Research Article

Examining Student Work for Evidence of Teacher Uptake of Educative Curriculum Materials

Amber Schultz Bismack, Anna Maria Arias, Elizabeth A. Davis, and Annemarie Sullivan Palincsar

610 E. University Ave., School of Education Building, University of Michigan, Ann Arbor, Michigan 48109

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Abstract: The purpose of this study was to identify evidence in student work of teachers' uptake of educative features in educative curriculum materials. These are features in curriculum materials designed with the specific intent of supporting teacher learning and enactment. This study was prompted by previous work on educative curriculum materials and the need to determine how teachers' use of educative curriculum materials can influence student learning. Student work from two fourth-grade teachers' enactment of an electric circuits unit was analyzed for evidence of teachers' uptake of educative features, which included characteristics of quality for particular science practices. Findings from the student work revealed that the teachers used many of the supports in the educative curriculum materials, especially those that could be used directly with students. The student work also reflected characteristics of high-quality science practices, which were only supported within the educative features. This study supports and extends other work related to how teachers' use of educative curriculum materials may influence student learning and has implications for supporting teachers' productive engagement in teaching that supports the integration of science content and scientific practices, as emphasized in current reform efforts. © 2015 Wiley Periodicals, Inc. J Res Sci Teach 52: 816–846, 2015

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New understanding of what it means to learn (National Research Council [NRC], 2000) and what it means to "do" science (e.g., Justi & van Driel, 2005; NRC, 2007; Osborne, Erduran, & Simon, 2004), among other factors, has led to the current reform of science education in the United States and elsewhere. In the United States, this reform is reflected in *A Framework for K-12 Science Education* (NRC, 2012) and the *Next Generation Science Standards* (NGSS) (NGSS Lead States, 2013) through the integration of science and engineering practices, disciplinary core ideas, and crosscutting concepts. A similar emphasis is found in other nations' standards documents (e.g., Australian Curriculum, Assessment and Reporting Authority [ACARA], 2013; United Kingdom Department for Education, 2014). The benchmarks do not just represent what a student should know, but also what they should be able to do. This integrative approach differs

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Correspondence to: Amber Schultz Bismack; E-mail: abismack@umich.edu
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from previous representations of the goals of science education where the only focus was on science content or where the science practices were separated from the content knowledge (Osborne et al., 2004). Worldwide, many experienced teachers were trained with these earlier goal sets, which means the new focus on integrating content, practices, and crosscutting concepts is not only new to students, but also new for many in-service teachers. Indeed, supporting teachers to engage in more ambitious science teaching is a concern gaining attention around the globe (e.g., Justi & van Driel, 2006; Simon, Erduran, & Osborne, 2006). For these reasons, it is important to understand how to help support teachers in integrating content and practices in their science instruction.

As teachers plan and enact their science instruction, it is important for them to understand students' capabilities with science practices and how to support students' engagement with those science practices (e.g., McNeill, 2009; McNeill & Krajcik, 2009). Three important science practices include recording observations, making scientific predictions, and making evidence-based claims (e.g., Eberbach & Crowley, 2009; Lee & Butler, 2003; McNeill & Krajcik, 2009) and students should be engaging in these practices, among others, during their science instruction (ACARA, 2013; Gilbert & Boulter, 1998; NGSS Lead States, 2013; NRC, 2012; Osborne et al., 2004). For these reasons, as well as the emphasis on only these three science practices in the curriculum materials used in this study (National Science Resources Center [NSRC], 2004), making scientific observations, predictions, and evidence-based claims are the three science practices addressed in the current study.

Observation involves the process of collecting data to be analyzed and used as evidence to support scientific explanations (e.g., NRC, 2007, 2012; Zembal-Saul, McNeill, & Hershberger 2012). Young children are capable of engaging in the practice of making and recording scientific observations (Arias, Davis, & Palincsar, 2012; Metz, 2008), while struggling with some aspects of the practice (Akerson & Donnelly, 2009; Eberbach & Crowley, 2009; Ford, 2005). For example, Ford (2005) found that 3rd grade students were able to make observations of rocks and minerals; however, she noted the conflict between everyday language and scientific language observing that everyday language (e.g., "shape") does not necessarily lead to more complex scientific observations (e.g., "fracture surfaces"). Eberbach and Crowley (2009) also identified the disciplinary characteristics that increase the complexity of observation. Though elementary students are capable of making and recording scientific observations, they need support to engage in a way that is more characteristic of scientists' observations. For this reason, teachers need to support students in making and recording scientific observations that (1) include scientific language, (2) accurately represent the phenomena being observed, and (3) are objective (Akerson & Donnelly, 2009; Arias et al., 2012; Eberbach & Crowley, 2009; Ford, 2005). This support can occur in many ways, including direct instruction on what a scientific observation is (including characteristics of scientific observations compared with everyday observations), providing students with the tools to make accurate and objective observations, modeling how to record observations, and providing the necessary time to make accurate observations (Tomkins & Tunnicliffe, 2001).

Students should also make and revisit scientific predictions. This practice, though often overlooked in elementary classrooms, works in the service of scientific argumentation (Arias, Palincsar, & Davis, 2014; Duschl & Osborne, 2002), which "addresses the coordination of evidence and theory to advance an explanation, a model, a prediction or an evaluation" (Duschl & Osborne, 2002, p. 55). Lee and Butler (2003) demonstrated students' capabilities making scientific predictions, particularly when interacting with authentic data, although this practice can be challenging because it requires students to justify their claims (McNeill, 2011; Sandoval & Millwood, 2005). Engaging elementary children in making scientific predictions can also be challenging because of the difference between predictions made during English language arts instruction compared to science inquiry (Casteel & Isom, 1994).

Finally, students should build on their prior knowledge and use scientific investigations to develop scientific explanations and arguments that support their understanding of the disciplinary core ideas (e.g., NRC, 2007, 2012; Osborne et al., 2004; Zembal-Saul et al., 2012). Constructing scientific explanations—including making evidence-based claims—is a complex science practice (Braaten & Windschitl, 2011) and can be challenging for students (e.g., Ruiz-Primo, Li, Tsai, & Schneider, 2010; Songer & Gotwals, 2012; Zembal-Saul et al., 2012), as well as teachers (McNeill, 2009; Zangori, Forbes, & Biggers, 2013). For example, Sandoval (2003) found that while students were successful in creating explanatory claims related to beak shapes and natural selection leading to finch diversity, they struggled to provide evidence and reasoning to support those claims. Support for teachers, specific to this practice, could include the following: (1) instruction on what a scientific explanation is, including what constitutes sufficient evidence and reasoning to support the explanation (Sandoval & Millwood, 2005; Zembal-Saul et al., 2012); and (2) providing opportunities for students to discuss claims and evidence.

Curriculum materials are one method for supporting teachers' learning and instruction (Ball & Cohen, 1996), including—potentially—around science practices. Specifically, educative curriculum materials, which are intended to support teacher learning as well as student learning (Davis & Krajcik, 2005), can be used to support teachers' understanding and implementation of reform agendas. Only a few studies have characterized teachers' use of educative science curriculum materials (e.g., Beyer & Davis, 2009; Schneider & Krajcik, 2002), and studies rarely connect teachers' use to student outcomes. The central problem explored in this study focuses on how educative curriculum materials can support teachers' enactment of science instruction around the science practices, and how this influences student learning. The current study—a part of a larger study of educative curriculum materials—investigates whether there is evidence in student work of teachers' uptake of educative curriculum materials, particularly associated with science practices.

Theoretical Framework

Science educators seek new methods of supporting science instruction and student learning, particularly because some elementary teachers experience challenges when teaching science (Abell, 2007). Curriculum materials can be used as one conceptual tool (Brown, 2009). Curriculum materials can support teachers' productive lesson enactment (Lewis & Blunk, 2012), particularly for teachers who struggle with understanding the content and how to engage their students in the content (Hill & Charalambous, 2012). In particular, educative curriculum materials with explicit focus on teacher learning have shown possibility in influencing teaching and instruction (Beyer & Davis, 2009; Lin, Lieu, Chen, Huang, & Chang, 2012; McNeill, 2009; Schneider & Krajcik, 2002). For example, Lin et al. (2012) describe the possible connections between educative teachers' manuals and increased teacher and student understanding of the nature of science.

Teachers' Participatory Relationships With Curriculum Materials

As teachers work with curriculum materials, they engage in a participatory relationship with those materials; teachers influence the curriculum materials through their reading and interpretation of those materials and the curriculum materials influence teachers' instruction through the information they contain (Remillard, 1999, 2005). Factors, such as the teachers' content knowledge, pedagogical content knowledge, beliefs, and perspectives can influence this relationship (Biggers, Forbes, & Zangori, 2013; Charalambous & Hill, 2012; Remillard & Bryans, 2004; Remillard, 2005; Zangori et al., 2013). Likewise, the characteristics of the curriculum materials, including the types of features, voice, and style of the curriculum may influence this participatory relationship (Beyer & Davis, 2009; Brown, 2009; Forbes & Davis, 2010; Remillard, 2005; Stylianides, 2007). In this way, the curriculum materials can influence what Brown (2009) refers to as teachers' *pedagogical design capacity*, which is teachers' "ability to perceive and mobilize" the information in the curriculum materials during their enactment (Brown, 2009, p. 29).

Stein, Remillard, and Smith (2007) delineate among the different dimensions of curriculum use (see Figure 1). These include the *written* curriculum (e.g., a commercial teacher's guide), the *intended* curriculum (i.e., what the teacher plans to do), and the *enacted* curriculum (i.e., the teacher's practice). They identified connections among the different phases of curriculum use and student learning, as well as research surrounding those different phases. Figure 1 represents a variation of how they identified those connections.

Studies have focused on different aspects of the connections in Figure 1, which is inherently a simplified representation of a complex interaction. Some have studied the influence of "teacher-proof" curriculum materials on student learning (e.g., Senk & Thompson, 2003). These focus directly on the influence of the written curriculum on student learning, bypassing the involvement of the teacher (i.e., intended curriculum and enacted curriculum). Others have studied ways teachers develop the intended curriculum (e.g., Forbes & Davis, 2010; Remillard & Bryans, 2004), without necessarily connecting it to student learning. Still others have studied teachers' enactment of curriculum materials (e.g., Biggers et al., 2013; Brown, 2009; Zangori et al., 2013) with limited attention to student learning (e.g., Weiss & Pasley, 2004). However, there is little research that connects the written curriculum materials to teacher's enactment and even less that traces this through to student learning.

When considering how information from the written curriculum materials can influence student learning, it is critical to consider the role of the teacher (Remillard, 2000, 2005). This can be a challenge, since each teacher will read, interpret, and enact information from the written curriculum in different ways (e.g., Arias, Palincsar, & Davis, in press; Bismack, Arias, Davis, & Palincsar, 2014; Schneider & Krajcik, 2002). The close study of teachers' enactment often focuses on determining "fidelity of implementation" (O'Donnell, 2008), in which the assumption is that teachers should be enacting instruction "as prescribed" and the researcher seeks to document departures from the designed intervention. We bring a different motivation to our research; we are not interested in teachers' "fidelity" to the curriculum materials, but rather, in the ways that teachers purposefully choose to use and adapt curriculum materials for their own classrooms, knowing that any teacher will do so in unique ways. This is consistent with the perspective that teachers engage in a participatory relationship (Remillard, 2005) with the curriculum.

The Design of Our Educative Curriculum Materials

Based on the perspective that curriculum materials can be conceptual tools (Brown, 2009) and support productive reform in the classroom (Ball & Cohen, 1996), we have developed a set of

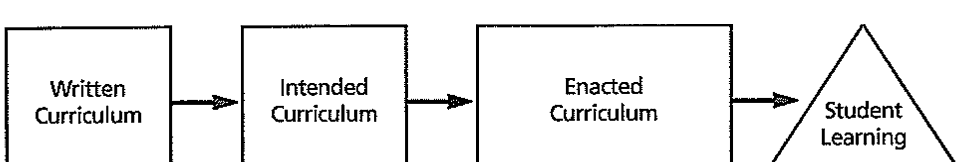


Figure 1. Temporal phases of curriculum use (modified from Stein et al., 2007)

educative curriculum materials with the intent of influencing teachers' enactment and thereby student learning (Davis & Krajcik, 2005). These educative curriculum materials were developed with the purpose of speaking *to* the teacher, rather than *through* the teacher (Remillard, 2000) in ways that may shape teachers' pedagogical design capacity (Brown, 2009).

We can use Sandoval's (2014) notion of conjecture mapping to delineate our thinking about our designs of these educative curriculum materials. Our *high-level conjecture* is that learning to engage students in the scientific practices of observing, predicting, and explaining requires the appropriation of knowledge and teaching moves that support those practices. We designed *tools* for teachers in the form of educative features. We anticipated being able to observe specific teaching practices and to analyze student work and teacher comments on that work, for evidence of the *mediating processes* that would allow the educative features to support the intended outcomes. Here, the *intended outcomes* would involve teachers supporting, and students engaging in, making high-quality observations, justifying their predictions, and supporting claims with evidence.

To embrace the challenges of studying the use of educative curriculum materials and testing these conjectures, the concept of "tracers" becomes an important lens in our research (Duncan & Frymier, 1967). Just as some doctors use tracers in the form of dyes to identify medical problems, Duncan and Frymier (1967) used tracers to identify how concepts within written curriculum materials are modified and used. The current study uses tracers purposefully built into educative curriculum materials as a way to identify connections among the written curriculum (which is enhanced by the addition of educative features), teachers' enactments, and the student work.

We use tracers in two ways. First, tracers serve as a design element for us; as we develop educative features for our curriculum materials, we incorporate unique characteristics, such as language or recommended teacher moves (described below) that teachers would encounter in the educative features but not in the rest of the curriculum materials. Including such design elements is the first step in letting us "trace" teachers' uptake of particular ideas from the educative features—recognizing full well that teachers will not adopt all of the ideas in the educative features, but rather will pick and choose from among options depending on their needs. Second, tracers serve as an analytic tool for us. After incorporating tracers into the design of the educative features, we then use the tracers to directly inform our coding schemes. We look for instances of the tracers in teachers' enactments and students' written work, as we describe below. Doing so, lets us take the second step in tracing teachers' uptake of particular ideas from the educative features. This decomposition helps us to analyze the *functions* of the design's components (Sandoval, 2014).

Our research investigating educative curriculum materials in elementary science explores these issues in the context of student work from two fourth-grade teachers' enactment of an enhanced Electric Circuits unit. By "enhanced," we mean high-quality commercial curriculum materials to which we added educative features for teachers (Davis et al., 2014). These educative features foregrounded science practices and content. The current study focuses on the educative features foregrounding science practices only.

The main research question for the study is as follows: To what extent does the student work reflect suggestions from the educative curriculum materials? Specifically, we asked:

- To what extent do students' drawn and written observations, written predictions, and evidence-based claims reflect the suggestions about quality included in the educative features?
- To what extent do teachers' comments on students' drawn and written observations, written predictions, and evidence-based claims reflect the suggestions about quality included in the educative features?

Returning to the Stein et al. (2007) model, we can envision tracers playing out throughout the process of teachers' curriculum use. Tracers, as design elements (e.g., characteristics of high-quality scientific observations), are embedded in educative features within the written curriculum. These design elements could, in turn, inform teachers' thinking about their plans, affecting the intended curriculum (typically not documented in writing). The enacted curriculum could be coded using tracers as analytic tools; here, evidence of the tracers could be visible in the teachers' enactments (e.g., through providing examples of the characteristics of high-quality observation). Finally, student work could be coded using tracers as analytic tools, and here, evidence of the tracers could be visible in the students' written work (e.g., labeled and accurate drawn observations). Using this process allows us to test our conjectures (Sandoval, 2014) about the mechanisms underlying the functionality of educative curriculum materials.

Methods

Participants

The current study is a qualitative case study (Merriam, 2009; Stake, 2000) of two teachers and their classrooms during a pilot study of the enhanced curriculum materials developed for the larger quasi-experimental study investigating teachers' and students' learning from educative curriculum materials (Davis et al., 2014).[1] The current study took place in the classrooms of the only two fourth-grade teachers, Ms. Chagall and Ms. Campbell, at Austin Elementary, in an urban-fringe school district in the Midwest (All proper names provided are pseudonyms). At Austin Elementary, 83% of students are eligible for free and reduced-cost lunch and the students' performance on the state standardized assessment tends to be low (greatschools.org). On all four state assessments, the students at Austin Elementary performed below the state average (see Table 1). Austin Elementary was chosen to participate in this study based on its need for resources and the two fourth-grade teachers were invited to participate, due to the content in the curriculum materials closely aligning with the fourth-grade Grade Level Content Expectations for the state of Michigan (Michigan Department of Education, 2009).

Ms. Chagall and Ms. Campbell had both been teaching for a number of years, but with varied experiences in fourth grade. Ms. Chagall taught for 18 years with the year of the current study being her first year teaching fourth grade (previously she taught in a self-contained sixth-grade classroom). Ms. Campbell taught for 9 years, with the year of the current study being her second year teaching fourth grade (previously she taught technology to students in grades K-8). Both teachers have minors in science and an education master's degree. Neither teacher regularly taught science and both mentioned that they were uncomfortable teaching science. Ms. Chagall mentioned that she had not taught physical science in many years. Ms. Campbell talked about feeling more confident with the curriculum materials since she taught a similar inquiry-based science unit during the previous year that also focused on scientific observations and predictions.

Table 1
Austin elementary student performance on state assessment

Fourth-Grade State Assessments	Student Proficiency (2012–2013)
Reading	45%
Writing	19%
Mathematics	4%
Science*	4%

*Assessment given in fifth grade.

In order to prepare for the unit, both teachers participated in two professional development sessions. The first session occurred prior to beginning the unit; in this session, the teachers worked through the first half of the lessons in the unit. These focused on connecting various simple circuits, lighting a household light bulb using many D-cell batteries, testing different items to determine if they are conductors or insulators, and creating a light bulb using wires, batteries, clay, and a nichrome wire for a filament. The second professional development session addressed the second half of unit. These lessons involved working with a diode, series and parallel circuits, designing and constructing a flashlight, and designing and wiring a cardboard house. During the professional development sessions, the teachers were directed toward the features of the curriculum materials. The teachers were not informed of which features were the educative features and which were not. While working through the lessons, the teachers were given brief overviews of the three science practices mentioned as they appeared throughout the lessons; however, these were not discussed in depth, as the main focus was on working through the activities in the lessons. The preponderance of the professional development focused on engaging in the activities in the lessons in order for the teachers to gain experience completing the different circuits and working through challenges their students might face.

Ms. Chagall had 25 students, with 23 students whose work we were able to use after obtaining parental IRB consent. Four students in her class had an Individualized Education Plan. Ms. Campbell had 25 students, with 20 students whose work we were able to use; however, we received student work from only 15 of those 20 students.

Curriculum Materials

Both teachers taught an enhanced version of the Science and Technology for Children (STC) *Electric Circuits* unit (NSRC, 2004). The STC *Electric Circuits* unit is a high-quality, kit-based curricular unit developed using National Science Foundation funding and was further enhanced by our research team to include features, throughout the unit overview and lessons, that were designed to be educative for teachers (see Figure S4 in the supplemental material for an example of an enhanced lesson). These educative features included enhanced supports for science practices and content already present in the original curriculum; as noted, this study focuses on those foregrounding science practices. The educative features foregrounding science practices were intended to support teachers' understanding of what the science practice is, the importance of students' engagement in the practice, and possible strategies for engaging students in the science practice (see Table 2; Davis & Krajcik, 2005). The science practices included in the educative features were chosen as a focus due to the kinds of work in which the students engaged in throughout the original STC *Electric Circuits* unit. For example, a lesson in the original curriculum materials may direct the teacher to have their students make predictions about whether a bulb will light or not based on the drawing of the circuit. However, the original curriculum materials do not clarify that the predictions should include both a claim as to what will happen *and* a justification supporting that claim. The call for the inclusion of a justification is an example of a tracer informing the design of our educative features (and, in our coding, as an analytic tool).

The design of the educative curriculum materials was both theoretically and empirically driven; we describe this design process in depth elsewhere (Davis et al., 2014), but recapitulate our key design decisions in this section. The choice of the type and content of the educative features was guided by previous work surrounding teachers' use of curriculum materials (e.g., Beyer & Davis, 2009; Davis & Krajcik, 2005; Schneider & Krajcik, 2002), as well as an empirical study of teachers' use of the original STC units without the added educative features (Bismack et al., 2014). We then made decisions as to where the various educative features would be embedded

Table 2
Description of educative features and their associated science practice

Educative Feature	Descriptions	Type of Science Practice Supported		
		Observations	Predictions	Evidence-Based Claims
Practice overview page	Included general characteristics of high-quality scientific observations, predictions, and evidence-based claims	X	X	X
In-lesson expository	Included characteristics of high-quality scientific observations, predictions, and evidence-based claims and how they could be incorporated in the specified lesson	X	X	X
Rubrics	Included the evaluation of and potential teacher's comments on a sample student's work regarding the characteristics of high-quality scientific observations or evidence-based claims	X		X
Narrative	Included a description of how a fictional teacher emphasized the use of scientific predictions and evidence-based claims within a given lesson		X	X
Reminder boxes	Included a symbol related to the practice and a quick reminder to the teacher to make sure students included all characteristics of quality for the specified science practice	X	X	X

within the lessons and unit, based on the science practices already highlighted in the original STC *Electric Circuits* unit.

The educative features incorporated within the lessons included two basic forms: expository and narrative (Beyer & Davis, 2009). The expository educative features provided either an overview of a particular science practice, or a description of the practice with regard to how it is used in an individual lesson. These were called Practice Overview pages (see Figure S1 for an example) and in-lesson expository supports, respectively.

The narrative educative features (see Figure S2 for an example) were descriptions of how a fictional teacher enacted the lesson and emphasized the use of a science practice within the given lesson. The account was based on the enactment of a pilot teacher during the first year of the study and on best practices identified by the researchers. The narratives foregrounded scientific predictions and evidence-based claims.

Other educative features included reminder boxes about science practices and rubrics guiding teachers' review of student work related to scientific observations, predictions, and evidence-based claims. The rubrics addressed students' written and drawn observations and students' evidence-based claims (see Figure S3 for an example).

Conjecture mapping (Sandoval, 2014) can inform thinking about our design. We identified tools that embody our design for supporting teachers in engaging students in making and recording scientific observations, predictions, and evidence-based claims. These tools include expository features (Practice Overview pages, in-lesson supports), narratives, reminders, and rubrics with sample student work and sample teacher comments. Within each educative feature, we included tracers (e.g., characteristics of high-quality scientific observations) that would allow us to identify evidence from the educative features (tools) in the student work and teacher comments on the student work (mediating processes) for teachers' use of the educative features to support students in engaging with the science practices (intended outcomes).

As we enhanced the curriculum materials with our educative features, we drew on our analysis of the original curriculum materials and our pilot data of teachers enacting the original curriculum materials, as well as interviews with those teachers and the student work from their classrooms, in determining what educative features to include and where to include them in the curriculum materials (see Davis et al., 2014). Our design was also informed, of course, by our theoretical commitments with regard to designing educative curriculum materials. In Davis and Krajcik (2005), for example, we outlined our hypotheses about how specific forms of educative features would promote specific learning processes such as adding ideas or integrating ideas within a teacher's repertoire. These hypotheses were later supplemented with our empirical work that bore out some of those hypotheses (e.g., Beyer & Davis, 2009). Thus, beyond the basic conjectures described above, we had reason to anticipate that:

- expository features, such as the Practice Overview pages, would help teachers add new and probably unfamiliar ideas about science practices, such as that predictions should be justified;
- narratives would help teachers add new specific teaching moves to support the practices, and these would be situated within specific lessons;
- rubrics would help teachers integrate ideas about practices in situated ways in thinking about student work.

In each case, we conjectured that we would see evidence of these functions in teachers' enacted practice, student work, and/or teacher comments on student work. Because of the complexities of human learning and of teaching, we anticipated seeing variation in how individual teachers would participate with and, thus, demonstrate uptake of the educative features.

To support engagement in high-quality scientific observations, a table at the bottom of the Practice Overview page (see Figure S1) indicated that the characteristics of high-quality observations include the following: clarity, completeness, accuracy, use of labels, and objectivity (Akerson & Donnelly, 2009; Arias et al., 2012; Eberbach & Crowley, 2009; Ford, 2005). These were also emphasized in the rubric at the end of Lesson 2, which included examples of students' drawn observations and characterized whether or not the student examples demonstrated characteristics of high-quality observations; the rubric also provided potential teacher's comments to the students (see Figure S3).

Characteristics of quality scientific predictions were supported in the Practice Overview page on predictions and in-lesson expository text (see Table 2) by explaining the parts of a scientific prediction and potential ways to support students' productive engagement in this science practice.

The main emphasis for the characteristics of quality predictions was that a prediction states both what will happen (here called a "claim") and a justification for that claim. It is this justification that distinguishes a prediction from a guess.

Characteristics of evidence-based claims were supported in the Practice Overview page on evidence-based claims, in-lesson expository text, and a rubric that explained the parts of an evidence-based claim and potential ways to support students in making evidence-based claims (see Table 2). The aspects of quality evidence-based claims were also included in "reminder boxes" urging teachers to support their students in this science practice.

Throughout our design process, one additional consideration that we took into account was a caution raised in Davis and Krajcik (2005) and elsewhere: there is a tension between providing needed support and overwhelming a teacher with too much support. Thus, within the parameters we have described thus far, we also made selections influenced by the length of the curriculum materials and the full set of forms of support we felt were needed. For example, while a lesson might have lent itself to two narratives, focused on two different scientific practices, we would make a choice about which to focus on in a given location.

The emphasis on science practices, including the descriptions of the characteristics of high-quality observations, predictions, and evidence-based claims and the suggestions for incorporating science practices, was found only in the educative features, not in the original curriculum materials. These descriptions and suggestions, then, were design elements serving as tracers. Thus, when we see evidence of effective engagement in the practices, we can reasonably attribute it to the teachers' uptake of the educative features, through using the tracers as analytic tools, in the ways described below (Arias, Bismack, Davis, & Palincsar, 2013; Duncan & Frymier, 1967).

Data Sources and Collection

The enhanced *Electric Circuits* unit was used as a data source, as described below. Student work was collected and analyzed for evidence of teachers' use of the educative features. The student work consisted of the following: (1) drawn observations; (2) written observations; (2) written predictions; (3) a few written evidence-based claims; and 4) other student artifacts (e.g., students' written statements about what they learned at the end of lessons, diagrams of design projects related to constructing a flashlight and wiring a cardboard house). Each student within each class had between 17 and 41 pages of student work with an average of 27 pages. In total, we had 631 pages of student work from Ms. Chagall's class and 411 pages of student work from Ms. Campbell's class. In addition, we interviewed each teacher using a semi-structured interview protocol (See Supplemental Artifact S5 for sample interview questions.). The teachers' enactment captured on video and the teachers' interview data were used to further validate the claims, as described below. The current study is complemented, in fact, by one focusing on the same two teachers' enactment; see Arias et al. (2013) for a detailed analysis of the teachers' enactment using the video data and teachers' interviews.

Thus, to answer our first research question, we relied primarily on the student work. To answer our second research question, we relied on the comments the teachers made on the student work. We used teacher enactment and interview data to provide context for the findings about how teacher uptake of the educative features was reflected in the student work.

Data Coding and Analysis

The data were coded in four incremental steps to look for evidence in the student work of teachers' use of the educative features. The first step focused on coding the enhanced *Electric Circuits* unit for instances when evidence of teachers' use of the educative features could potentially appear in the student work. These instances were referred to as "student work tracers" (Duncan & Frymier, 1967) and were coded as either "could appear in student work" or "could not appear in student work." Student work tracers included either part of an educative feature or the entire educative feature. For example, only part of the narrative included in Lesson 4 about predictions (see Figure S2) was identified as a student work tracer. The narrative described how a fictional teacher (Ms. Carter) engaged her students in prediction-making. One sentence in the narrative stated, "To begin the lesson, Ms. Carter displayed the standard (unlit) household light bulb for her students to see and asked them [to] write predictions in their notebooks as to the number of batteries they thought it would take to light the light bulb and why." This sentence was coded as "could appear in student work," since the teacher was prompted to have her students write in their notebooks about predictions. This varied from the original curriculum materials, where teachers were not prompted to have their students write their predictions with justifications. Other educative features were coded in their entirety as a student work tracer (e.g., a chart included in Lesson 11 about differences between series and parallel circuits).

The second coding step involved two parts: (1) identifying, within the student work, the opportunities students had to make drawn and written observations, written predictions, and written evidence-based claims; and (2) coding the student work for the quality of their recorded observations, predictions, and evidence-based claims. The characteristics of high-quality observations, predictions, and evidence-based claims—as described in the following paragraphs—were only found in the educative features and were emphasized in the teachers' enactments in varying ways (see Arias et al., 2013), thus, serving as design elements that could work as tracers. There were nine lessons identified in the student work that included drawn observations, eight that included written observations, two that included scientific predictions, and two that included evidence-based claims. Of the lessons identified as opportunities students had to engage in the three science practices, only a few were sampled across the unit and coded for quality of the identified science practice. We coded the lessons that had a majority of the respective science practices appearing in the student work; our choices were also informed by the location of the lesson within the unit. For example, we only coded students' drawn observations in Lessons 2, 5, and 8 because a number of students had completed those drawn observations and they represented lessons at the beginning, middle, and end of the portion of the unit focusing on scientific observations.

The students' drawn scientific observations were coded for quality, based on the characteristics of high-quality observations identified as student work tracers in the educative features (see Figure S1). These characteristics and associated codes were based on Arias et al. (2012) work focusing on student observations, which were in turn modified from the literature (e.g., Beyer & Davis, 2006; Eberbach & Crowley, 2009). Drawn observations were coded as *clear, complete, accurate, labeled*, and including *scientific vocabulary* (see Table 3). The drawn observations were coded by one researcher with a second researcher coding 10% of the students' drawn observations for each class. The inter-rater reliability was 93% agreement for both classes with discrepancies resolved through discussion.

The students' written observations were also coded for quality. Again drawing on prior work (Arias et al., 2012; Eberbach & Crowley, 2009), the codes for written observations included clear, complete, accurate, objective, and including scientific vocabulary. Written observations were coded as *excellent, good*, or *needs improvement* along each dimension (see Table 4). The written observations were coded by one researcher with a second researcher coding 10% of the students' written observations for each class. The inter-rater reliability was 88% and discrepancies were resolved through discussion.

Table 3
Codebook for students' drawn observations. Addressing research question: To what extent do students' drawn observations reflect the suggestions about quality included in the educative features?

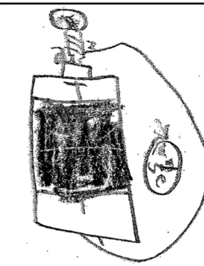
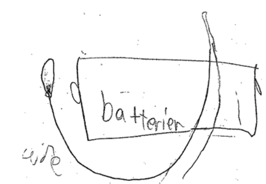
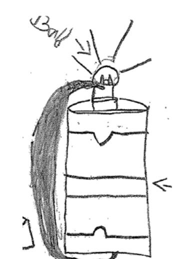
Code	Description	Example
Clear	Observation looks to be related to what they should be observing	
Complete	All parts of circuit are included in the observation (i.e., battery, wire, bulb—Lesson 2)	
Accurate	Setup of the circuit is correct and the wire is connected appropriately	
Labeled	Student labels the parts of their circuit	Lesson 2—Student labeled the battery, bulb, wire, and compass
Scientific vocabulary	Student uses scientific language for their labels	Student labels "wire"—instead of "cord"

Table 4
Codebook for written observations. Addressing research question: To what extent do students' written observations reflect the suggestions about quality included in the educative features?

Codes	Description: Excellent	Good	Needs Improvement
Clear	Observation is coherent and all items in the observation are clearly explained (e.g., *There was smoke flying in the air when I knew the light bulb lit*.)	The written observation is legible, but the description of the items or what happened is missing details (e.g., *The compass was wiggleing relly fast*)	The written observation is not clear (e.g., *one of my observation were using and ? the clay*)
Complete	The written observation includes all parts of the circuit and any other items included in the investigation (i.e., compass) (e.g., *We have made our own lightbulb by using clay and a nichrome wire and. . .we hooked the wires to the batterys and the clay felt squishy*.)	The written observation includes most parts of the circuit, but not all (e.g., *We put the 2 batterys next to each other*.)	The written observation does not include any part of the circuit (NOTE: All students included at least some parts of the circuit in their written observations.)
Accurate	The written observation describes what happened in the investigation. If it includes the setup of the circuit, it should also include the specific connections in the circuit (e.g., *The wire connects to the side of the metal part of the light bulb and the bottom of the light bulb touches the battery*.)	The written observation describes what happens in the investigation and generally explains the connections in the circuit. It does not necessarily explain every connection (e.g., *The bulb was on one end of the battery and the wire touched the other end of the battery and the bulb.*)	The written observation inaccurately describes the circuit or what happened (e.g., *You can make a light bulb with playdo.*)
Objective	The written observation is objective and not subjective (e.g., *There was smoke flying in the air when I knew the light bulb lit*.)	The written observation includes portions that are objective and portions that are subjective statements (e.g., *I nocited that the wire turn orange yellow orange and red and got hoter and hoter*.)	The written observation is subjective (e.g., *First it did not work then we keep triying and tring and it stell did not work*)
Scientific vocabulary	The written observation uses all scientific vocabulary (i.e., battery, bulb, wire—not cord)	The written observation includes some scientific vocabulary and some common words for items in the circuit (i.e., cord instead of wire)	The written observation does not use any scientific vocabulary.

The students' scientific predictions were coded for quality, based on the description of high-quality predictions included as student work tracers in the educative features. Because the educative features emphasize that a prediction includes a claim about what will happen supported by a justification, the codes focus on the "claim" about what the student thinks will happen—whether it is *present* and whether it is *reasonable*—as well as the *justification* for the claim—whether it is *present, aligned with the claim*, and *logical*. Only predictions from Ms. Chagall's students were coded.[2] Ms. Chagall encouraged her students to include a justification with their predictions, as emphasized in the educative features (Arias et al., 2013). The written predictions from Ms. Chagall's class were coded by one researcher with a second researcher coding 10% of the students' written predictions. The inter-rater reliability was 96% with discrepancies resolved through discussion.

Because there were few opportunities for students to write evidence-based claims, these were only analyzed for descriptive purposes to help characterize the students' work with regard to evidence of the teacher' use of the educative features related to evidence-based claims.

The third step involved coding the teacher's comments on the student work. Only Ms. Chagall made comments regarding students' observations and predictions.[3] Neither teacher made comments on students' evidence-based claims. Ms. Chagall's comments were coded using the same coding schemes as were used for the student work; the comments were coded as referring to (or not) a characteristic of high-quality scientific observations or predictions, as supported by the educative features. One researcher coded the teacher's comments and a second researcher coded 10% of the comments for each of the science practices with 95% inter-rater reliability. Discrepancies were resolved through discussion.

Thus, throughout the coding of the student work and the teachers' comments on the student work, we used the tracers as analytic tools to guide our coding. This allowed us to infer the aspects of the educative features teachers seemed to "take up," and hence characterize their participatory relationship with the curriculum materials.

The teachers' interviews were coded with respect to their evaluation of the usefulness and purpose of the educative features. The interviews were initially coded for mention of the types of educative features (e.g., narrative, overview page, rubric). These instances were then open coded for the following: (1) how helpful the teacher reported the educative feature to be; (2) the ways the teachers used the educative feature to support their planning and instruction; and (3) how the teacher described the student work in relation to the science practices in the educative features. When coding about the teachers' views of helpfulness, the codes were *helpful, somewhat helpful,* and *not helpful*. Samples of codes regarding the teachers' view of use of the educative features included *envisioning the activity or lesson, anticipating problems,* and *assessing students' learning*. When coding the teachers' responses related to the science practices in the student work, they were first coded for the type of science practice and then the comment about the student work. Sample codes included the following: *high quality characteristic, definition of scientific practice*, and *supporting students' writing*. For example, in Ms. Chagall's first interview, she explained that if a student did not include "the why" with their written scientific predictions, then it would just be a "good, fun guess"—which was coded as *defining the scientific practice* when referencing student work. The findings from coding and analyzing the teachers' interviews were then used to support claims (based on student work) regarding how the teachers took up ideas within the educative features.

The teachers' enactment was also coded using similar codes to the student work tracers. These were used to triangulate the data in order to support the claims surrounding teachers' uptake of the ideas in the educative features and to provide context about the enactments. See Arias et al. (2013) for the codebook used.

Results

Based on evidence in the student work, we found that both teachers used many of the educative features, but in differing ways. We also found that students were able to engage in making scientific observations and predictions. The teacher comments on the students' drawn and written observations and written predictions mentioned characteristics of quality scientific observations and predictions, as highlighted in the educative features. The students tended to struggle with writing quality evidence-based claims. In the next section, we provide an overview of our findings. In subsequent sections, we explore these findings in more depth.

Instances of Teacher Uptake of Educative Features: An Overview

We analyzed the enhanced STC *Electric Circuits* unit to identify student work tracers. Then, we analyzed the student work, to check for evidence of those tracers (see Table 5). Presence of a student work tracer meant the following: (1) the teacher may have discussed some concepts only found in the educative features with their students, allowing the concepts to appear in the student work; or (2) the teacher gave the educative feature directly to the students. The student work in Ms. Chagall's class revealed 17 out of a possible 29 student work tracers that appeared in the student artifacts, compared with 16 out of 29 student work tracers present in the student artifacts in Ms. Campbell's class, as shown in Table 5.

An example of a student work tracer is the reminder box in Lesson 5, which reminded the teacher that predictions need a justification that supports a claim. When coding the student work for Ms. Chagall's class, we found that the students had written their predictions with justifications so this lesson was coded as showing evidence in the student work of the student work tracer. This was supported in Ms. Chagall's enactment, in which she directed her students to write initial and revised predictions with justifications in two class periods. However, in Ms. Campbell's class students did not write predictions with justifications, so no code for evidence of the student work tracer was given.

In some instances, the teachers directly used aspects of the educative feature, or, in fact, the entire educative feature with their students. For example, Ms. Campbell used the exact wording from the prompt included on the rubric in Lesson 11 about the differences between series and parallel circuits. She had her students write evidence-based claims answering this prompt.

In summary, we saw consistent evidence in the student work that the teachers took up some of the suggestions in the educative features based on the presence of student work tracers. The teachers' enactment also showed that they regularly used educative features (Arias et al., 2013). The following sections elaborate on this overview.

Ways Students' Drawn Observations Reflect Teacher Uptake of Educative Features

During Ms. Chagall's and Ms. Campbell's enactments, they discussed the characteristics of high-quality observations with their students—clear, complete, accurate, labeled, and inclusion of scientific vocabulary—in more than six lessons. These characteristics were *only* emphasized in the educative features, which also included suggestions—such as "modeling how to make an observation" (see Figure S1)—of how to help students make and record observations. These educative features included the following: a Practice Overview page, in-lesson expository text, rubric, and reminder boxes (see Table 2). The teachers regularly reminded their students to label their drawings and to completely and accurately document their observations. Ms. Campbell discussed these qualities when modeling for her students how to draw a scientific observation, as suggested in the Practice Overview page. Ms. Chagall included these characteristics when

Table 5
Evidence in student work of teacher uptake of educative features

Educative Feature	Student Work Tracers	Evidence in Student Work: Ms. Chagall's Class	Evidence in Student Work: Ms. Campbell's Class
Scientific observations			
Overview page	*Lesson 2*: Characteristics of high-quality scientific observations	X	X
In-lesson expository	*Lesson 2*: Characteristics of high-quality scientific observations	X	X
Reminder box	*Lesson 7*: Characteristics of high-quality scientific observations		
Rubric	*Lesson 2*: Characteristics of high-quality drawn scientific observations	X	X
Scientific predictions			
Narrative	*Lesson 4*: Predictions with Justification	X	X**
	Lesson 4: Revised Predictions	X	
Overview page	*Lesson 3*: Predictions with Justification		
In-lesson expository	*Lesson 3*: Predictions with Justification		
	Lesson 3: Revised Predictions		
Reminder box	*Lesson 4*: Predictions with Justification	X	X**
	Lesson 5: Predictions with Justification	X	
	Lesson 7: Predictions with Justification		
Evidence-based claims			
Narrative	*Lesson 8*: Evidence-based claim of energy transformation		X**
	Lesson 11: Evidence-based claim of differences: series & parallel circuits	X**	X**
	Lesson 11: Use of Chart	X	X
	Lesson 16: Evidence-based claim of parallel circuit		
Overview Page	*Lesson 5*: Evidence-based claim of complete circuit		
In-lesson expository	*Lesson 5*: Evidence-based claim of complete circuit		
Reminder box	*Lesson 5*: Evidence-based claim of complete circuit		
	Lesson 8: Evidence-based claim of energy transformation		
Rubric	*Lesson 11*: Evidence-based claim of differences: series & parallel circuits		X*

(*Continued*)

Educative Feature	Student Work Tracers	Evidence in Student Work: Ms. Chagall's Class	Evidence in Student Work: Ms. Campbell's Class
Other educative features			
Narrative	*Lesson 1*: Written KWL	X	X
	Lesson 6: Written ideas of troubleshooting	X	X
	Lesson 13: Use of flashlight presentation rubric	X	X*
	Lesson 16: Use of cardboard house presentation rubric	X	X*
Reminder box	*Lesson 14*: Addition of diode symbol to worksheet	X	
	Lesson 16: Use of cardboard house presentation rubric	X	X*
Rubric	*Lesson 13*: Use of flashlight presentation rubric	X	X*
	Lesson 16: Use of cardboard house presentation rubric	X	X*

*The teachers' enactment coded in the video recordings and observation notes (see Arias et al., 2013) shows that Ms. Campbell used these rubrics. However, they were not found in the student folders.

**Only a few students had these in their work, so they were not coded for quality during the second round of coding.

commenting on her students' drawn and written observations (see Tables 7 and 9). During Ms. Chagall's interview, she commented on how she saw a student "making his [observation] really creative. . .and [she] said, 'You know, is that exactly what you see?. . .it has to be as you see it'" (Chagall, Interview 2, 94–98). She emphasized the need for the student's observation to be accurate, which was one of the characteristics of high-quality observations highlighted in the educative features stating that "observations should include only what is actually seen" (see Figure S1).

The students' drawn observations reflected characteristics of high-quality observations as stressed in the educative features. The lessons sampled to code students' drawn observations were Lessons 2, 5, and 8 for both classes with the total number of drawn observations for Ms. Chagall's class and Ms. Campbell's class being 54 and 70, respectively.[4]

Overall, the coding indicated that students from both classes were judged to have made high-quality observation (see Table 6). Most of the drawn observations in Ms. Chagall's class were clear and labeled using scientific vocabulary. Students struggled with the accuracy of their drawn observations, particularly when drawing the wire connections in the circuit. The completeness of their drawn observations also declined across the three lessons. One consideration is that the number of materials (e.g., battery, bulb, wire) included in the complete circuit increased as the lessons progressed. For example, in Lesson 2 there were four materials, in Lesson 5 there were six materials, and in Lesson 8 there were 10 materials that the students used while investigating the circuits.

The students' drawn observations in Ms. Campbell's class also were of high quality. They tended to be clear and complete, even with the large numbers of materials in the later lessons. Students appeared to struggle more with including labels in their drawn observations (see Table 6); however, this could have been due to Ms. Campbell's directions for drawing observations during Lesson 2. She directed them to draw observations of the setup of circuits where the bulb lit, did not light, and of a short circuit with a compass—and to make sure to "label the top" of the drawn observation to identify which circuit they were drawing. She did not distinguish between this form of "labeling" and labeling the parts of a drawn observation. The latter is the form of labeling that is suggested in the educative features regarding high-quality observations. The students also struggled to draw accurate observations.

In sum, students in both classes tended to draw observations that reflected some characteristics of high-quality observations that were described in the educative features. Across both classes, students struggled most with making their drawn observations accurately represent the phenomena being observed. Yet, overall, the drawn observations reflected many of the characteristics emphasized in the educative features, reflecting substantive uptake by the teachers of the ideas presented in the educative features.

Table 6
Quality of students' drawn observations in Ms. Chagall's and Ms. Campbell's classes

	Ms. Chagall ($n = 54$)	Ms. Campbell ($n = 70$)
Clear	53 (98%)	66 (94%)
Complete	46 (85%)	61 (87%)
Accurate	39 (72%)	49 (70%)
Labeled	50 (93%)	36 (51%)
Scientific vocabulary	50 (93%)	35 (50%)

Ways Teacher Comments on Drawn Observations Reflect Uptake of Educative Features

Ms. Chagall made 147 comments on students' drawn observations and—of those comments—46% related to at least one characteristic of high-quality observations (Recall that Ms. Campbell did not comment on student work.). In the educative features (see Table 2), teachers were informed of the characteristics of high-quality observations in the Practice Overview Page (see Figure S1 and previous discussion) and suggested teacher comments on student work in the Rubric (see Figure S3). For example, the Rubric for Drawn Observations included sample teacher comments about the completeness and accuracy of an observation stating, "This drawing is missing the wire. Try this circuit again and see if you can figure out where the wire goes" (see Figure S3). Ms. Chagall tended to comment on similar qualities of students' drawn observations; in particular, the completeness, accuracy, and labeling of students' drawn observations (see Table 7). For example, she wrote, "Is this how it was laid out? Where is the bulb? The wire? Please fix," which addresses both the completeness (i.e., lack of bulb and wire) and accuracy (i.e., questioning how the circuit was laid out) (Work from Student 21, Ms. Chagall's Class, p. 6). In interviews, Ms. Chagall commented on using the rubrics as a guide to how to evaluate and comment on the student work, "The information from the other teacher, student drawings, and comments—teacher comments. That helped so when you can kind of say, 'Oh, I can model my comments sort of on this but a little bit different depending on what your kids were doing'" (Chagall, Interview 3, 902–918).

Of the other comments Ms. Chagall wrote on students' drawn observations, 13% involved telling students to draw another observation and 7% involved telling students to write an observation. Overall, many of Ms. Chagall's comments on the students' drawn observations reflected likely uptake of the characteristics of high-quality observations only presented in the educative features.

Ways Students' Written Observations Reflect Teacher Uptake of Educative Features

Overall, students' written observations tended to reflect some characteristics of high-quality observations. The sample lessons in which students' written observations were coded included Lessons 2 and 8 for Ms. Chagall's class and Lessons 2 and 5 for Ms. Campbell's class with the total number of written observations being 59 and 57, respectively. In Ms. Campbell's class for Lesson 2, each student wrote more than one observation.

Students' written observations in Ms. Chagall's class tended to reflect characteristics of high-quality observations, though some characteristics were better represented than others (see Table 8). These characteristics were mentioned across several educative features (see Table 2), but were described in more depth in the Practice Overview page (see Figure S1) and in-lesson expository supports for observations. For example, the Practice Overview page for scientific observations says that "[objective observations] should not state an opinion. Another person should be able to look at the object of interest and make the same observation. An objective statement is 'the mustard seed is one millimeter across.' A less objective statement is 'the seed is

Table 7
Ms. Chagall's comments related to quality of students' drawn observations (n = 67)

Clear	5 (8%)
Complete	18 (27%)
Accurate	23 (34%)
Labeled	24 (36%)
Scientific vocabulary	2 (3%)

Table 8
Quality of students' written observations in Ms. Chagall's class (n = 59) and Ms. Campbell's class (n = 57)

	Excellent		Good		Needs Improvement	
	Ms. Chagall (*n* = 59)	Ms. Campbell (*n* = 57)	Ms. Chagall (*n* = 59)	Ms. Campbell (*n* = 57)	Ms. Chagall (*n* = 59)	Ms. Campbell (*n* = 57)
Clear	18 (31%)	10 (18%)	38 (64%)	39 (68%)	3 (5%)	8 (14%)
Complete	22 (37%)	17 (30%	37 (63%)	36 (63%)	0 (0%)	4 (7%)
Accurate	15 (25%)	12 (21%)	36 (61%)	34 (60%)	8 (14%)	11 (19%)
Objective	24 (41%)	38 (67%)	34 (58%)	15 (26%)	1 (2%)	4 (7%)
Scientific vocabulary	48 (81%)	47 (82%)	10 (17%)	6 (11%)	1 (2%)	4 (7%)

Note: n refers to the total number of written observations.

really small'" (see Figure S1). Ms. Chagall mentioned, during her interviews, that she used the Practice Overview page, though not as often as other supports. Students' written observations were generally objective, though sometimes students would include a subjective statement with their observation. For example one student wrote:

> This time we used two batterys & clay with our compus [compass]. When my partner & I made it up. We had a problem we had to change one positive side. When we fixed our problem & our night crom [nichrome wire] lite up it was so amazing. The clay, battery & the wire made a complete circuit. The battery flow to the night crown [nichrome wire].

This student's written observation was considered "good" because most of the statements were objective, except the portion referring to the nichrome wire lighting up as "amazing." Students struggled most with writing accurate scientific observations, which involved being descriptive about the connections and set up of the circuit.

The written observations from students in Ms. Campbell's class tended to also reflect characteristics of high-quality observations, although to varying levels (see Table 8). Similar to Ms. Chagall's students, Ms. Campbell's students demonstrated more difficulty writing accurate scientific observations, particularly when describing the connections in their circuits. These students also had difficulty writing clear statements, which involved clearly identifying all parts of their observation, instead of referring to "it." They tended to write observations that were objective, particularly during Lesson 2, although this was not as apparent in Lesson 5.

Overall, the students' written observations tended to include at least some representation of the characteristics of high-quality observations, potentially reflecting teachers' uptake of the ideas that were only described in the educative features. The quality of the writing in the observations was consistent with the relatively low scores on the state standardized tests. Overall, though, these findings demonstrate elementary students' capability for recording drawn and written, high-quality, scientific observations.

Ways Teachers' Comments on Written Observations Reflect Uptake of Educative Features

Ms. Chagall wrote many comments on students' written observations ($n = 83$) with only 32% of them referencing at least one characteristic of high-quality observations (see Table 9). This differs from almost half of the comments on the students' drawn observations relating to

Table 9
Ms. Chagall's comments related to quality of students' written observations (n = 26)

Clear	9 (35%)
Complete	8 (31%)
Accurate	10 (39%)
Objective	0 (0%)
Scientific vocabulary	1 (4%)

characteristics of high-quality observations, discussed above. (As with the drawn observations, Ms. Campbell did not comment on the student work for written observations.) On the students' written observations, Ms. Chagall commented about the clarity and accuracy more than any other characteristic. For example, she wrote, "Scientists are specific—wire, bulb, battery, etc. Not thing and it" (Work from Student 9, Ms. Chagall's Class, p. 4) and "Is it really the 'clay' that makes the light bulb?" (Work from Student 11, Ms. Chagall's Class, p. 9), respectively.

Though the characteristics of high-quality scientific observations were described in the Practice Overview page and in-lesson expository text for observations, they were also emphasized in the rubric discussed above, which included sample teacher comments of students' drawn observations (see Figure S3). For example, one sample teacher comment from the rubric states, "This drawing has all of the pieces, but I cannot determine which part is which and where the connections are. Can you draw the connections more clearly and label the parts of your drawing?" (Figure S3). Ms. Chagall commented that she used the rubrics; however, she did so to understand the quality she should expect from her students generally, rather than to assess or provide comments on individual work.

Ms. Chagall also wrote 56 other comments unrelated to high-quality observations, of which 23% directed students to include the investigation question in their written statements, 18% involved reminding students to draw an observation, and 21% included suggesting to students to write another observation. Though she was not referencing the characteristics of high-quality scientific observations, she was still supporting her students in engaging in the "doing" of science by recording observations and including the investigation question. Overall, some of Ms. Chagall's comments on the students' written observations referenced the characteristics of high-quality observations, which reflects some potential uptake of the ideas in the educative features.

Ways Students' Written Predictions Reflect Teacher Uptake of Educative Features

During Ms. Chagall and Ms. Campbell's enactments, they both engaged their students in the practice of making scientific predictions; however, only Ms. Chagall emphasized the need to justify predictions. She did this in four class periods. The characteristics of high-quality predictions, which emphasize the need for a justification, are only mentioned in the educative features, specifically the Practice Overview page, in-lesson expository text, narrative, and reminder boxes (see Table 2). For example, the Practice Overview page states, "Predictions require reasoning based on previous observations or experiences." Ms. Chagall mentioned, during an interview, that predictions should always include support, "because if you just make a prediction and you don't have the why, it's kind of not really a prediction at all. It's just kind of like a good, fun guess" (Chagall, Interview 1, 650–652). She also mentioned the usefulness of various educative features, specifically the narratives, which provided strong support for engaging students in making scientific predictions (Chagall, Interview 3). Ms. Campbell, on the other hand, stated she did not find some of the educative features, particularly the narratives, very helpful (Campbell, Interview 1, 612–613)

Ms. Chagall's students were prompted to write predictions in Lessons 4 and 5 only, which were the two lessons analyzed.[5] In Lesson 4, students were prompted to answer the question, "How many batteries do you think it would take to light a household light bulb? And why?" (Chagall Video, Lesson 4) and 22 students did so. This was similar to the narrative educative feature in Lesson 4 that states that the fictional teacher, Ms. Carter, "asked [her students] to write predictions in their notebooks as to the number of batteries they thought it would take to light the bulb and why" (Figure S2). In Lesson 5, there were many more predictions, due to students being given a worksheet with six different images of setups for a circuit with one battery, one bulb, and one wire. They were to write a prediction for each, as to whether or not the bulb would light and why (Chagall Video, Lesson 5). Since each student wrote more than one prediction, there were a total of 69 predictions for Lesson 5, yielding a total of 91 predictions across the two lessons.

Students' written predictions in Ms. Chagall's class reflected characteristics of high-quality scientific predictions (see Table 10), which may have represented Ms. Chagall's uptake of the ideas emphasized in many educative features foregrounding scientific predictions. Ms. Chagall's students included reasonable claims and logical justifications for their predictions. For example, "I predict that 2 batterys can light a big bulb because if one battery can light one little bulb then 2 batteryes can light one big bulb" (Work from Student 4, Lesson 4, Chagall). Many students, as represented in this example, drew on their prior experience to justify their claims—a quality frequently mentioned in the educative features.

Ways Teachers' Comments on Written Predictions Reflect Uptake of Educative Features

Ms. Chagall wrote many comments on the students' written predictions ($n = 86$). Of her comments on the predictions, 21% referenced characteristics of quality scientific predictions that were based on descriptions of scientific predictions in the educative features. Among those, she reminded students to include a justification with their prediction much more than any other characteristic (see Table 11). This was similar to the fictional teacher, Ms. Carter, in the narrative who "looked through [her students'] written ideas, checking on students' understanding of the concepts, as well as their use of reasons to support their new predictions" (see Figure S2). In one comment, Ms. Chagall reminded students to include a claim with their prediction and in two comments she referenced the relevance of the claims to the investigation. Ms. Chagall commented during an interview about what she liked about the narrative educative features related to predictions, "Well, you got this teacher, this Miss Carter. And. . .it gives me an idea how I can work things in. Like about predictions or whatever. . .There was one where it talked about her—what she was doing with her kids and I thought, 'Oh yeah.' . . .Well it was sort of like, okay, there's a teacher who did this. She may be fictional, but that's okay" (Chagall, Interview 1, 1013–1020). Ms. Chagall's comments during the interviews and her emphasis on providing a justification for a prediction seems to be evidence of uptake from the educative features, since the curriculum materials otherwise did not emphasize this.

Table 10
Quality of students' written predictions in Ms. Chagall's class (n = 91)

Claim is present	85 (93%)
Claim is reasonable	80 (88%)
Justification is present	78 (86%)
Justification is aligned with claim	76 (84%)
Justification is logical	66 (73%)

Table 11
Ms. Chagall's comments related to quality of students' predictions (n = 18)

Claim is present	1 (6%)
Claim is reasonable	2 (11%)
Justification is present	14 (78%)
Justification is aligned with claim	0 (0%)
Justification is logical	0 (0%)

Ways Students' Evidence-Based Claims Reflect Lack of Uptake of Educative Features

Throughout the unit, neither Ms. Chagall nor Ms. Campbell regularly prompted their students to write evidence-based claims (Arias et al., 2013). Ms. Chagall did use the words "claim" and "evidence" during her enactments, but she did not explain to her students what they meant and did not directly engage her students in the practice of making evidence-based claims. During an interview after the unit ended, she also expressed uncertainty regarding how to make and engage her students in this practice (Chagall, Interview 3). It follows that there were limited numbers of evidence-based claims in the student work. Across two lessons, there were only 16 evidence-based claims written in Ms. Chagall's class and only 16 in Ms. Campbell's class.

Students' evidence-based claims included some of the characteristics of high-quality evidence-based claims, but not many, reflecting the teachers' lack of uptake of the educative features foregrounding evidence-based claims. In both classes, students almost always included a claim, but struggled with answering all parts of the investigation questions (completeness) and fully relating the claim to the investigation question. For example, in the second part of Lesson 11, Ms. Campbell prompted her students to answer the question (verbatim from the rubric educative feature (Arias et al., 2013)), "What is the difference between circuits when the batteries are in series and when batteries are in parallel?" (Lesson 11 Rubric, Enhanced STC Curriculum, p. 9). A sample answer from a student was, "The difference between the two circuits is the brightness and set up. The series circuit is brighter because 2 batteries working together means more electricity" (Work from Student 20, Ms. Campbell's Class, May 5, 2012). This student provided a strong claim that was accurate and complete; that is, the student mentioned brightness and setup, but did not provide evidence that was fully sufficient by failing to reference parallel circuits. This represents a relatively strong evidence-based claim found in the student work. Of the written evidence-based claims, few provided evidence at all (eight out of 32 total evidence-based claims). Students also tended to struggle with making *complete* claims and *sufficient* evidence to support their claims. Again, similar to the lack of clarity of the written observations, this was consistent with the students' difficulties with writing, in general.

Summary of Results

Overall, the teachers seemed to take up some aspects of the educative features, as evidenced by the presence of student work tracers within the students' drawn and written science practices, as well as the presence of some full educative features in the student work. The whole educative features used directly with students included a chart and the rubrics. The student work also tended to include high-quality drawn and written observations and predictions, as emphasized only in the educative features. The students struggled with making accurate drawn scientific observations and writing accurate and clear written scientific observations. In their written predictions, the students included reasonable claims and logical justifications. In contrast, there were few evidence-based claims in the student work and those that were included tended to lack evidence and complete claims. This, along with teacher's comments during interviews, shows that the teachers did not take up the ideas from the educative features foregrounding evidence-based claims. Ms. Chagall provided many comments on the students' observations and predictions with some referencing characteristics of high-quality scientific observations and predictions that were only described in the educative features.

Discussion

With the new reforms in science education (ACARA, 2013; NGSS Lead States, 2013; NRC, 2012; United Kingdom Department for Education, 2014), many in the science education community are searching for new ways to support teachers. The current study demonstrates how educative curriculum materials can be used as one tool (Ball & Cohen, 1996; Brown, 2009; Davis & Krajcik, 2005) to support teachers' learning and science instruction that incorporates the science practices outlined in those reforms.

Ms. Chagall and Ms. Campbell engaged in a participatory relationship with the educative curriculum materials (Remillard, 2005). The ideas only presented in the educative features (e.g., characteristics of high-quality scientific observations, the need for a justification with predictions) seem to have influenced the teachers' instruction and their use of the educative features with their students (Beyer & Davis, 2009; Brown, 2009; Forbes & Davis, 2010; Remillard, 2005; Stylianides, 2007). Similarly, the teachers' beliefs and perceptions may have influenced how they read and interpreted the ideas in the educative features (Charalambous & Hill, 2012; Remillard & Bryans, 2004). For example, Ms. Campbell did not find the educative features particularly helpful, possibly due to her general comfort teaching science and using inquiry-based science curriculum materials, and we saw less uptake of some ideas from the educative features in Ms. Campbell's class. The current study thus begins to connect the dots in how written curriculum materials can influence the intended and enacted curriculum, which, in turn, affects student learning.

We used tracers (Duncan & Frymier, 1967) as design elements within the educative features and analytic tools during the analysis of the educative features and student work. This allowed us to follow from the educative features through to the student work, in order to assess the teachers' possible uptake of the ideas presented in the educative features. As a result, we were able to test our design conjectures about how educative curriculum materials can promote teacher learning and thus change in classrooms (Sandoval, 2014). In order to be responsive to teachers' varying relationships with curriculum materials (Charalambous & Hill, 2012; Davis et al., 2014; Remillard, 2005; Remillard & Bryans, 2004; Zangori et al., 2013) the educative features were designed to support each of the science practices in different ways (Davis et al., 2014). We included expository features to support teachers' general understanding and use of the science practices throughout their teaching practice, as compared to narratives, which were intended to serve as lesson-specific guides for how teachers may incorporate the practices into and adapt their lessons (Beyer & Davis, 2009). Rubrics are embedded in teachers' practice (Ball & Cohen, 1999) and, in our materials, were intended to provide the teacher with an illustration of how students have engaged with the science practices in other classrooms, as well as how a teacher may comment on student work.

Our findings indicated that the student work showed evidence of teachers' uptake of the rubrics and narratives much more than the other forms of support; directly situated in teachers' practice, these educative features seemed most powerful in helping teachers adopt new ideas that could directly impact their practice. The expository features (most notably, the Practice Overview pages), intended mainly to help teachers add new, somewhat more abstract ideas about the nature of the scientific practice, appeared less salient for teachers. That said, *each* of the educative features served a unique purpose in our design; *each* was constructed to include student work tracers for the purpose of studying their impact on the mediating processes evident in the teachers' practice, student work, and teachers' comments on the student work; and we saw evidence of teachers taking up *each* type of educative feature in the students' work.

We turn next to an exploration of how these educative features were useful in supporting teachers and students in each of the science practices of focus in this study.

Nature of the Educative Features and Their Uptake by Teachers: Observations

Making and recording high-quality scientific observations can be a complex science practice due to the disciplinary knowledge necessary to productively engage in the practice (Akerson & Donnelly, 2009; Eberbach & Crowley, 2009; Ford, 2005). This science practice, however, seems to be relatively straightforward to incorporate into the science instruction when teachers are given support for what the practice is and how to engage their students in making and recording scientific observations (Arias et al., 2012; Davis & Krajcik, 2005). There were four types of educative features designed to foreground scientific observations (a Practice Overview page, in-lesson expository text, reminder boxes, and a rubric), which were provided across two lessons. We expected that the teachers would take up the ideas from the educative features foregrounding scientific observations. Indeed, some uptake was apparent from Ms. Chagall's comments relating to the characteristics of high-quality scientific observations and the students' productive engagement with this practice in both classes. The finding that only one teacher commented, fairly extensively, on the student work aligns with the literature that suggests that teachers vary in how they use curriculum materials (Bismack et al., 2014; Charalambous & Hill, 2012; Remillard & Bryans, 2004; Zangori et al., 2013) and in some classrooms, reform agendas are not taken up as expected or hoped, due to the realities of classroom contexts (Kennedy, 1997, 2004).

In comparison, we were surprised by both teachers' use of the rubric, and a chart about series and parallel circuits, directly with their students. We know that rubrics are deeply situated in teachers' practice (Ball & Cohen, 1999) and we intended to use this common tool to support teachers' understanding of how to assess and respond to students' scientific observations and evidence-based claims. Though the rubrics were designed to support the teachers' understanding, both Ms. Chagall and Ms. Campbell chose to use the rubric for drawn scientific observations directly with their students—an unexpected, yet productive, adaptation. We speculate that, since rubrics are often used directly with students to guide and assess their work, the teachers used the rubric in a way that reflects their typical teaching practice. Based on these findings, we would recommend that educative curriculum materials foregrounding scientific observations be designed as pedagogical tools that not only support teachers' understanding of what the practice entails, why students should make and record observations, and how to engage their students in this science practice, but can also be used and adapted by teachers in their instruction.

Nature of the Educative Features and Their Uptake by Teachers: Predictions

Four educative features (narrative, a Practice Overview page, in-lesson expository text, and reminder boxes) located in four different lessons emphasized the need for a prediction to include a reasonable claim with an aligned, logical justification supporting that claim. This science practice is important in that it can serve as an entrée into scientific argumentation (Arias et al., 2014; Duschl & Osborne, 2002) and should be supported as such. However, scientific prediction-making can be challenging because it requires justifying a claim (McNeill & Krajcik, 2007; Sandoval & Millwood, 2005) and differs from predictions in language arts disciplines, which are common in elementary classrooms (Casteel & Isom, 1994). For these reasons, and the need to support elementary teachers' and students' engagement with scientific predictions, the educative features were purposefully designed to include both expository and narrative educative features due to research indicating that teachers use these features differently (Beyer & Davis, 2009).

Our findings supported those from Beyer and Davis (2009) in that Ms. Chagall expressed how useful she found the educative features, particularly the narrative foregrounding scientific predictions. Ms. Chagall mentioned during an interview that she, "just read what [Ms. Carter—fictional teacher] did and then [she] would tweak it for [herself]" (Chagall, Interview 3, 134–140). Also, Ms. Chagall's comments on the student work frequently referenced the need for a justification with the predictions, which was mentioned in a variety of educative features including the narratives. Ms. Campbell, on the other hand, did not find the educative features very helpful, which supports Smylie's (1995) findings that some teachers choose to dismiss information if they do not see its relevance. For example, Ms. Campbell mentioned in an interview that the narratives were, "a little extra help, but. . .at the same time, you can do the lesson without them" (Campbell, Interview 2 630–638). Ms. Campbell also expressed more comfort with the topic of electric circuits and had taught a similar inquiry-based science unit the previous year, thereby potentially increasing her comfort level with the unit and decreasing her reliance on the curriculum materials. Ms. Chagall, on the other hand, had expressed initial concerns with teaching physical science; this may explain why she demonstrated more potential uptake of the educative features and expressed more positive reactions to them.

Though Lee and Butler (2003) found that early middle school students are capable of making scientific predictions, the current study emphasizes *elementary* students' capabilities with justifying scientific predictions. Unexpectedly, the students struggled most with providing logical, aligned justifications and Ms. Chagall never commented on the student work regarding the need for justifications to be logical and aligned. It is possible that the need for a justification with a claim when writing a scientific prediction varies in itself from the common "best guess" emphasis in typical elementary science classrooms. A focus on justifying high-quality predictions may need to be further supported in the educative features including the possible addition of sample student written predictions—in the form of a rubric—highlighting each of the characteristics of high-quality predictions (as was useful for Ms. Chagall with the scientific practice of observation, discussed above). As for Ms. Campbell, it is difficult to determine her uptake of the ideas in the educative features foregrounding scientific predictions. Her students drew their predictions (which were not coded due to the difficulty in distinguishing these from the observations) and she did not comment on any student work—most likely due to her many responsibilities in the school (Kennedy 1997, 2004).

Based on how Ms. Chagall took up the characteristics of high-quality scientific predictions and how she engaged her students in this important science practice, we recommend that educative features foregrounding scientific predictions frequently and explicitly emphasize the characteristics of a justification that would support a high-quality scientific prediction.

Nature of the Educative Features and Their Uptake by Teachers: Evidence-Based Claims

When considering the complexity of constructing scientific explanations (Braaten & Windschitl, 2011) and the challenges students and teachers face when engaging in making and recording evidence-based claims (McNeill, 2009, 2011; McNeill & Krajcik, 2007, 2009; Ruiz-Primo et al., 2010; Songer & Gotwals, 2012; Zangori et al., 2013; Zembal-Saul et al., 2012), it was important that the design of the educative features include thorough and regular supports for teachers in what the practice is, why students should make evidence-based claims, and how to support students in such a complex science practice (Davis et al., 2014; Davis & Krajcik, 2005). There were five types of educative features foregrounding evidence-based claims that were extended across four lessons. Though making evidence-based claims was supported in the educative features more than any other science practice, the teachers took up this practice much less, as evidenced by the limited attention to this practice during their enactments (Arias et al., 2013) as well as the presence of few evidence-based claims in the student work. However, we did not anticipate *how* little the teachers, and therefore the students, would take up the characteristics of high-quality evidence-based claims. Though Ms. Campbell did use a prompt from the educative features to guide her students in writing evidence-based claims, her students wrote few evidence-based claims. The students particularly struggled with including evidence for their claims, which is consistent with other work documenting the increased difficulty of gathering relevant, sufficient evidence for evidence-based claims compared to just the claim itself (Gotwals & Songer, 2013; Sandoval, 2003). When students did include evidence, it was often not sufficient to support the claim. In contrast, Ms. Chagall did not have her students write any evidence-based claims and did not directly discuss this science practice with her students (Arias et al., 2013). She also mentioned, during her interviews, her uncertainty with this science practice in comparison to observation and prediction.

Due to the importance of evidence-based claims (Osborne et al., 2004; Zembal-Saul et al., 2012), the limited attention and take up from the educative features by the teachers, the struggles of the students, and how atypical this practice is in American schools, further research is needed to understand how educative curriculum materials can better support teachers' and students' engagement with evidence-based claims. Curriculum materials can be used as a tool to support teachers' learning and instruction (Ball & Cohen, 1996; Brown, 2009; Davis & Krajcik, 2005), but they may need to be coupled with effective, ongoing professional development in order to develop ambitious, productive science instruction (e.g., Collopy, 2003; NRC, 2007, 2012; Schneider, Krajcik, & Blumenfeld, 2005).

Implications and Conclusion

The current study holds implications for curriculum developers and professional development designers who seek to identify further ways to support teachers' science instruction that reflects the integration of science practices (NRC, 2012). Curriculum designers can use the information about how educative curriculum materials are used by teachers to inform the development of curriculum materials that can better support teachers' understanding and enactment of reform-oriented science instruction that foregrounds science practices. Particularly, the curriculum materials should include the following: (1) what the science practice is; (2) rationales for why teachers should engage their students in the science practices; and (3) suggestions for how to engage students in that practice, including characteristics of high-quality engagement in the practice (Davis & Krajcik, 2005). Furthermore, a preponderance of the educative features should be directly situated in the teachers' practice. This last point implies the need for extensive pilot work that can generate the substance for such educative features; our narratives and rubrics were developed out of such pilot work (Davis et al., 2014), and this gave credibility to the sample student work and recommended teaching practices embedded in the educative features.

Science educators are searching for ways of supporting teachers in understanding and incorporating science reforms in their instruction, with the intent of improving student learning. Curriculum materials are one method of influencing teachers' practice (Ball & Cohen, 1996) and educative curriculum materials (Davis & Krajcik, 2005; Schneider & Krajcik, 2002), more specifically, can be used to support teachers' understanding and integration of science practices, disciplinary core ideas, and crosscutting concepts in their science instruction. The current study has identified teachers' use of educative features found in educative curriculum materials and thus begins to fill the gap in the literature with regard to how the written curriculum, intended curriculum, and enacted curriculum can affect student learning (Stein et al., 2007). Though the current study is only one step, it suggests the potential that educative curriculum materials hold for supporting teachers to include science practices in their science instruction—and thus influence students' opportunities to learn.

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Endnotes

[1]The quasi-experimental study involved studying 50 teachers who were divided into comparison and treatment groups where the comparison group taught the original STC curriculum materials and the treatment group taught the enhanced STC curriculum materials. Teachers and students both took pre- and post-assessments regarding their understanding of science practices and content. There was also a small subset of teachers who participated in case studies of their teaching practices and uses of the educative curriculum materials. The current study focuses on a pilot study conducted prior to the larger quasi-experimental study.

[2]Ms. Campbell had her students draw predictions instead of write them. These were difficult to distinguish from drawn observations, so they were not coded. Ms. Campbell also did not encourage her students to justify their predictions (Arias et al., 2013).

[3]Due to time constraints—as Ms. Campbell mentioned during her interviews—writing comments on the students' work was not a regular part of her teaching practice. The rubrics in the educative features, which provided sample teacher comments on student work, were used by Ms. Campbell as tools to inform her students of what to include in their work, but not for writing her own comments.

[4]Ms. Campbell's students each drew two or three observations for Lesson 2, which is why the number of drawn observations is so much higher than the total number of students.

[5]Ms. Campbell prompted the students to draw predictions in Lesson 4 only. However, these were not coded, due to the difficulty in distinguishing the drawn predictions from the drawn observations.

References

Abell, S. (2007). Research on science teacher knowledge. In S. Abell & N. Lederman (Eds.), Handbook of research on science education (pp. 1105–1149). Mahwah, NJ: Lawrence Erlbaum Associates.

Akerson, V., & Donnelly, L. A. (2009). Teaching nature of science to K-2 students: What understandings can they attain? International Journal of Science Education, 32(1), 97–124.

Arias, A. M., Bismack, A. S., Davis, E. A., & Palincsar, A. S. (2013). Finding evidence in the enactment: Elementary science teachers' use of educative curriculum materials. Unpublished paper presented at 2013 National Association for Research in Science Teaching Annual International Conference, Rio Grande, Puerto Rico.

Arias, A. M., Davis, E. A., & Palincsar, A. S. (2012). Supporting elementary students in makind and recording scientific observations. Unpublished paper presented at 2012 National Association for Research in Science Teaching Annual International Conference, Indianapolis, IN.

Arias, A. M., Palincsar, A. S., & Davis, E. A. (2014). Using educative curriculum materials to support teachers in engaging students to justify predictions. In J. Polman, E. Kyza, K. O'Neill, I. Tabak, W. Penuel, S. Jurow, K. O'Connor, T. Lee & L. D'Amico (Eds.), The international conference of the learning sciences 2014 (Vol. 3, pp. 1429–1431). Boulder, CO: Inernational Society of the Learning Sciences.

Arias, A. M., Palincsar, A. S., & Davis, E. A. (in press). The design and use of educative curricular supports for text-based discussions in science. To appear in Journal of Education.

Australian Curriculum, Assessment and Reporting Authority (ACARA). (2013). Australian curriculum: Science. Retrieved from http://www.australiancurriculum.edu.au.

Ball, D. L., & Cohen, D. K. (1996). Reform by the book: What is - Or might be - The role of curriculum materials in teacher learning and instructional reforms? Educational Researcher, 25(9), 6–8, 14.

Ball, D., & Cohen, D. (1999). Toward a practice-based theory of professional education. Teaching as the learning profession. San Francisco: Jossey-Bass.

Beyer, C. I., & Davis, E. A. (2006). Characterizing the quality of second graders' observations and explanations to inform the design of educative curriculum materials. In Proceedings of the 7th international conference on Learning sciences (pp. 43–49). International Society of the Learning Sciences.

Beyer, C. J., & Davis, E. A. (2009). Using educative curriculum materials to support preservice elementary teacher's curricular planning: A comparison between two different forms of support. Curriculum Inquiry, 39(5), 679–703.

Biggers, M., Forbes, C. T., & Zangori, L. (2013). Elementary teachers' curriculum design and pedagogical reasoning for supporting students' comparison and evaluation of evidence-based explanations. The Elementary Science Journal, 114(1), 48–72.

Bismack, A. M., Arias, A. M., Davis, E. A., & Palincsar, A. S. (2014). Connecting curriculum materials and teachers: Elementary science teachers' enactment of a reform-based curricular unit. Journal of Science Teacher Education, 25(4), 489–512.

Braaten, M., & Windschitl, M. (2011). Working toward a stronger conceptualization of scientific explanation for science education. Science Education, 95(4), 639–669.

Brown, M. (2009). Toward a theory of curriculum design and use: Understanding the teacher-tool relationship. In J. Remillard, B. Herbel-Eisenman & G. Lloyd (Eds.), Mathematics teachers at work: Connecting curriculum materials and classroom instruction (pp. 17–37). New York: Routledge.

Casteel, C. P., & Isom, B. (1994). Reciprocal processes in science and literacy learning. The Reading Teacher, 47(7), 538–545.

Charalambous, C. Y., & Hill, H. C. (2012). Teacher knowledge, curriculum materials, and quality of instruction: Unpacking a complex relationship. Journal of Curriculum Studies, 44(4), 443–466.

Collopy, R. (2003). Curriculum materials as a professional development tool: How a mathematics textbook affected two teachers' learning. The Elementary School Journal, 103(3), 227–311.

Davis, E. A., & Krajcik, J. S. (2005). Designing Educative Curriculum Materials to Promote Teacher Learning. Educational Researcher, 34(3), 3–14.

Davis, E. A., Palincsar, A. S., Arias, A. M., Bismack, A. S., Marulis, L., & Iwashyna, S. (2014). Designing educative curriculum materials: A theoretically and empirically driven process. Harvard Educational Review, 84(1), 24–53.

Duncan, J. K., & Frymier, J. R. (1967). Explorations in the systemic study of curriculum. Theory into Practice, 6(4), 180–199.

Duschl, R. A., & Osborne, J. (2002). Supporting and promoting argumentation discourse in science education. Studies in Science Education, 38(1), 39–72.

Eberbach, C., & Crowley, K. (2009). From everyday to scientific observation: How children learn to observe the biologist's world. Review of Educational Research, 79(1), 39–68.

Ford, D. J. (2005). The challenges of observing geologically: Third graders' descriptions of rock and mineral properties. Science Education, 89(2), 276–295.

Forbes, C. T., & Davis, E. A. (2010). Curriculum design for inquiry: Preservice elementary teachers' mobilization and adaptation of science curriculum materials. Journal of Research in Science Teaching, 47(7), 820–839.

Gilbert, J. K., & Boulter, C. J. (1998). Learning science through models and modelling. International handbook of science education, 2, 53–66.

Gotwals, A. W., & Songer, N. B. (2013). Validity evidence for learning progression-based assessment items that fuse core disciplinary ideas and science practices. Journal of Research in Science Teaching, 50(5), 597–626.

GreatSchools, Inc. (1998–2015). [Austin Elementary]. Retrieved from [website].

Hill, H. C., & Charalambous, C. Y. (2012). Teacher knowledge, curriculum materials, and quality of instruction: Lessons learned and open issues. Journal of Curriculum Studies, 44(4), 559–576.

Justi, R., & van Driel, J. (2005). The development of science teachers' knowledge on models and modelling: Promoting, characterizing, and understanding the process. International Journal of Science Education, 27(5), 549–573.

Justi, R., & van Driel, J. (2006). The use of the Interconnected Model of Teacher Professional Growth for understanding the development of science teachers' knowledge on models and modelling. Teaching and Teacher Education, 22, 437–450.

Kennedy, M. M. (1997). The connection between research and practice. Educational Researcher, 26(7), 4–12.

Kennedy, M. M. (2004). Reform ideals and teachers' practical intentions. Education Policy Analysis Archives, 12(13), 13.

Lee, H., & Butler, N. (2003). Making authentic science accessible to students. International Journal of Science Education, 25(8), 923–948.

Lewis, J. M., & Blunk, M. L. (2012). Reading between the lines: Teaching linear algebra. Journal of Curriculum Studies, 44(4), 515–536.

Lin, S. F., Lieu, S. C., Chen, S., Huang, M. T., & Chang, W. H. (2012). Affording explicit-reflective science teaching by using an educative teachers' guide. International Journal of Science Education, 34(7), 999–1026.

McNeill, K., & Krajcik, J. (2009). Synergy between teacher practices and curricular scaffolds to support students in using domain-specific and domain general knowledge in writing arguments to explain phenomena. Journal of the Learning Sciences, 18(3), 416–460.

McNeill, K. (2009). Teachers' use of curriculum to support students in writing scientific arguments to explain phenomena. Science Education, 93(2), 233–268.

McNeill, K. (2011). Elementary students' views of explanation, argumentation, and evidence, and their abilities to construct arguments over the school year. Journal of Research in Science Teaching, 48(7), 793–823.

Merriam, S. B. (2009). Qualitative research: A guide to design and implementation. San Francisco, CA: Jossey-Bass.

Metz, K. E. (2008). Narrowing the gulf between the practices of science and the elementary school science classroom. The Elementary School Journal, 109(2), 138–161.

Michigan Department of Education. (2009). Science grade level content expectations. Lansing, MI: Michigan Department of Education.

National Research Council. (2000). How people learn: Brain, mind, experience, and school: Expanded edition. Washington, DC: The National Academies Press.

National Research Council. (2007). Taking science to school: Learning and teaching science in grades K-8. Washington, DC: The National Academies Press.

National Research Council. (2012). A framework for K-12 science education: Practices, crosscutting concepts, and core ideas. Washington, DC: The National Academies Press.

National Science Resources Center. (2004). Science technology and children electric circuits (Second ed.). Burlington, NC: Carolina Biological Supply Company.

NGSS Lead States. (2013). Next generation science standards: For states, by states. Washington, DC: The National Academies Press.

O'Donnell, C. L. (2008). Defining, conceptualizing, and measuring fidelity of implementation and its relationship to outcomes in k-12 curriculum intervention research. Review of Educational Research, 78(1), 33–84.

Osborne, J., Erduran, S., & Simon, S. (2004). Enhancing the quality of argumentation in school science. Journal of Research in Science Teaching, 41(10), 994–1020.

Remillard, J. T., & Bryans, M. B. (2004). Teachers' orientations toward mathematics curriculum materials: Implications for teacher learning. Journal of Research in Mathematics Education, 35(5), 352–388.

Remillard, J. T. (1999). Curriculum materials in mathematics education reform: A framework for examining teachers' curriculum development. Curriculum Inquiry, 29(3), 315–342.

Remillard, J. T. (2000). Can curriculum materials support teachers' learning? Two fourth-grade teachers' use of a new mathematics text. The Elementary School Journal, 100(4), 331–350.

Remillard, J. T. (2005). Examining key concepts in research on teachers' use of mathematics curricula. Review of Educational Research, 75(2), 211–246.

Ruiz-Primo, M. A., Li, M., Tsai, S. P., & Schneider, J. (2010). Testing one premise of scientific literacy in classrooms: Examining students' scientific explanations and student learning. Journal of Research in Science Teaching, 47(5), 583–608.

Sandoval, W. A., & Millwood, K. A. (2005). The quality of students' use of evidence in written scientific explanations. Cognition and Instruction, 23(1), 23–55.

Sandoval, W. A. (2003). Conceptual and epistemic aspects of students' scientific explanations. The Journal of the Learning Sciences, 12(1), 5–51.

Sandoval, W. A. (2014). Conjecture mapping: An approach to systematic educational design research. Journal of the Learning Sciences, 23(1), 18–36.

Schneider, R. M., & Krajcik, J. (2002). Supporting science teacher learning: The role of educative curriculum materials. Journal of Science Teacher Education, 13(3), 221–245.

Senk, S. L. & Thompson, D. R. (Eds.), Standards-based school mathematics curricula: What are they? What do students learn? Mahway, NJ: Erlbaum.

Simon, S., Erduran, S., & Osborne, J. (2006). Learning to teach argumentation: Research and development in the science classroom. International Journal of Science Education, 28(2–3), 235–260.

Songer, N. B., & Gotwals, A. W. (2012). Guiding explanation construction by children at the entry points of learning progressions. Journal of Research in Science Teaching, 49(2), 141–165.

Stake, R. E. (2000). Case studies. In Handbook of qualitative research. Thousand Oaks: Sage Publications, Inc.

Stein, M. K., Remillard, J., & Smith, M. (2007). How curriculum influences student learning. In F. K. Lester (Ed.), Second handbook of research on mathematics teaching and learning (pp. 319–369). Greenwich, CT: Information Age Publishing.

Stylianides, G. J. (2007). Investigating the guidance offered to teachers in curriculum materials: The case of proof in mathematics. International Journal of Science and Mathematics Education, 6, 191–215.

Tomkins, S. P., & Tunnicliffe, S. D. (2001). Looking for ideas: Observation, interpretation and hypothesis-making by 12-year-old pupils undertaking science investigations. International Journal of Science Education, 23(8), 791–813.

United Kingdom Department for Education. (2014). National curriculum in England: science programmes of study (Publication No. DFE- 00182–2013. London, England: Crown Publishing.

Weiss, I. R., & Pasley, J. D. (2004). What is high quality instruction? Educational Leadership, 61(5), 24–28.

Zangori, L., Forbes, C. T., & Biggers, M. (2013). Fostering student sense making in elementary science learning environments: Elementary teachers' use of science curriculum materials to promote explanation construction. Journal of Research in Science Teaching, 50(8), 989–1017.

Zembal-Saul, C. L., McNeill, K. L., & Hershberger, K. (2012). What is your evidence? Engaging K-5 children in constructing explanations in science. Boston, MA: Pearson.

Supporting Information

Additional Supporting Information may be found in the online version of this article.