum materials also tended to use a greater number of types of curriculum materials, both in RT1, $r(46) = 0.66$, $p = 0.001$, and RT2, $r(46) = 0.44$, $p = 0.002$. These relationships suggest that the more curriculum materials a preservice teacher used, the more likely he/she was to also use a greater variety of types of curriculum materials.

Summary. The preservice teachers predominantly used existing lesson plans and student worksheets in their curriculum design for inquiry. They tended to use roughly three distinct science curriculum materials for each RT assignment. However, they did not always use an equal number of different *types* of science curriculum materials, which suggests they often used more than one of the same type of curriculum material to plan a given lesson. Within each RT assignment, preservice teachers who used more science curriculum materials to plan their lessons also tended to use more types of science curriculum materials. However, across RT assignments 1 and 2, they did not necessarily use similar numbers or types of science curriculum materials.

Types and Frequencies of Adaptations Made

As with the curriculum materials they mobilized, trends in the types and frequencies of adaptations made by the preservice teachers were similar across both RT assignments. The insertion of new elements into their curriculum materials was the most common form of adaptation the preservice teachers made in both RT1, $t(46) = 6.97$, $p < 0.001$, $d = 0.79$, and RT2, $t(45) = 4.55$, $p < 0.001$, $d = 1.08$. The preservice teachers made an average of 2.11 ($SD_{RT1} = 1.34$) and 2.16 ($SD_{RT2} = 1.22$) insertions in their RT1 and RT2 lessons, respectively. The substitution of new elements for existing elements in their curriculum materials was the second most common form of adaptation the preservice teachers made in both RT1, $t(46) = -3.74$, $p = 0.001$, $d = 0.75$, and RT2, $t(45) = -3.1$, $p = 0.003$, $d = 0.59$. The preservice teachers made an average of 1.15 ($SD_{RT1} = 1.07$) and 1.0 ($SD_{RT2} = 0.91$) substitutions to their RT1 and RT2 lessons, respectively. The deletion of existing elements from their curriculum materials was the third most common form of adaptation the preservice teachers made in both RT1, $t(46) = 3.38$, $p = 0.001$, $d = 0.65$, and RT2, $t(45) = 4.17$, $p < 0.001$, $d = 0.90$. The preservice teachers made an average of 0.46 ($SD_{RT1} = 0.72$) and 0.51 ($SD_{RT2} = 0.76$) deletions to their RT1 and RT2 lessons, respectively. The remaining types of adaptations—inversions, duplications, and relocations—were rarely if ever used in either RT assignment.

Frequencies of Adaptations Made to Curriculum Materials. The preservice teachers made an average of 3.78 ($SD_{RT1} = 1.74$) and 3.71 ($SD_{RT2} = 1.49$) unique adaptations to the curriculum materials they used to plan their RT1 and RT2 science lessons, respectively. Though the preservice teachers made slightly more adaptations in their first RT assignment than the second, the difference was not statistically significant, $t(45) = 0.28$, $p = 0.78$, $d = 0.04$. However, the number of adaptations made in RT1 and RT2 was moderately correlated, $r(45) = 0.509$, $p < 0.001$. This suggests that the preservice teachers who made more adaptations in RT1 tended to also be the ones who made more adaptations in RT2, and vice versa.

Types of Adaptations Made to Curriculum Materials. In addition to analyzing the total number of adaptations the preservice teachers made, we also investigated the number of unique types of adaptations they made.[2] The preservice teachers made an average of 1.96 ($SD_{RT1} = 0.85$) and 2.04 ($SD_{RT2} = 0.77$) unique types of adaptations to the curriculum materials they used to plan their science lessons in RT1 and RT2, respectively. Though the preservice teachers made slightly more types of adaptations in their second RT assignment than the first, the difference was not statistically significant, $t(45) = -0.628$, $p = 0.53$, $d = 0.10$. However, the number of types of adaptations made in RT1 and RT2 was weakly correlated, $r(45) = 0.316$, $p = 0.034$. This suggests that the preservice teachers who made more types of adaptations in RT1 tended to also be the ones who made more types of adaptations in RT2, and vice versa.

Comparing Frequencies and Types of Adaptations Made. The preservice teachers made a greater total number of adaptations than unique types of adaptations to the curriculum materials they used, both in RT1, $t(45) = -9.40$, $p < 0.001$, $d = 1.34$, and RT2, $t(44) = -9.13$, $p < 0.001$, $d = 1.41$. This suggests that preservice teachers often made more than one adaptation of a particular type in a given RT assignment. Additionally, preservice teachers who made more adaptations also tended to make more types of adaptations, both in RT1, $r(46) = 0.68$, $p < 0.001$, and RT2, $r(46) = 0.57$, $p < 0.001$. These correlations suggest that the more adaptations a preservice teacher made, the more likely he/she was also to make a greater variety of types of adaptations.

Summary. The preservice teachers predominantly added new elements to the science lesson plans they used to plan their science lessons. They tended to make between three and four distinct adaptations in each RT assignment. However, they did not tend to make an equal number of different types of adaptations, which suggests that they often made more than one type of adaptation to the lesson plans they used to plan their science lessons. For example, the preservice teachers often inserted multiple new elements into their lesson plans. Within each reflective assignment, preservice teachers who made more adaptations also tended to make more types of adaptations. Across RT assignments, the preservice teachers who made more adaptations and more types of adaptations in RT1 tended to do so again in RT2.

Inquiry Orientation of Pre- and Post-Adaptation Curriculum Materials

In research question 2, we asked, ''how inquiry-oriented are the preservice teachers' lessons before and after adaptation?'' In order to ascertain whether or not the preservice teachers developed more inquiry-oriented science lessons through their curriculum design decisions, we also scored their science lessons for elements of inquiry before and after adaptation. Across the two RT assignments the preservice teachers completed, trends in the inquiry scores of their initial curriculum materials, their final, revised lessons, and the difference between the two were consistent. In both RT assignments, the preservice teachers were able to modify existing science curriculum materials to make them more inquiry-oriented. An overview of these findings is shown in Figure 2.

In the next three sections, we describe the inquiry scores of the curriculum materials the preservice teachers used, the post-adaptation inquiry scores of their modified lessons, and changes in their inquiry scores.

Inquiry Scores of Initial Curriculum Materials. In both RT assignments, the curriculum materials the preservice teachers used to plan and develop their lessons were not highly inquiry-oriented ($M < 1$ on a 4-point scale).[3] In the first RT assignment, the curriculum materials they used had an average inquiry score of 0.85 ($SD = 0.77$) while those they used in the second RT assignment were even slightly less inquiry-oriented than those they used in the first ($M = 0.83$, $SD = 0.70$). However, the difference between these inquiry scores was not statistically significant, $t(45) = 0.24$, $p = 0.79$, $d = 0.05$, suggesting that the curriculum materials the preservice teachers initially used in both RT assignments, on average, were similarly inquiry-oriented.

Inquiry Scores of Revised Lessons. In both RT assignments, the preservice teachers modified these existing curriculum materials to construct revised science lessons that were more inquiry-oriented than the original ones. In the first RT assignment, the average inquiry score for the preservice teachers' revised lessons was 1.32 ($SD = 0.76$) and, in the second RT assignment, the mean inquiry score of the preservice teachers'

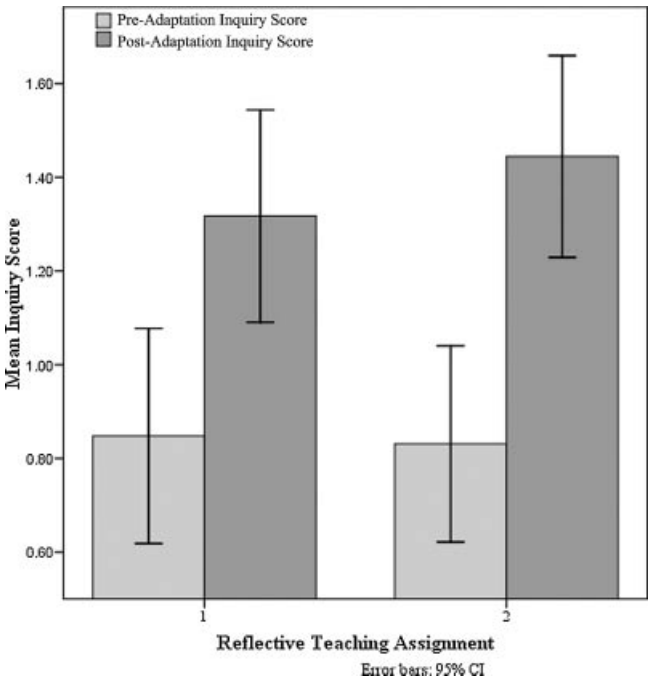

Figure 2. Pre- and post-adaptation inquiry scores of preservice teachers' lesson plans in reflective teaching assignments 1 and 2.

revised lessons was 1.44 ($SD = 0.72$). While the inquiry scores of the preservice teachers' revised lessons were slightly higher in the second RT assignment, this difference was not statistically significant, $t(45) = -0.757$, $p = 0.11$, $d = 0.14$. This suggests that the preservice teachers were equally able to effectively adapt science lessons they used in both RT assignments to make them more inquiry-oriented.

Change in Inquiry Scores. In both RT assignments, the preservice teachers' adaptations impacted the inquiry scores of the science lesson plans they used. In both RT assignments, 35 of the 46 preservice teachers increased the inquiry scores of their curriculum materials through their adaptations. In the first RT assignment, the mean change in inquiry score was 0.46 ($SD = 0.43$), a statistically significant increase, $t(46) = -7.5$, $p < 0.001$, $d = 0.61$. Similarly, in the second RT assignment, the mean change in inquiry score was 0.61 ($SD = 0.61$), also a statistically significant increase, $t(45) = -6.75$, $p < 0.001$, $d = 0.87$. There was no statistically significant difference in the change in inquiry scores between RT1 and RT2, $t(45) = -1.30$, $p = 0.20$, $d = 0.17$.

Results also suggest that the preservice teachers' capacities to make their lessons more inquiry-oriented were independent across the two RT assignments. Preservice teachers who had higher post-adaptation inquiry scores for their RT1 lessons were equally as likely as preservice teachers who had lower post-adaptation inquiry scores on the RT1 lessons to have higher post-adaptation inquiry scores on their RT2 lessons, $r(45) = 0.24$, $p = 0.11$. In other words, a preservice teacher whose revised lesson in RT1 was less inquiry-oriented was equally as likely to have a RT2 lesson that was more inquiry-oriented. The overall change in inquiry scores between the first and second RT assignments were not significantly correlated, $r(45) = 0.06$, $p = 0.71$. This finding suggests that the preservice teachers who significantly increased the inquiry scores of their science lesson in one reflective assignment did not necessarily do so in the other reflective assignment, and vice versa. In other words, a preservice teacher who did not increase the inquiry score of her RT1 lesson was no less likely than a preservice teacher who had to significantly increase the inquiry score of her RT2 lesson.

Finally, in their RT assignments, the preservice teachers were also asked to assess how inquiry-oriented they felt their revised science lessons were. Response options for this question included "very," "somewhat,"

''not very,'' and ''not at all'' inquiry-oriented. Differences between the preservice teachers' self-assessment of the inquiry orientation of their revised lessons and the post-adaptation inquiry scores were not statistically significant, either in RT1, $F(3, 42) = 1.71, p = 0.180, \omega^2 = 0.09$, or RT2, $F(2, 42) = 3.00, p = 0.061, \omega^2 = 0.21$. This finding shows that the preservice teachers were able to accurately assess the inquiry orientation of their revised lessons in both RT assignments.

Summary. These analyses suggest that across the first and second RT assignments, there was little difference between the inquiry orientation of the existing curriculum materials the preservice teachers used and adapted or between their revised lesson plans. In both assignments, they were able to make adaptations that resulted in statistically significant increases in the inquiry scores of their lessons. However, their abilities to do so were largely independent across RT assignments. Additionally, the preservice teachers were able to accurately assess how inquiry-oriented their lessons were in both RT assignments.

Effect of Curriculum Materials and Preservice Teachers' Curriculum Design Decisions on Inquiry Scores and Change in Inquiry Scores

Finally, in research question 3, we asked, ''how do the preservice teachers' curriculum design decisions and inquiry-orientations of the curriculum materials they use influence the inquiry-orientations of their revised, post-adaptation planned science lessons?'' We created a hierarchical linear regression model to determine whether there were relationships between the preservice teachers' curriculum design decisions and the inquiry scores of their revised lesson plans. We used hierarchical multiple regression because the predictor variables are added to the model one at a time such that the cumulative effect of these variables on the outcome variable can be ascertained. The primary purpose of this analysis is to provide a degree of statistical explanatory power for how the types and frequencies of curriculum materials the preservice teacher used, the types and frequencies and adaptations they made, as well as the inquiry score of the initial lesson plans and/or curriculum materials they used affected the inquiry scores of their revised lessons.

Description of Regression Model. We used three predictor variables in the regression model, an appropriate number of independent variables given our sample size (Milton, 1986). For the first and third predictor variables, we used composite, calculated scores, one for the curriculum materials the preservice teachers used and the other for the adaptations they made.[4] These individual scores were calculated by averaging the total number and total number of types of both curriculum materials and adaptations. As such, they did not directly reflect real-world phenomena but are composite, proxy measures of the preservice teachers' overall mobilization and adaptation of curriculum materials. For the second predictor variable, we include the inquiry scores of the original lesson plans and/or curriculum materials the preservice teachers used to engage in curriculum planning. This provides a measure of how inquiry-based these curriculum materials were initially. These three variables are consistent with theoretical models of the teacher–curriculum relationship that foreground dynamic interactions teachers have with curriculum materials based on their own personal characteristics and features of the curriculum materials themselves (Brown, 2009; Remillard, 2005).

In the regression model, the three independent variables were added stepwise to determine the degree to which they each affect the outcome variable. The order of addition to the model is based on theory (Brown, 2009; Remillard, 2005) as well as a practical understanding of the curriculum design process in this study. First, the preservice teachers mobilized curriculum materials to use in planning their two RT assignments. Therefore, the composite variable for ''curriculum materials'' is first to be added to the model. Second, these curriculum materials, once selected and mobilized, afforded a certain level of inquiry through their design. Thus, the second predictor variable added to the model is ''inquiry pre,'' or the inquiry score of the lesson plans and curriculum materials the preservice teachers used. Finally, the preservice teachers made adaptations to these lessons to varying degrees. The last predictor variable added to the model is therefore the composite variable for ''adaptations.''

Regression Analysis Results. For the regression model, we used the inquiry scores of the preservice teachers' revised lessons as the outcome variable. In Table 3, we present the unstandardized regression coefficients, significance levels for each of the independent variables, as well as the coefficient of

Table 3
Effect of teachers' curriculum materials' use on post-adaptation inquiry scores of lessons ($n_{RT1} = 46$, $n_{RT2} = 45$)

Independent Variables	RT1			RT2		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
Curriculum materials	−0.117	0.005	−0.006	0.312*	0.175	0.100
Inquiry score (Pre)	—	0.838***	0.861***	—	0.574***	0.655***
Adaptations	—	—	0.093	—		0.196*
Constant	1.622***	0.595*	0.334***	0.615	0.504	0.071
R^2	0.032	0.718***	0.739***	0.161*	0.44***	0.470
Change in R^2	—	0.686***	0.021	—	0.279***	0.066*

*$p < 0.05$.
***$p < 0.001$.

determination (R^2) and change in R^2. These statistics are included for both the first and second RT assignments the preservice teachers completed.

The first independent variable added to the model was the composite variable for the curriculum materials the preservice teachers used (Model 1). In the first RT assignment, *curriculum materials* was not a statistically significant predictor for the inquiry scores of their revised lessons, $F(1,44) = 1.475$, $p = 0.23$, and explained only 3.2% of the variance of the post-adaptation inquiry scores of the preservice teachers' lessons. However, in the second RT assignment, *curriculum materials* was a statistically significant predictor for the inquiry scores of their revised lessons, $F(2,43) = 8.274$, $p = 0.006$ and accounted for 16.1% of the variance of the post-adaptation inquiry scores of the preservice teachers' lessons. This suggests that the preservice teachers' decisions about the types and frequencies of curriculum materials to use in the RT assignment did not significantly affect the post-adaptation inquiry scores of their RT1 lessons, but did in their RT2 lessons.

The second independent variable added to the model was the inquiry score of the lesson plans and curriculum materials the preservice teachers used (Model 2), or the *pre-adaptation inquiry score*. In the first RT assignment, the addition of the *pre-adaptation inquiry scores* of the curriculum materials the preservice teachers used were statistically significant for the inquiry scores of their revised lessons, $F(2,43) = 54.86$, $p < 0.001$. Alone, ''inquiry pre,'' or the *pre-adaptation inquiry score* of the preservice teachers' lessons, explained 68.6% of the variance in post-adaptation inquiry scores of their revised lessons. Combined with the types and frequencies of *curriculum materials* the preservice teachers used, the two predictor variables in Model 2 accounted for a combined 71.8% of the variance in the post-adaptation inquiry scores of the preservice teachers' lessons. In the second RT assignment, this trend was repeated, though to a lesser extent. In RT2, *pre-adaptation inquiry scores* were statistically significant for the inquiry scores of their revised lessons, $F(2,42) = 16.528$, $p < 0.001$. Alone, ''inquiry pre'' accounted for 27.9% of the variance in post-adaptation inquiry scores of the revised lessons. Combined with the types and frequencies of *curriculum materials* the preservice teachers used, the two predictor variables in Model 2 accounted for a combined 44% of the variance in the post-adaptation inquiry scores of the preservice teachers' lessons. This suggests that the inquiry scores of the curriculum materials that preservice teachers used had a highly significant effect on how inquiry-oriented their revised lessons were, though to a lesser extent in RT2 than RT1.

The third and final independent variable added to the model was the composite variable for the preservice teachers' *adaptations* (Model 3). In the first RT assignment, the addition of *adaptations* to the model was statistically significant for the inquiry scores of their revised lessons, $F(3,42) = 39.65$, $p < 0.001$. *Adaptations* explained 2.1% of the variance in post-adaptation inquiry scores of the preservice teachers' revised lessons while, combined, the three predictor variables accounted for a combined 73.9% of the variance in the post-adaptation inquiry scores of the preservice teachers' revised lessons. In the second RT assignment, the addition of *adaptations* was statistically significant for the inquiry scores of their revised lessons, $F(3.41) = 14.02$, $p < 0.001$. Adaptations explained 6.6% of the variance in post-adaptation inquiry scores of the preservice teachers' revised lessons while, combined, the three predictor variables accounted for a combined 47% of the variance in the post-adaptation inquiry scores of the preservice teachers' revised

lessons. This suggests that the adaptations the preservice teachers made did not alone have significant effects on how inquiry-oriented their revised lessons were in RT1, but did so in RT2.

Summary. The regression analysis for the post-adaptation inquiry scores of the preservice teachers' lessons indicate that the single most significant determinant was the inquiry scores of the lesson plans and/or curriculum materials they began with. In RT1, neither of the other two predictor variables, curriculum materials and adaptations, were significant contributors to explanations of the variance of post-adaptation inquiry scores of the preservice teachers' lessons. However, in RT2, both were significant. Additionally, in RT2, the explanatory power of the pre-adaptation inquiry scores, as well as the regression model overall, decreased substantially.

Summary of Results

We have presented findings from the two RT assignments completed by preservice teachers in both sections of the undergraduate elementary science teaching methods course. These findings show that the preservice teachers predominantly used the most common forms of curriculum materials—lesson plans and various forms of student worksheets. They also show that they predominantly added or substituted new elements into these lesson plans. The preservice teachers' adaptations did result in more inquiry-oriented lessons. However, as shown in the results of regression analysis, the inquiry scores were highly influenced by how inquiry-based the lesson plans were that the preservice teachers used. Each of these trends was consistent in both RT assignments.

Synthesis and Discussion

Findings from this research inform and extend a small but growing body of research focused on preservice elementary teachers and curriculum materials (e.g., Beyer & Davis, 2009; Davis, 2006; Dietz & Davis, 2009; Forbes & Davis, 2008; Schwarz et al., 2008). These studies have made important contributions to the field's understanding of how preservice elementary teachers evaluate existing science curriculum materials. For example, existing research has identified the criteria that preservice elementary teachers tend to emphasize, such as hands-on science and making science relevant to students' lives, in their critique of science curriculum materials. However, the process by which preservice teachers adapt their curriculum materials based on these critiques remains largely unexplored. Findings presented here extend this research by illustrating preservice elementary teachers' curriculum design decision-making around their critique of science curriculum materials, as well as the measurable outcomes of those decisions, when they engage in curriculum design for inquiry.

Preservice Teachers' Mobilization and Adaptation of Science Curriculum Materials

Based on these findings, a generalized picture of the preservice teachers' curriculum planning for inquiry begins to emerge. The preservice teachers primarily used existing lesson plans and student worksheets in their planned science lessons. This suggests that the preservice teachers largely relied on the curriculum materials to which they had ready access. In many ways this is not surprising given the need for them to teach their placement classroom's curriculum. However, it does suggest that these preservice teachers, like practicing elementary teachers, tend to use existing curriculum materials when available rather than engaging in all-out curriculum design (Forbes & Davis, 2010; Grossman & Thompson, 2004; Kauffman et al., 2002). Because the preservice teachers did adapt the curriculum materials they used, the process of curriculum design observed in this study is indicative of *invention* (Remillard, 1999) or *adaptation* and *improvization* (Brown, 2009). These two findings, to draw on the model of teachers' curriculum materials use from Figure 1, show that the preservice teachers' curriculum design actions lie primarily in the *curriculum adaptation* domain and illustrate a curriculum design pattern characterized by *focused improvization*. This is shown in Figure 3.

By engaging in focused improvization, which is characterized by the adaptation of existing, easily accessible curriculum materials, the preservice teachers were able to make revised planned lessons that were more inquiry-based. In this sense, the preservice teachers were successful at achieving the goal of developing more inquiry-based lesson plans through their curriculum design for inquiry.

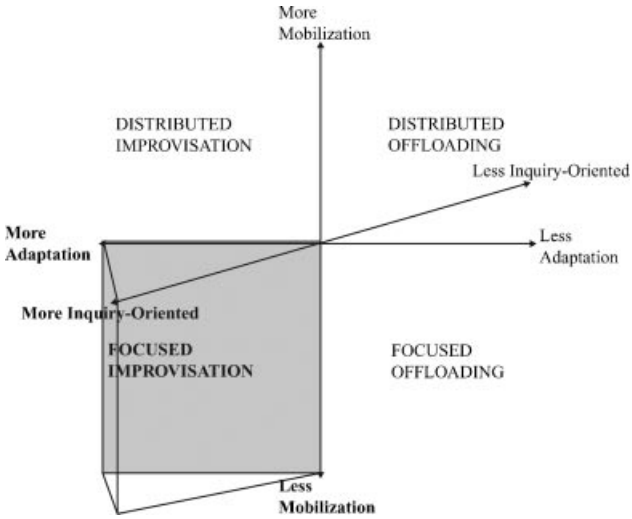

Figure 3. Preservice elementary teachers' curriculum design for inquiry.

Findings from this study also suggest that the preservice teachers varied in the extent to which they adapted the curriculum materials they mobilized. First, recall that there were no statistically significant relationships between the number or types of curriculum materials the preservice teachers used across the two assignments. This finding indicates that the same preservice teacher tended to use very different types and frequencies of curriculum materials for each of his/her lessons. However, there were moderate to strong, statistically significant correlations between the types and frequencies of preservice teachers' adaptations across the two RT assignments. This suggests that preservice teachers who tended to make more adaptations in RT1 also tended to do so in RT2, and vice versa. In short, while the preservice teachers largely mobilized the curriculum materials they had at their disposal, some combination of underlying teacher characteristics (Brown, 2009) and/or features of their professional contexts appeared to help shape, in part, the ways in which individual teachers adapted the science curriculum materials they mobilized and used. These are important findings that suggest patterns of curriculum adaptation are teacher-specific and embedded in teachers' knowledge, beliefs, identities, and orientations, as well as cultural and social aspects of their professional contexts, reinforcing findings from other research (Enyedy & Goldberg, 2004; Pintó, 2004; Remillard, 1999; Schneider et al., 2005). Future research should investigate how these additional factors influence teachers' curriculum design decision-making and outcomes of teacher–curriculum interactions.

Preservice Elementary Teachers and Inquiry

These findings also shed light on how preservice elementary teachers engage in inquiry-oriented teaching. Many previous studies have shown that preservice teachers struggle to translate their ideas into science teaching practice (Bryan & Abell, 1999; Crawford, 1999; Southerland & Gess-Newsome, 1999; Zembal-Saul et al., 2000). However, as shown in the results here, the preservice teachers were able to adapt their lessons to make them more inquiry-based in both RT assignments. This finding does show that the preservice teachers were able to engage in curriculum planning, or the design domain of professional practice (Remillard, 1999), to better support inquiry-based science instruction, reinforcing findings from other studies (Schwarz et al., 2008). These results also support those from a select few other studies that suggest preservice teachers can learn to engage in more inquiry-based science teaching practices more generally (Crawford, 1999, 2007).

A large body of research has also outlined how preservice teachers often hold views of inquiry and inquiry-based teaching and learning that are sometimes inconsistent with those advocated in science education reform (Bryan, 2003; Gess-Newsome, 2002; Haefner & Zembal-Saul, 2004; Windschitl, 2003). While this study did not directly characterize the preservice teachers' knowledge of inquiry, there is evidence

that the preservice teachers were able to accurately assess how inquiry-based their planned lessons were. Recall that the inquiry scores of the preservice teachers' revised lesson plans were compared to the inquiry scores they self-assigned their lessons in the lesson plan rationale documents. There were no statistically significant differences between these scores in either RT assignment, suggesting that the preservice teachers self-assessed their lesson plans similarly to how the authors characterized those same plans. This finding suggests that, at least at a general level, the preservice teachers' conceptions of inquiry were largely consistent with those of the authors, those promoted in the methods course, and those articulated in science education reform documents (NRC, 1996, 2000, 2007).

Despite the increasing emphasis on the important role teachers play in critiquing and adapting curriculum materials, a tension, whether real or perceived, still exists between teachers' curricular decision-making and intentions of the curriculum developers. Past curriculum development efforts have sought to minimize the influence of the "teacher effect" on curriculum enactment, thus promoting enactment with fidelity (Nye et al., 2004). Indeed, viewed through the eyes of curriculum developers and science education researchers, teachers' adaptations can vary in quality (Pine et al., 2006; Pintó, 2004; Remillard, 1999; Schneider et al., 2005). However, it is important to note that here, in only 3 out of the 93 lessons analyzed in this study, did the preservice teachers' adaptations actually make their lessons less inquiry-oriented than those with which they began. In some way, this finding contrasts with a reasonable assumption that preservice teachers, due to their lack of expertise, might be most likely to unintentionally develop lessons that are less effective. Rather, as shown in the regression model, the inquiry scores of the curriculum materials they used were the greatest influence on the inquiry scores of the preservice teachers' revised lessons. These findings suggest that the preservice elementary teachers are unlikely to decrease the effectiveness of existing science lessons through their curriculum design decision-making.

Implications and Conclusion

Results from this research further inform science teacher education and science curriculum development. This study has important implications for efforts in teacher education designed to foster preservice teachers' PDCs for inquiry. The findings presented here provide science teacher educators with insight into the types of science curriculum materials preservice teachers utilize, the ways in which they modify them, and how these adaptations lead to an increasing emphasis on essential features of inquiry in the science lessons they plan. These findings can help science teacher educators design effective instructional strategies in science methods courses and university-based elements of the teacher education programs. Future research should investigate the impact of specific instructional strategies and learning opportunities that best promote preservice elementary teachers' curriculum design decision-making for inquiry.

However, field experiences are also critical components of teacher education programs as they provide preservice teachers with opportunities to develop frameworks within and through which future learning can occur (Zembal-Saul et al., 2000). Previous research has shown that effective field experiences are long-term and stable, involve the careful selection of cooperating teachers, and are tightly integrated with methods courses that promote reflective, intellectual, and professional teaching practice (Sim, 2006; Zembal, Starr, & Krajcik, 1999). Findings from this study also inform efforts to more fully integrate university-based components and school-based field experiences by providing preservice teachers with opportunities to use science curriculum materials in authentic ways and to put their knowledge of inquiry to use through curriculum design for inquiry. To maximize preservice teachers' opportunities to develop their PDCs for inquiry, they should be afforded experiences using science curriculum materials to plan *and* enact inquiry-based science lessons.

This research also helps curriculum developers design science curriculum materials that meet the needs of elementary teachers at this early stage along the teacher professional continuum. While a growing number of studies show that teachers often adapt curriculum materials rather than using them "as-is," novice teachers nonetheless rely heavily on curriculum materials they use (e.g., Forbes & Davis, 2010; Grossman & Thompson, 2004). Findings from this study indicate that the fear of teachers' unproductive adaptation of science curriculum materials, and the prospect of these adaptations resulting in "lethal mutations" that negatively impact student learning, is perhaps unfounded. By designing inquiry-based science curriculum

materials, curriculum developers are insuring that the curriculum materials themselves still determine, in large part, how inquiry-based the lessons are even if teachers adapt them. If the goal remains to engage students in inquiry in the classroom, these findings support an argument for the continued emphasis on science as inquiry in newly developed science curriculum materials.

By embracing teachers' adaptation of curriculum materials, curriculum developers can take steps to actively support teachers' use of science curriculum materials by not only making them inquiry-based, but also flexibly adaptive and educative for teachers (Beyer & Davis, 2009; Beyer et al., 2009; Davis & Krajcik, 2005). The development of such curriculum materials requires a thorough understanding of those to whom such materials are meant to be educative for and by whom they are meant to be adapted. Elementary teachers have been shown to prioritize hands-on science that is engaging for students through the use of ''activities that work'' for elementary science (Abell, 2007; Appleton, 2002; Howes, 2002). Such research provides some insight into the unique needs of elementary teachers. However, there is still little research that informs our understanding of how teachers use these educative features of curriculum materials. By better understanding how preservice elementary teachers mobilize, adapt, and enact science curriculum materials in light of their professed models of inquiry, these curriculum materials can be better designed to simultaneously support their use and teacher learning.

The findings presented here shed important light on the process by which preservice elementary teachers engage in curriculum design for inquiry. However, this research has generated additional questions for future research. First, to fully understand how these curriculum design processes are embedded in teachers' PDCs for inquiry, more research is needed to explore the effect of teachers' personal characteristics (knowledge, beliefs, identity, and orientations) on both curriculum design processes and outcomes. Second, it is necessary to understand the degree to which the *enacted* lessons are inquiry-based and consistent with planned lessons, especially since some research suggests elementary teachers' enactments of inquiry-based science curriculum materials may sometimes be ineffective (Pine et al., 2006). Future research on preservice teachers' use of curriculum materials should also characterize how these lessons actually play out in elementary classrooms. Third, because teachers' PDCs for inquiry evolve over time, so too do their curriculum design practices. Future research should investigate the ways in which elementary teachers' curriculum design practice evolves at stages along the teacher professional continuum, as well as in light of characteristics of their curriculum materials and professional contexts. Such research will also help in promoting teachers' development of PDC through preservice and inservice teacher education, as well as educative science curriculum materials.

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Notes

[1]For example, a preservice teacher may have used four total curriculum materials to plan her lesson. However, if one was a lesson plan and the other three were student worksheets, she only used two unique types.

[2]For example, a preservice teacher may have made three total adaptations to plan her lesson. However, if one was a deletion and the other two were insertions, she only made two unique types.

[3]These inquiry scores represent a mean score for all five essential elements of inquiry (NRC, 2000) in any given science lesson or group of science curriculum materials. Many lessons were particularly inquiry-oriented for one or two elements of inquiry but not for the remainder, suggesting individual lessons emphasized a subset of inquiry practices rather than all of them.

[4]Using these individual variables (i.e., number of curriculum materials and number of types of curriculum materials, number of adaptations and number of types of adaptations) directly in the regression model would not have been appropriate since each of these sets of two variables was significantly correlated.

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Appendix: Inquiry Scoring Rubric for Lesson Plans

	3	2	1	0
Lesson engages students in scientifically oriented questions	Lesson uses investigation question that is feasible, worthwhile, contextualized, meaningful, ethical, and sustainable. Inv. questions and other questions are in "how" rather than "why" form. Inv. question is answerable in light of the lesson activities and other questions explicitly scaffold students' investigation and sense-making	Lesson uses investigation question that meets at least some of the criteria for effective inv. questions. Inv. question may be in "why" or "how" form. Question is at least to some extent answerable in light of the lesson activities. Lesson provides at least some additional questions teachers may use to reasonably support students' investigation and sense-making	Minimal evidence of use of scientific question and questioning. Investigation question may be present but meet few to no criteria for effective investigation questions. Questions may be in "why" rather than "how" form. Lesson makes unproductive suggestions for additional questions teachers can use to support students. Questions are likely not answerable in the classroom contexts	No evidence
Lesson engages students in gathering, organizing, and analyzing data	Students collect, organize, and analyze data/evidence. Opportunities to gather, organize, and analyze evidence are linked to the investigation question and/or phenomenon under investigation	Students do 2 out of 3 of the following: collect, organize, and analyze data/evidence. Opportunities to gather, organize, and analyze evidence are at least somewhat linked to the investigation question and/or phenomenon under investigation	Students do 1 out of 3 of the following: collect, organize, and analyze data/evidence. Opportunities to gather, organize, and analyze evidence are marginally linked to the investigation question and/or phenomenon under investigation	No evidence
Lesson engages students in formulating explanations from evidence to address scientifically oriented questions	Opportunities to construct explanations are connected to the evidence and data collected. Claims can be supported by evidence collected. Opportunities to construct explanations are connected to the investigation question and/or phenomenon under investigation	Opportunities to construct explanations are less explicitly connected to the evidence and data collected and the investigation question and/or phenomenon under investigation or lesser degrees of both. Claims may be supported by evidence collected	Opportunities to construct explanations are either marginally connected to the evidence and data collected and the investigation question and/or phenomenon under investigation or, in one case or the other, not at all linked. Claims are likely not to be able to be supported with evidence collected	No evidence
Lesson engages students in evaluating their explanations in light of alternative explanations	Lesson supports students to engage in dialogs, compare results, or check their results with those proposed by the teacher or instructional materials Lesson supports students to do so in ways that are highly likely to lead students to explanations that are consistent with currently accepted scientifi knowledge and the lesson's standard-based learning goals	Lesson supports students to evaluate their explanations by comparing to at least one alternative explanation Lesson supports students to do so in ways that are reasonably likely to lead students to explanations that are consistent with currently accepted scientific knowledge and the lesson's standard-based learning goals	Lesson supports students to evaluate explanations without taking alternative explanations into account Lesson is unlikely to lead students to explanations that are consistent with currently accepted scientific knowledge and the lesson's standard-based learning goals	No evidence
Lesson engages students in communicating and justifying their explanations	Lesson provides students with opportunities to share and justify their question, procedures, evidence, proposed explanation, and review of alternative explanations	Lesson provides students with opportunities to share AND justify some aspects of their question, procedures, evidence, proposed explanation, and review of alternative explanations	Lesson provides students with opportunities to share OR justify some aspects of their question, procedures, evidence, proposed explanation, and review of alternative explanations	No evidence