International Journal of Science Education

ISSN: 0950-0693 (Print) 1464-5289 (Online) Journal homepage: http://www.tandfonline.com/loi/tsed20

Teachers' use of educative curriculum materials to engage students in science practices

Anna Maria Arias, Elizabeth A. Davis, John-Carlos Marino, Sylvie M. Kademian & Annemarie Sullivan Palincsar

To cite this article: Anna Maria Arias, Elizabeth A. Davis, John-Carlos Marino, Sylvie M. Kademian & Annemarie Sullivan Palincsar (2016): Teachers' use of educative curriculum materials to engage students in science practices, International Journal of Science Education, DOI: 10.1080/09500693.2016.1198059

To link to this article: http://dx.doi.org/10.1080/09500693.2016.1198059

Published online: 17 Jun 2016.

INTERNATIONAL JOURNAL OF SCIENCE EDUCATION, 2016
http://dx.doi.org/10.1080/09500693.2016.1198059

Routledge
Taylor & Francis Group

Teachers' use of educative curriculum materials to engage students in science practices

Anna Maria Arias[a], Elizabeth A. Davis[b], John-Carlos Marino[b], Sylvie M. Kademian[b] and Annemarie Sullivan Palincsar[b]

[a]College of Education, Illinois State University, Normal, IL, USA; [b]School of Education, University of Michigan, Ann Arbor, MI, USA

ABSTRACT

New reform documents underscore the importance of integrating science practices into the learning of science. This integration requires sophisticated teaching that does not often happen. Educative curriculum materials – materials explicitly designed to support teacher and student learning – have been posited as a way to support teachers to achieve these ambitious goals, yet little is known about how elementary teachers actually use educative curriculum materials to support student engagement in science practices. To address this gap, this study investigated how five upper elementary teachers supported students to engage in science practices during an enactment of two curriculum units. Three of the teachers had units enhanced with educative features, informed by current research and reforms, while two of the teachers had units without these features. The teachers varied in how they supported students in the science practices of justifying predictions, constructing evidence-based claims, recording observations, and planning investigations. For example, some of the teachers with the educative features supported students in constructing evidence-based claims and justifying predictions in ways called for by the educative features. Implications for curriculum developers and teacher educators are discussed based on the patterns found in the teachers' use of the educative curriculum materials.

ARTICLE HISTORY
Received 31 August 2015
Accepted 1 June 2016

KEYWORDS
Curriculum development; elementary school science; science teachers

Introduction

New science education reforms make engaging students in science practices a goal of science learning. By science practices, we mean practices that scientists engage in during their work such as asking questions and constructing explanations (National Research Council [NRC], 2012). Elementary or primary students can engage in these science practices (Metz, 2004), yet this engagement is complex and does not happen often (Appleton, 2007; Banilower et al., 2013) because it requires more ambitious science teaching than that which regularly occurs. Educative curriculum materials, materials developed to support both teacher and student learning, have been proposed

CONTACT Anna Maria Arias aarias4@ilstu.edu College of Education, Illinois State University, Campus Box 5330, Normal, IL 61790-5300, USA

to support this ambitious teaching (Davis & Krajcik, 2005). Research suggests that educative curriculum materials can facilitate science teachers' learning and lead to changes in their teaching practices (Cervetti, Kulikowich, & Bravo, 2014; McNeill, 2009; Schneider & Krajcik, 2002); however, this research focuses on science instruction in general or on a single science practice. Little is known about how curriculum materials can support teachers to engage their students in multiple science practices.

This paper helps to redress this gap by reporting how upper elementary teachers drew on curriculum materials to engage their students (typically nine years of age) across multiple science practices. We added educative features to existing kit-based science units focused on ecosystems and electric circuits. To support teachers' learning and teaching practice, these features proposed a set of instructional strategies including specific teaching moves and language to engage students in science practices. This paper considers how teachers used the suggested teaching moves and language. We ask, 'How might curriculum materials support teachers to engage students in science practice integrated with science content?' Specifically, we ask,

> In what ways were teachers' use of teaching moves and language, suggested by the educative features to engage students in science practices, similar and different between the teachers with and without the educative features? How were they similar and different across the various science practices?

Supporting elementary students in science practices

New reforms, globally, outline science practices that are important for science learning (e.g. Australian Curriculum, Assessment and Reporting Authority [ACARA], 2013; NRC, 2012; United Kingdom Department for Education, 2014). Engagement in these science practices supports students' deeper understanding of the science content and the processes of science (NRC, 2007, 2012). Moreover, these science practices connect closely to the literacy and mathematics practices called for in similar reforms (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010a, 2010b). In this paper, we focus on four science practices: recording scientific observations, constructing evidence-based claims, making predictions with justification, and designing investigations. These science practices are aspects of the larger science practices of conducting investigations, scientific argumentation, and constructing explanations as included in the Next Generation Science Standards (NGSS; NGSS Lead States, 2013).

Young students are capable of engaging in the science practices of recording scientific observations, constructing evidence-based claims, making predictions with justification, and designing investigations (Herrenkohl, Palincsar, DeWater, & Kawasaki, 1999; Metz, 2004; Tomkins & Tunnicliffe, 2001). However, students also face many challenges when engaging in these science practices. For example, without deep disciplinary knowledge, children may struggle to record salient aspects of a phenomenon when making observations (Eberbach & Crowley, 2009; Garcia-Mila & Andersen, 2007). Justifying arguments, explanations, or predictions with evidence or reasoning is also difficult for most novices (Kuhn, 1989; Lee & Songer, 2003). Given these struggles, elementary students require teacher guidance.

Several studies have described guidance and tools that can support student engagement in science practices (e.g. Bell, 2000; Erduran, Simon, & Osborne, 2004). However, supporting science learning requires an extensive repertoire of knowledge and teaching practices (Abell, 2007; NRC, 2007). Given that new reforms ask teachers to use methods unfamiliar from their experiences as elementary learners (Lortie, 1975), elementary teachers who teach across subjects face many challenges in providing this support in science (Appleton, 2007). For example, elementary teachers may struggle to know the science content or how to engage in science practices themselves or may perceive themselves as not well prepared to teach science (Abell, 2007; Appleton, 2007; Banilower et al., 2013), making it difficult for them to support their students in this work.

The role of curriculum materials in supporting teachers

Teachers' interactions with curriculum materials have been suggested as a site for supporting teacher learning and facilitating change in teaching practice, which could, in turn, create new learning opportunities for students. Curriculum materials can play an important role in shaping teachers' instruction and knowledge (Arzi & White, 2008; Nowicki, Sullivan-Watts, Shim, Young, & Pockalny, 2013). For example, use of kit-based science units increased teachers' presentation of accurate science content (Nowicki et al., 2013). However, how different teachers use curriculum materials varies, resulting in varied student learning opportunities (McNeill, 2009; Roehrig & Garrow, 2007). Teachers' knowledge, experience, orientations, and context influence how teachers instruct students using curriculum materials (e.g. Biggers, Forbes, & Zangori, 2013; Charalambous & Hill, 2012; Remillard, 2005).

To support the interaction of teachers with curriculum materials, Ball and Cohen (1996) proposed using educative curriculum materials with explicit focus on teacher learning along with student learning. Researchers suggest that certain characteristics of curriculum materials might support teacher learning (Arias, Bismack, Davis, & Palincsar, 2015; Beyer & Davis, 2009; Davis & Krajcik, 2005; Stylianides, 2007). For example, Beyer and Davis (2009) found that vignettes describing an elementary teacher's teaching and rationale for her choices supported preservice teachers to envision the possibilities for a science lesson and include more reformed-based science teaching in their lesson plans. Similarly, in-service teachers stated that reading similar vignettes encouraged them to give students more opportunities to engage in science investigations themselves (Arias et al., 2015). Educative curriculum materials can influence science teaching, and thus student learning, across multiple settings (Cervetti et al., 2014; Lin, Lieu, Chen, Huang, & Chang, 2012; McNeill, 2009; Schneider & Krajcik, 2002). For example, educative curriculum materials facilitated teachers in supporting English-language learners in a science-literacy integrated unit, positively influencing the students' learning (Cervetti et al., 2014). The current study extends this research by considering how educative curriculum materials might support elementary teachers to integrate *multiple* science practices with content.

Theoretical framework

We define science learning as co-constructing the meaning of science content and practices, which occurs through the support of others (e.g. teachers) and tools within a particular context (Vygotsky, 1978). Learning to engage in science practices involves 'knowing how and why' to engage in a practice *and* 'doing the work' involved in the practice (NRC, 2012). To support the knowing and doing, a teacher can scaffold students' engagement in science practices with increasing level of complexity over time (Berland & McNeill, 2010). Tools such as sentence stems, charts for observations, and physical resources may enable students to do this work with increasing independence (e.g. McNeill, 2009; Tomkins & Tunnicliffe, 2001). Teaching moves such as discussing why to engage in a practice, modeling how to do so, and showing connections among science practices can support knowledge development of the science practices (Herrenkohl et al., 1999; McNeill, 2009; McNeill & Krajcik, 2009; Metz, 2004; NRC, 2007).

Tools such as curriculum materials offer the possibility of supporting teachers to facilitate student learning (Brown, 2009). Drawing on Remillard's (2005) framework, we view this work as a participatory relationship in which the teacher and curriculum materials interact to support the design and enactment of a lesson. This framework recognizes the resources and perspectives that the teacher brings to the participatory relationship including their pedagogical content knowledge, subject matter knowledge, orientations towards the discipline, and knowledge of their students (Abell, 2007; Shulman, 1986). The curriculum materials have certain features and voice that also influence the teacher-curriculum relationship (Enfield, Smith, & Grueber, 2008; Herbel-Eisenmann, 2007). This relationship offers opportunities for teacher learning as she or he designs a planned curriculum with the text and enacts the curriculum within a particular context (Remillard, 2005). We are especially interested in how a specific type of curricular resource – educative features that focus on science practices – are used by teachers and how these features might support changes in teachers' subject matter knowledge, pedagogical content knowledge, and teaching practice.

Methods

This study uses a qualitative case study approach (Miles & Huberman, 1994; Stake, 2000) to consider how five upper elementary classrooms teachers supported students in science practices during two science units. Three teachers were provided an enhanced curriculum with educative features and two teachers had the original curriculum materials. These case studies were a subset of a large-scale, quasi-experimental study to test the effects of the enhanced curriculum materials on teacher learning, teacher practice, and student learning (Davis et al., 2014).

Design of the educative features

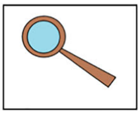
The curriculum materials included kit-based, inquiry-oriented units for electric circuits (National Science Resources Center, 2004b) and ecosystems (National Science Resources Center, 2004a). The electric circuits unit involved investigations including how complete circuits work, the transfer of electric energy into light and heat energy, the role of conductors and insulators in the flow of electric current, and the differences between series and parallel circuits. The ecosystems unit included two investigations: one investigated the relationships and interactions within a small-scale ecosystem (i.e. an aquarium/terrarium) and the other investigated the effects of pollution on a small-scale ecosystem. We enhanced these units with educative features to promote teacher and student learning. To design these supports, we drew on empirical research (e.g. Cervetti et al., 2014; Metz, 2004), reform documents (NRC, 2007, 2012), and our pilot studies of teachers using these units (Davis et al., 2014). In this design process, we left the goals, objectives, and procedures of the lessons the same and added educative features to the existing lessons to support teacher learning.

We designed several types of educative features to support teacher learning and teaching. Several of the features foregrounded the work of engaging students in science practices. The *practice overviews,* specific to each practice, described the science practice, provided a rationale for teaching it, and gave possible teaching moves applicable across multiple lessons (Figure 1). Targeted, lesson-specific *in-lesson how and why* supports provided suggestions for supporting science practice within the context of lesson and rationales for why to engage students in this practice (Figure 2). We inserted *practice reminder boxes* into the procedure sections of lessons to briefly highlight important aspects of science practices (Figure 3). A *rubric and examples* feature gave a framework for analyzing written work in conjunction with example student work and teacher comments (Figure 4). *Narratives* described a teacher's adaptation of the lesson and her rationale for the decisions made in enacting the lesson (Figure 5). The narratives depicted a fictional teacher whose enactment reflected a composite of effective teaching moves and decisions we observed in our pilot work.

To guide our research and design, we drew on Duncan and Frymier's (1967) conceptualization of tracers to provide evidence of how a concept or idea is being used and modified within the curriculum, similar to the use of tracers in medicine. We used tracers in two ways: as a design element and as an analytic tool. First, in developing educative features, we incorporated unique characteristics (such as language, or recommended teacher moves for supporting science practices). These recommendations and rationales were not available in the original curriculum materials. We then used the tracers to inform our coding schemes to identify instances of the tracers in teachers' enactments, as we describe below. Using tracers allowed us to trace teachers' uptake of particular ideas from the educative features. For example, Figure 2 shows how our educative features focused on the practice of scientific prediction, emphasizing the justification of predictions. The original curriculum materials did not mention supporting predictions with justification, so our incorporation of this design element served as a tracer. Other educative features foregrounding science practices incorporated similar design elements as tracers.

Participants and context

We purposefully selected these 5 cases from the large sample of the quasi-experimental study in which 50 teachers were randomly assigned to either the comparison condition, which received the original curriculum materials, or the treatment condition, which received the enhanced curriculum materials. In selecting the case study teachers, we chose to oversample teachers with the educative features because we were interested in the teachers' use and uptake of these features given our previous work in the project examining teachers' enactments of the original curriculum materials (Bismack, Arias, Davis, & Palincsar, 2014; Davis et al., 2014). Thus, we selected three teachers with the educative



Making and Recording Observations

Making and recording observations entails using one's senses or other tools to create written documentation (such as measurements or drawings) of what one notices about a phenomenon. Recording observations allows students to remember and refer back to those observations. These recorded observations can then serve as evidence for students' scientific explanations and predictions about a phenomenon. Observations may be qualitative (descriptions of what is observed) or quantitative (measurements counted or recorded in a numerical format). The type of record depends on the scientific field and purpose of the observation.

While humans often make inferences in the process of observing, an observation is different from an inference. An **inference** is an explanation a person makes about a phenomenon based on an observation. For example, "the grass is brown," is an observation that leads to the inference, "the grass died."

Why should my students make and record observations?
These are scientific practices that:

- Enable students to remember what they have observed. (Students often do not recognize that they will forget what they observed if it is not recorded,)
- Require students to notice the details of a phenomenon.
- Enable students to provide evidence for their own scientific explanations and predictions.
- Engage students in the practices of scientists.

How can I help my students make and record observations?
Some possible strategies include:

- Explaining what scientific observations are and how students will use them as evidence in explanations and predictions.
- Teaching students the characteristics of high-quality observations. *See the table below.*
- Providing students with the proper tools (for example, hand lenses, rulers, space for drawings and lines for writing, and colored pencils).
- Generating a list of words that students can use when making their observations.
- Designating a regular time each day for students to make and record their observations.
  - Students need repeated opportunities to hone this scientific practice.
- Modeling how to make an observation for students.
- Sharing examples of strong student observations with the class.

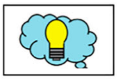
Characteristics of High-Quality Recorded Observations

Clear	Observations should be neat and specific so that you or another person can understand what is written or drawn (for example, "the mustard plant" rather than "the plant").
Complete	Observations should describe all parts of the phenomenon of interest.
Accurate	Observations should include only what is actually seen. Drawings should include authentic colors, sizes, and shapes.
Labeled/Scientific vocabulary	Drawn observations should have labels to identify the items. Written observations should use appropriate scientific language.
Objective	An observation 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 really small."

Figure 1. Example Practice Overview Page for predictions found in both units.

features and two teachers without the educative features. In the selection, we considered the school context and teacher characteristics to develop a sample that would be similar to the classrooms and teachers in the larger project. We sampled to show the range of student and teacher demographics and we considered characteristics including the teachers' content knowledge and beliefs as measured on the initial survey, willingness to participate in videotaping, logistics of travel time and timing of teaching the units, and the context of the school. We purposefully did not choose teachers at the extremes, such as beginning teachers or schools with extreme percentages of students eligible for free and

Making and Revisiting Predictions:



Making and revisiting predictions is a scientific practice that focuses students' thinking around a scientific idea and allows the teacher and students to keep track of their thinking.

How can I help my students make and revisit predictions in this lesson?

Some strategies for working with students in making and revisiting predictions are:

- Before students begin making predictions, describe what a scientific prediction is and how predictions can be revised.
- Discuss with students that predictions should be based on their observations of the circuits.
- Encourage your students to write their justifications for their predictions on their activity sheets.
- Model how to make predictions. Think aloud for the students about your reasoning for the prediction.
- Have the students return to their predictions after the activity. Allow students to use a different color on the worksheet to revise their predictions in order to show how their thinking changed.

Figure 2. Example In-Lesson How and Why Educative Features from Lesson 3 of electric circuits unit.

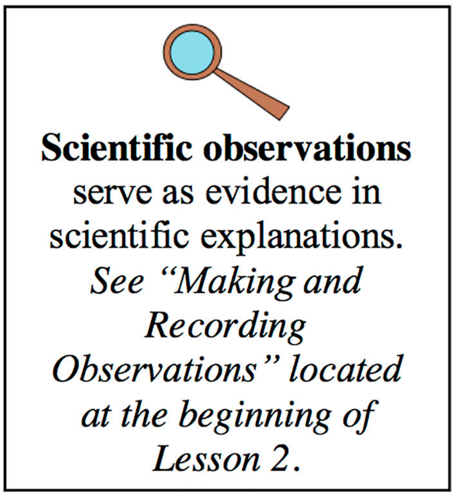


Figure 3. Example Reminder Box from Lesson 7 of the electric circuits unit.

reduced lunch. Finally, we selected teachers who were interested in discussing their teaching practice and had support from the school administration to implement the research.

The resulting case study participants included five upper elementary teachers and their students in a Midwestern state in the United States: Mr Decker, Ms Rosser, Ms Jay, Mr Beal, and Ms Arnold. Their schools varied in terms of the socio-economic and ethnicity/race make-up of the student body. All of the teachers had standard certification, as well as a master's degree. Mr Decker, Ms Rosser, and Ms Jay used the enhanced curriculum with the educative features; Ms Arnold and Mr Beal used the original curriculum materials without educative features. Table 1 describes the characteristics of the teachers and students in their classes and the school context.

The initial teacher survey determined that Mr Decker's, Ms Arnold's, and Ms Rosser's content knowledge for ecosystems and electric circuits fell within the mid-range of the teachers in the larger study. Ms Jay and Mr Beal had stronger content knowledge than the

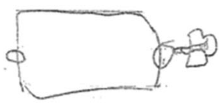
Student Work	Category		Teacher Comments
	Complete	Proficient	*This is a nice drawing of a lit bulb. Next time, be sure to label the different parts.*
	Accurate	Proficient	
	Clear	Proficient	
	Labeled	Needs Improvement	
	Complete	Needs improvement – missing a wire	*This drawing is missing the wire. Try this circuit again and see if you can figure out where the wire goes.*
	Accurate	Needs improvement - the wire is needed for the circuit to be complete.	
	Clear	Proficient	
	Labeled	Needs improvement	

Figure 4. Example Rubrics and Examples Feature from Lesson 2 of the electric circuits unit.

Ms. Carter's Use of Predictions with Students

Ms. Carter's students would often make predictions without providing reasons for their thinking. For this reason, she felt the predictions students make about the number of batteries would provide an opportunity for students to draw on their experiences with circuits in Lessons 2 and 3 as justification for supporting their predictions. This would help both her and her students recognize the ideas they held and help them expand on their understanding of complete circuits by collaborating with one another and testing their predictions.

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 bulb and why. After sharing their predictions, the class decided to begin their trials with five batteries. They continued to test their predictions in increments of three batteries. They conducted the same test with the stripped household bulb. Ms. Carter then held a discussion with her students about what caused the bulb to light and where the wires were located inside the bulb. Each time students made a statement, she prompted them for justification in the form of evidence or reasoning to support their ideas. She asked questions like, "What do you see that makes you think that?"

Figure 5. Example Narrative from Lesson 4 of the electric circuits unit.

average teachers in the study. All of the teachers showed similar growth in their content knowledge for the subject areas on the post-surveys. The beliefs aspect of the survey indicated that Mr Decker, Ms Arnold, Ms Rosser, and Ms Jay had beliefs similar to the teachers in the larger study, whereas Mr Beal seemed to hold beliefs more aligned with reformed-oriented science teaching than most of the teachers in the larger study. This suggests that Mr Beal had a view of teaching that would align with how the NGSS describe incorporating science practices, whereas the other teachers held a somewhat more traditional view of science teaching. All of the teachers expressed interest in supporting their students' learning in science. They reported including experiments, but not a focus on science practices, in their classrooms in previous years.

Table 1. Characteristics of the five case study teachers, classrooms, and school context.

Type of Curriculum	Mr Decker Educative Features	Ms Rosser Educative Features	Ms Jay Educative Features	Ms Arnold Original	Mr Beal Original
Years teaching (total)	18	13	19	15	15
Years teaching grade 4	15	1	17	12	15
Class make up	4th	4th	4th	4th	4/5split
Number of students in the class	24	31	30	27	30
Number of English learners in the class as identified by teacher	1	5	5	0	0
Number of students with an IEP in the class	5	5	2	5	10
Reported reading level range of class	1st–6th	1st–6th	1st–5th	2nd–6th	2nd–7th
Percent of students in the school who receive free and reduced lunch	83%	54%	60%	22%	43%

The teachers participated in a 3-day professional development to learn how to use the science units with two days focused on introducing the electric circuits unit and one focused on teaching the ecosystem unit. The professional development for the teachers with the educative features also included a discussion of the supports found in the educative features, whereas the professional development for the teachers without the educative features highlighted elements of the original curriculum materials. The teachers were not involved in other professional development opportunities related to science teaching during the study.

Data sources and analysis

The main data sources are videorecords of teachers enacting the circuits and ecosystems units and teacher interviews. For each teacher, we videorecorded approximately four lessons from electric circuits and six lessons from ecosystems (see Table 2). Lessons ranged from 45 minutes to 3 hours. We conducted semi-structured interviews with each teacher with questions focused on the teachers' use of the curriculum and support for students. We also collected teacher logs and surveys, student work, and teacher notes and smartboard slides used in the lessons. We also asked for any lesson plans that the teacher created, but none of the teachers created new plans.

In the teachers' logs and the interviews, the teachers reported teaching the procedures of the lesson and having similar objectives for the lesson as those written. Given this information, we could look closely at the enactments of the lessons for similarities and differences in the support for the science practices rather than considering broad differences in

Table 2. Data collected for each teacher.[a, b]

	Mr Decker	Ms Rosser	Ms Jay	Ms Arnold	Mr Beal
Observed lessons – circuits	4	4	4	4	4
Observed lessons – ecosystems	8	6	6	5	6
Approximate hours of videorecords	18	17	16	10	14
Class period fieldnotes	18	17	16	11	14
Interviews	4	5	4	5	5
Lesson Logs	5	31	28	34	34
Survey	5	5	5	5	5

[a]We have an additional class of fieldnotes for Ms Arnold because during one class she requested that we should not videorecord due to problems in the classroom.
[b]Ms. Arnold and Mr. Beal had curriculum materials without the educative features.

their instruction. To describe the opportunities provided for students to engage in science practices, the videorecordings were divided into 2-minute segments (Borko, Jacobs, Eiteljorg, & Pittman, 2008). Using partial-interval time sampling, we marked segments where students were supported to learn about or engage in the targeted science practices.

To look for evidence of uptake of the tracers from the educative features in the teachers' enactment, we identified particular language and teaching practices that were in the educative features but not the original curriculum materials to serve as tracers to use in our coding schemes. These became a set *language tracers codes*. For example, 'claim' and 'forecast of future events based on data already collected' were only found in the educative features but not the original curriculum materials and served as language tracer coded. Table 3 provides additional examples of these tracers for each of the science practices.

We also identified *teaching moves tracers* suggested by the enhanced curriculum but not discussed in the original unit. By teaching move, we mean a specific action the teacher makes during a lesson meant to facilitate learning (Yinger, 1979). For example, the educative features for the science practice of explanation suggested describing how to include evidence for claims. The original unit did not include this teaching move. Thus, we coded any instance in the video where a teacher described how to include evidence for their claims. These instances could be marked even if the teacher did not use the specific *language tracers* of 'claim' or 'evidence' but still described how to support a statement with observed data. Another example of a teaching move tracer is to provide a sentence stem for prediction. This occurs when a teacher provides students with a particular sentence stem that would support students to write their prediction such as 'I predict … .' or 'I think ____ because ____.' (see Table 4 for additional examples). Reviewing the videorecords and field notes enabled us to code instances where teachers made a particular move without necessarily making a verbal comment. We divided these teaching moves tracers into three categories: development of knowledge of how to engage in the practice, development of knowledge of why to engage in the practice, and providing tools to support the engagement of students in the practice.

Each of the marked 2-minute time segments coded for each science practice was then coded using the schemes based on the *language* and *teaching practice tracers*. This coding served two purposes. First, it enabled a description of how the teachers supported students in engaging in the science practices beyond what was provided in the original curriculum. Second, it allowed us to identify teachers' potential uptake of the educative features because the codes point to language or suggestions unique to the educative features. We used teacher notes and smartboard slides, student work, and field notes to verify the existence of a particular teaching move or language use. For example, we could see in teacher notes, field

Table 3. Example language tracers for each science practice.

Science practice	Example language tracer
Making and recording observations	'evidence,' 'accurate, clear, complete, labeled, and objective'
Making predictions	'justification,' 'forecast of future events based on data already collected'
Planning investigations	'systematic,' 'controlling variable'
Constructing evidence-based claims	'claim,' 'evidence' 'What have you seen or done that makes us think that is the answer?'

Table 4. Coding scheme based on teaching moves tracers with descriptions and examples.

	Description	Examples of teaching moves tracers
Supporting knowledge of how to engage in the practice	Teacher facilitates students' understand of how to engage in the science practice appropriately	Describes what an observation is, models how to make a prediction
Supporting knowledge of why to engage in the practice	Teacher facilitates students' understanding of why to engage in the science practice	Collecting data can be used as evidence, scientists engage in this practice
Providing tools for engaging in the practice	Teacher provides tools to students that would facilitate their ability to enact the science practice	Provides sentence stems for prediction, prompts for evidence for claim, provides color pencils for recording observations

notes, and student work if students were being asked to provide evidence for their claims on a worksheet in addition to the discussions available on the videorecording.

We coded the interviews to triangulate the findings from the videorecords and to understand how the teachers viewed their support for science practices. The interviews were split into meaning units, usually a question and response (Miles, Huberman, & Saldana, 2014). Then, we identified meaning units in which teachers described supporting students in science practices and coded these meaning units based on emergent themes (see Table 5).

Two researchers coded the video data and checked inter-rater reliability on 20% of the data. Inter-rater reliability exceeding 90% agreement was achieved for all coding schemes. One researcher coded the interview data and a second researcher reviewed the coding. The two researchers reached 100% agreement through discussion.

We entered the codes for the interview coding and the tracer coding into a matrix and analyzed for patterns within each teacher's support for science practices, use of the educative features, and rationale for their support of science practices (Miles & Huberman, 1994). For example, we looked for common methods of support across science practices within a teacher's enactment as suggested by the coding for the tracers, as well as the teachers' self-report of their teaching in the interviews. We also compared the type of support and language used by the teachers with the educative features to those without the educative features.

Findings

Our analysis found that students across the classes were given opportunity to engage in the science practices of recording scientific observations, making predictions, and planning

Table 5. Coding scheme for teacher interviews.

Theme	Description	Example codes
The importance/role of the science practice	The teacher describes the importance or role of the science practice	A practice that scientists do, supports student thinking
Support provided	The teacher discusses the type of support they provided	Provides worksheet, provides sentence stems
Students' successes and struggles	The teacher describes a success or struggle that students had with the practice	High student participation, did not write their ideas,
Teacher comfort	The teacher describes their comfort or discomfort in engaging students in the science practice	Comfortable, uncomfortable
Teacher use of the curriculum materials	The teacher describes how they interacted with the curriculum materials to support students in the science practice	Does not influence, uses rubrics and examples feature

investigations, but only two classrooms (Ms Jay's and Ms Rosser's) engaged in constructing evidence-based claims and only for a limited time. Based on our analysis of the teachers' support for these scientific practices, we make three major assertions:

(a) Similarities existed across all of the teachers' supports for recording scientific observations;
(b) Teachers with the educative features used similar support and language from the features, particularly focused on the role of justification in the practices and the use of rubrics. In contrast, the teachers without the educative features did not;
(c) Two of the teachers explicitly discussed why to engage in the scientific practices, whereas the other teachers did not do so consistently.

We elaborate on these assertions within the next sections.

All of the teachers provided similar support for scientific observations

All five of the teachers provided similar support for students to engage in scientific observation. All teachers used teaching moves that were suggested in the educative features to support knowledge development of how and why to engage in the practice and provided tools for student engagement in scientific observations. Table 6 outlines these teaching moves.

All of the teachers supported their students to develop knowledge of how to record quality scientific observations during the ecosystems and electric circuits units as Table 6 shows. For example, all five teachers emphasized characteristics of high-quality observations, although these characteristics varied across the teachers. For example, Mr Beal, who did not have the educative features, talked about describing observations as 'really notic[ing] what's going on' (Y3_Eco_B_Interview1), whereas Mr Decker, who had the educative features, talked about how he 'started with—right from the very beginning—that observations … were clear, accurate, and labeled' (Y3_D_FinalInterview). All the teachers continued to provide verbal supports about the characteristics of high-quality observations throughout the units. Table 6 shows how the teachers also used

Table 6. Evidence of teaching moves tracers for science practice of observations.

	Teaching move tracer	Ms Jay	Ms Rosser	Mr Decker	Ms Arnold	Mr Beal
How to engage	Describe what an observation		x			
	Distinguish between inference and observation	x			x	
	Discuss high-quality characteristics of observations	x	x	x	x	x
	Model how to make a high-quality observation	x	x	x		x
	Commenting on exemplars of high-quality observations	x	x		x	x
	Discuss rubric	x	x			
Why to engage	Discuss that observations help you remember what you see	x			x	
	Discuss that observations provide evidence for explanations and predictions	x	x	x	x	
	Discuss that scientists make observations		x			x
Tools for engaging	Provide specific categories of what to look for	x	x	x	x	x
	Provide colored pencils/crayons	x			x	

Ms. Arnold and Mr. Beal had curriculum materials without the educative features.

other teaching moves suggested by the educative features to support knowledge development for making observations; however, the use of specific teaching moves varied across the teachers.

All of the teachers also used teaching moves suggested by the educative features to support knowledge development regarding why to engage in this science practice. For example, in Lesson 4 of ecosystems, Ms Arnold provided a rationale for students to make observations by pointing out how observations would serve as evidence for making claims about their aquarium at a later time, saying, ‘If you don’t draw accurate diagrams now, in three weeks, when we do … [a] comparison, you will not have a clear record of what happened’ (Y3_A_Eco_L4_transcript). Like Ms Arnold, Ms Rosser, Mr Decker, and Ms Jay also emphasized how observations would serve as evidence for claims or conclusions in later lessons, whereas Mr Beal emphasized that students should make and record observations because ‘this is what scientists do’ (Y3_B_Eco_L3_transcript). Although the teachers emphasized different reasons for why to engage in scientific observations, all emphasized the rationale for recording observations.

The five teachers provided tools for the students by providing categories for students to look for in making observations. These categories became a tool for students to make focused observations that could support students in developing knowledge of the content of the lesson. For example, Ms Arnold regularly used a list of aspects of their small-scale ecosystems for students to use in recording their observations. In her interviews, Ms Arnold discussed how she felt her students had internalized the categories she had provided them in class. She commented ‘When I would say, “Okay, record your data,” they knew what that meant’ (Y3_A_FinalInterview).

In sum, all of the teachers used teaching moves to *support knowledge development of how and why to enga*ge in making and recording observations and *tools* to support students’ engagement. The teachers drew on similar teaching moves such as discussing characteristics of high-quality observations. As seen in Table 6, the teachers also used unique teaching moves such as Ms Rosser’s discussion of what an observation is. In their interviews, the teachers discussed how they felt that their support facilitated the students’ success in learning to make and record observations. For example, in his final interview, Mr Decker commented ‘I was impressed with their drawings … with the way they were so specific with labels’ (Y3_TD_FinalInterview). All of the teachers’ enactments were relatively similar in these ways whether or not the teachers had access to the educative features.

Differences in support existed between teachers with and without the educative features

Our analyses showed differences between enactments of teachers with the educative features and those without the features. We saw differences in three areas: (a) the teachers’ emphasis on the role of justification; (b) the teachers’ discussion and use of rubrics across the practices; and (c) the teachers’ use of language from the educative supports.

Differences in the teachers’ emphasis on the role of justification and data

The three teachers with the educative features, Ms Rosser, Ms Jay, and Mr Decker, used several similar teaching moves to emphasize the role of justification in the science practices, and the teachers without the educative features did not use usually include this emphasis (see Table 7). For example, all of the teachers with the educative features supported their students to provide justification for their predictions as emphasized in the educative features, whereas the teachers with the original curriculum materials did not emphasize doing so. For example, in Lesson 2 of the ecosystems unit, Ms Rosser pushed her students to write justifications for their predictions, saying, 'people, do not forget to tell me why, if you think the plants will grow, tell me why, if you think all of the plants will grow, tell me why' (Y3_R_Eco_L2_Transcript). Highlighting that their predictions should include a 'why' was a common teaching move for Ms Rosser throughout both units as well as for the other teachers with the educative features. To support students in justifying their predictions, all of the teachers with educative features used the sentence stem 'I think ____ because___,' which was a tool provided in the educative features.

This use of justification for predictions appears connected to the teachers' use of the educative features. Ms Jay commented that she learned 'how to teach them [her students] to create a prediction, to use justification' from the educative curriculum materials (Y3_J_FinalInterview). The interviews highlighted how these three teachers drew on the educative features including the rubrics and examples feature, reminder boxes, and narrative to support students' knowledge development of how to justify their predictions with reasoning, prior knowledge, or previous observations.

In addition to predictions, Ms Rosser and Ms Jay – who both had the educative features – emphasized this role of justification and data use across other science practices. For example, in Lesson 10 of ecosystems, Ms Jay discussed with students what evidence might be sufficient to answer an investigation question and noted the importance of having controls and variables. In Lesson 14 of the ecosystems unit, she reminded students how their observations serve as their evidence in answering their investigation questions: 'look back at the observation of your team's experiment and find evidence of what the effect of the pollutants are' (Y3_J_Eco_L14p1). Each of these instances highlights the importance for science practices of having evidence in the form of written data for

Table 7. Evidence of use of the teaching moves tracers for emphasizing justification in science practices.

	Teaching move tracer	Ms Jay	Ms Rosser	Mr Decker	Ms Arnold	Mr Beal
How to engage in the practice	Discuss that students need to include justification for predictions	x	x	x		
	Discuss that students need to include evidence for evidence-based claims		x			
	Discuss that students need to collect sufficient evidence for investigations	x	x	x	x	x
	Discuss the need for appropriate and sufficient evidence for evidence-based claims	x				
	Probe or question students for justification	x	x	x		
Why to engage	Discus that observations serve as evidence	x	x	x	x	
Tool for engaging	Use verbal prompts for justification	x				
	Provide sentence stem for predictions	x	x	x		
	Provide sentence stems for evidence-based claims	x	x			
	Provide sentence stem for writing investigation question	x				

Ms. Arnold and Mr. Beal had curriculum materials without the educative features.

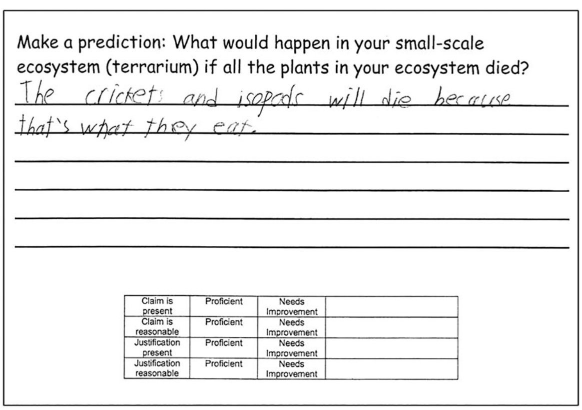
science practices. Ms Rosser had similar discussions with students about the role of evidence and justification in supporting the science practices of predictions, observation, evidence-based claims, and investigations. To support the role of justification with evidence and reasoning, these two teachers used sentence stems across multiple science practices. For example, Ms Rosser provided the following sentence stems for students to write evidence-based claims during the students' study of parallel and series circuits:

'The difference between a series and a parallel circuit is that the light bulb in a ______ circuit is brighter. I know this because … Also, the light bulb in a ______ circuit is ________. I know this because … '(Y3_R_Circuits_Worksheets).

The other teachers, including Mr Decker with the educative features, and the two teachers without the educative features, did not include this emphasis on justification across the science practices in their support. We designed the educative features to emphasize justification for science practices, and the difference suggests that educative features might support some teachers to include this emphasis in their teaching.

Teachers' use of rubrics

The teachers with the educative features also tended to use rubrics included as educative features to support their students' learning, whereas the teachers without the educative features did not. For example, Figure 6 shows how Ms Jay included the rubrics (directly from the educative features) in the worksheets she created for students' observations and predictions. The class would regularly discuss these rubrics before doing their work. Ms Jay discussed her purpose for including these rubrics on her worksheets in the interviews, saying 'I've told [the students] what I am looking for in the rubric; it … reminds them' (Y3_T_ J_MidInterview). Ms Jay pointed out how the rubric supports students in developing knowledge of how to make a high-quality prediction. Ms Rosser also shared and discussed the rubric for observations with her students. Mr Decker used the rubrics for predictions with his students. For example, in Lesson 4, Mr Decker reviewed each category of the rubric for predictions while he displayed the rubric on the overhead. In their lesson logs, Ms Jay, Mr Decker, and Ms Rosser reported that they found the rubrics useful for supporting student learning. This extensive use of the rubrics and examples from the educative features suggested that they supported teachers to engage


Make a prediction: What would happen in your small-scale ecosystem (terrarium) if all the plants in your ecosystem died?

The crickets and isopods will die because that's what they eat.

Claim is present	Proficient	Needs Improvement	
Claim is reasonable	Proficient	Needs Improvement	
Justification present	Proficient	Needs Improvement	
Justification reasonable	Proficient	Needs Improvement	

Figure 6. Worksheet created by Ms Jay with the rubric from the educative features.

students in science practices. The teachers without the educative features did not use rubrics to support students in science practices.

Teachers' use of language from the educative features

In addition to using common teaching moves, the teachers with the educative features used language found in the educative features and not in the original curriculum materials, whereas the teachers without the original curriculum materials typically did not (see Table 8). The teachers with the educative features consistently used words such as 'claim' and longer phrases such as 'accurate, clear, complete, labeled, objective' that were only found in the educative features verbatim. These teachers also defined these terms. For example, Ms Jay defined evidence as 'what did you see—I'm looking for something that you observe' (Y3_PJ_Cir_L11). Mr Decker described that a 'claim' is 'what you are saying is true' (Y3_TD_Circuits_L4). Evidence of these language tracers seems to point to the teachers regularly drawing on the educative features. One piece of counter-evidence from the enactments is that Ms Arnold, without the educative features, used the word 'inference' in one lesson to explain how to make observations although. However, she did not define this term during the lesson. Other counter-examples were not identified.

The teachers with the educative features also used this language in their interviews. For example, Mr Decker stated, 'I want them to make a claim … and then I want them to make the justification.' Ms Jay also discussed using *justification* for predictions in her interviews. Ms Jay and Ms Rosser also included the language tracers in their smartboard presentations they created for the class. For example, Ms Rosser included 'I think ___ (claim) because _______ (justification)' on her slides. We also found that over 90% of the students in Ms Jay and Rosser's class used the phrase 'I think _____ because ______' or 'I think this because_____' on their post-assessment, a significant difference from the pre-assessment (see Arias, Davis, & Palincsar, 2014 for more information on student work). However, the teachers' pre-survey and initial interviews did not include these tracers. In addition, these examples of the language tracers were not seen in the Ms Arnold's and Mr Beal's interviews and student work. A piece of counter-evidence is that these terms did not appear in any of the teachers' end of the year survey. Despite the counter-evidence, the wide use of the terms suggests that the teachers with the educative features had begun to adopt these terms to support students in engaging students in science practices.

Table 8. Teachers' use of language tracers for science practices.

	Language tracer	Ms Jay	Ms Rosser	Mr Decker	Ms Arnold	Mr Beal
Phrases	Forecast of future events based on data already collected	X				
	I think _____ because ___	X	X	X		
	What have you seen or done that makes you think this?	X	X			
	Accurate, clear, complete, labeled, objective	X	X			
Words	Claim	X		X		
	Justification	X		X		
	Evidence	X	X			
	Inference				X	
	Variable	X	X	X		
	Systematic		X			

Two teachers consistently supported students' knowledge of why to engage in science practices

Only Mr Beal with the original curriculum materials and Ms Jay with the educative features consistently provided rationales for why to engage in science practices across the suite of science practices. In contrast, Ms Rosser, Mr Decker, and Ms Arnold did not provide these rationales.

In describing why to engage in science practices, Mr Beal typically highlighted how the practices that students engaged were similar to the work of scientists. For example, when introducing predictions in Lesson 3 of electric circuits, Mr Beal discussed how scientists use their predictions, emphasizing, 'scientists sometimes have things work differently than they predicted' and this allows the scientist to learn new information (Y3_B_Circuit_L3_transcript). In Lesson 4 of ecosystems, Mr Beal explained why to observe closely: 'really study something, really make those observations, that's what scientists do' (Y3_Eco_B_L4_transcript). These comments, along with others that he made throughout the unit, facilitated students' knowledge development of why to engage in a science practice.

In giving a rationale for why to engage in a scientific practice, Ms Jay typically discussed how the practices advance scientific thinking. For example, in Lesson 3 of electric circuits, Ms Jay posed the question 'Why should we make predictions?' on the smartboard and then unveiled the statement that predictions 'focus our thinking' (J_Circuits_L3). In Lesson 10 of ecosystems, Ms Jay asked: 'what's the question I want answered? What's the reason for the investigation?' highlighting how investigations facilitate the ability to answer questions that students have about science (Y3_J_Eco_L10). These instances show how Ms Jay supported students to understand how the science practices enable the advancement of scientific thinking by underscoring why a practice is used.

Discussion

Our analysis found similarities and differences in how the teachers used the language and teaching moves suggested by the educative features to support students in science practices. All of the teachers used teaching moves and tools to support their students' knowledge development of engagement in recording scientific observations, regardless of whether they had access to the educative features; this suggests that there were some common ways teachers approached this particular scientific practice. On the other hand, teachers with and without the educative features differed in how they supported their students in the science practices, which suggested uptake of the educative features. We also saw differences in whether and how teachers provided a rationale for engaging the scientific practices.

Although individual differences in how teachers use curriculum materials are expected, given that teachers' prior knowledge, beliefs, experiences, and contexts affect how they use similar resources (Remillard, 2005), we suggest the patterns found from the cross-case comparisons point to commonalities and differences in how teachers support students in the science practices, as well as the possible influence of the educative features. Given the limitation of considering five teachers' enactments in making generalizable claims, we focus on what these teachers' practice and their interactions with the curriculum materials might suggest about supporting student engagement in science practices and the use of educative features in doing so.

Supporting elementary children in science practices

Adding to the research on how elementary or primary teachers support their students in engaging in science practices (e.g. Biggers et al., 2013), the study provides several examples of how teachers supported knowledge development of how and why to engage in science practices provided tools to support engagement in practices. Likewise, the common teaching moves in supporting making and recording observations suggest that teachers might be regularly facilitating learning this science practice, but not for others, such as constructing evidence-based claims. The findings extend the current research on teachers' support in specific or closely linked science practices (e.g. Lee & Songer, 2003; McNeill, 2009) by highlighting patterns in teachers' support *across* the science practices. These areas suggest common ways that teachers may facilitate the science practices emphasized in new reforms (ACARA, 2013; NGSS Lead States, 2013; United Kingdom Department for Education, 2014).

This work highlights which science practices might be more challenging for teachers to incorporate within their existing teaching practices without additional support. All teachers struggled with supporting the construction of evidence-based claims and those without supports did not push for justification for predictions, whereas all the teachers provided a range of support for recording scientific observations. Other research underscores the lack of opportunity students have to engage in argumentation (Banilower et al., 2013) and identifies challenges that teachers face in supporting students to learn these practices (e.g. McNeill, 2009).

We suggest four possible reasons why differences may exist in the teachers' support across the science practices. First, teachers may not have had opportunities with certain science practices from their own experiences as students (Lortie, 1975), making it difficult for them to envision doing this work. Second, these teachers may not have the science content knowledge or pedagogical content knowledge specific to science practices (Abell, 2007; Charalambous & Hill, 2012; Shulman, 1986). Third, the teachers may have had different views about science teaching. For example, Mr Beal seemed to show a more reform-oriented view of science teaching on his initial survey and provided students with more opportunities to think how scientists engage in science practices. Finally, the students in these classrooms may not have had experience with the science practices, and teachers may have made conscious decisions about which practices to introduce.

These findings have implications for developing learning opportunities for teachers. Curriculum developers and teacher educators might be able to build on the teachers' existing teaching moves to support certain science practices and create learning opportunities to facilitate the seemingly more challenging science practices. For example, providing a description of characteristics of high-quality science practices through rubrics seemed to support the teachers in communicating what they expected to students. Providing these rubrics could build on work teachers already do to describe to students how to engage in a particular practice. Likewise, high-quality professional development opportunities, in hand with educative curriculum materials (as discussed below), may provide such support (e.g. Diamond, Maerten-Rivera, Rohrer, & Lee, 2014)

The role of educative curriculum materials

This paper also extends the empirical research base that discusses how educative curriculum materials can support teachers to facilitate science learning (e.g. Lin et al., 2012; McNeill, 2009). The differences in teaching moves between the teachers with and without the educative features suggest that educative features could help teachers integrate science practice with science content. The teachers with the educative features used teaching moves such as discussing justification in predictions and modeling the uses of variables in investigations. These teaching moves emphasized the importance of evidence and justification. The teachers also drew on the rubrics to support their students in developing high-quality observations, predictions, investigation questions, and explanations. This study suggests that educative curriculum materials may support teachers in facilitating students' learning of the science practices in a way that underscores learning the knowing and doing of science practices suggested by reforms (ACARA, 2013; NRC, 2012; United Kingdom Department for Education, 2014).

There were limitations in the amount of time we were able to observe the teachers and lack of information about the teachers' enactments of science lessons their teaching before the project. This requires us to draw on the teachers' surveys and interviews to determine what their teaching may have been beforehand. These data suggested that most of the teachers, except for Mr Beal, had a more traditional view of science teaching and did not focus on engaging students deeply in science practices. Given this inference, we suggest that the teachers with the educative features began to develop their teaching practice for the facilitation of science practices. Although we cannot make claims about their learning over longer periods of time, given the research on the difficulty teachers face in changing their practice (Cohen, 2011) and elementary teachers' challenges in science teaching (e.g. Appleton, 2007), the teachers' movement towards more reform-oriented science within this timeframe is important.

In addition to these potential strengths, these findings also suggest two areas of potential challenge. The first challenge is supporting the construction of evidence-based claims. Teachers with the educative features were supported to engage students in constructing evidence-based claims, yet they did not often provide their students opportunities to engage in this practice. As discussed above, this finding connects to other work on the lack of opportunity students often have to engage in supporting claims with evidence (Appleton, 2007; Banilower et al., 2013). Teachers may need more extensive support from a variety sources to learn to facilitate the complexity of supporting claims with evidence involved in scientific explanation and argumentation. We hypothesize that science practices, such as justifying predictions or making and recording observations, might serve as a way for teachers to begin incorporating the need for evidence or reasoning within their science teaching.

Another potential challenge is supporting teachers to help students understand the reasons why they engage in the science practices. This study shows that some teachers (even those with the educative features) did not regularly provide a rationale for engaging in particular science practices while other teachers did provide this rationale. Other research highlighted how providing students a rationale for engaging in the practices and elements of the practices improves their ability to do this work, suggesting that this knowledge development of why to engage in a practice is important (McNeill &

Krajcik, 2009). Building on the current thinking specific to characteristics of curriculum materials hypothesized as educative for teachers (Beyer, Delgado, Davis, & Krajcik, 2009; Davis & Krajcik, 2005; Stylianides, 2007), our features included explicit rationales for why teachers should engage students in certain science practices. However, we did not explicitly discuss how to explain these rationales to students. Based on these findings, we hypothesize that educative curriculum materials and professional development should include explicit supports for teachers to provide students rationales for engaging in the science practices.

Conclusions

This study suggests that educative curriculum materials can support teachers in facilitating student learning of the science practices integrated with science content by supporting teachers' knowledge development of the science practices and teaching moves. Likewise, teachers may already use moves that support students in some science practices. However, more explicit support may be needed in other areas. Purposeful design of educative features can support teachers in moving toward the goal of the ambitious science teaching that reflects current thinking in the field.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This research is supported by the National Science Foundation through a REESE Award [grant number 1007753] to Elizabeth A. Davis, Annemarie Sullivan Palincsar, and P. Sean Smith.

Notes on contributors

Anna Maria Arias is an assistant professor of elementary and middle school science education at Illinois State University. Her research is focused on teacher learning during teacher education and through the use of curriculum materials.

Elizabeth A. Davis is a Professor of Science Education at the University of Michigan School of Education. Davis is a science educator, teacher educator, and learning scientist whose research interests focus on beginning and experienced elementary teachers, teachers learning to engage in ambitious teaching, and the roles of curriculum materials and teacher education in supporting teacher learning and practice.

John-Carlos Marino is a doctoral student in the Education Studies program at the University of Michigan School of Education. His research focuses on elementary students and their reasoning in in science and social studies.

Sylvie M. Kademian is a doctoral student in Science Education at the University of Michigan. Her research interests focus on teachers' use of curriculum materials and other tools that can support learning to teach science.

Annemarie Sullivan Palincsar is the Jean and Charles Walgreen Jr. Chair of Reading and Literacy, Arthur F. Thurnau Professor and a teacher educator at the University of Michigan. Her research focuses on the learning of literacies in the conduct of investigation-based teaching. She completed her doctorate at the University of Illinois at Urbana-Champaign.

References

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

Appleton, K. (2007). Elementary science education. In S. K. Abell & N. Lederman (Eds.), *Handbook of research on science education* (pp. 493–535). Mahwah, NJ: Lawrence Erlbaum Associates.

Arias, A. M., Bismack, A. S., Davis, E. A., & Palincsar, A. S. (2015). Interacting with a suite of educative features: Elementary science teachers' use of educative curriculum materials. *Journal of Research in Science Teaching*, *53*(3), 422–449.

Arias, A. M., Davis, E. A., & Palincsar, A. S. (2014). Using educative curriculum materials to support teachers in engaging students to justify predictions. In J. Polman, E. Kyra, K. M. O'Neill, I. Tabak, W. R. Penuel, S. Jurow, … L. D'Amico (Eds.), (Vol. 3, pp. 1429–1431). *The International Conference of the Learning Sciences 2014* (Vol. 3, pp. 1429-1431). Boulder, CO: International Society of the Learning Sciences.

Arzi, H. J., & White, R. T. (2008). Change in teachers' knowledge of subject matter: A 17-year longitudinal study. *Science Education*, *92*, 221–251.

Australian Curriculum, Assessment and Reporting Authority (ACARA). (2013). Australian curriculum: Science.

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.

Banilower, E. R., Smith, P. S., Weiss, I. R., Malzahn, K. A., Campbell, K. M., & Weis, A. M. (2013). *Report of the 2012 national survey of science and mathematics education*. Chapell Hill, NC: Horizon Research.

Bell, P. (2000). Scientific arguments as learning artifacts: Designing for learning from the web with KIE. *International Journal of Science Education*, *22*(8), 797–817.

Berland, L. K., & McNeill, K. L. (2010). A learning progression for scientific argumentation: Understanding student work and designing supportive instructional contexts. *Science Education*, *94*(5), 765–793.

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

Beyer, C. J., Delgado, C., Davis, E. A., & Krajcik, J. S. (2009). Investigating teacher learning supports in high school biology curricular programs to inform the design of educative curriculum materials. *Journal of Research in Science Teaching*, *46*(9), 977–998.

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 School Journal*, *114*(1), 48–72.

Bismack, A. S., 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*, 489–512.

Borko, H., Jacobs, J., Eiteljorg, E., & Pittman, M. E. (2008). Video as a tool for fostering productive discussions in mathematics professional development. *Teaching and Teacher Education*, *24*(2), 417–436.

Brown, M. W. (2009). The teacher-tool relationship: Theorizing the design and use of curriculum materials. In J. T. Remillard, B. A. Herbel-Eisenmann, & G. M. Lloyd (Eds.), *Mathematics teachers at work: Connecting curriculum materials and classroom instruction* (pp. 17–36). New York, NY: Routledge.

Cervetti, G. N., Kulikowich, J. M., & Bravo, M. A. (2014). The effects of educative curriculum materials on teachers' use of instructional strategies for English language learners in science and on student learning. *Contemporary Educational Psychology 40*, 86–98.

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.

Cohen, D. K. (2011). *Teaching and its predicaments*. Cambridge, MA: Havard University Press.
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. M., & Iwashyna, S. (2014). Designing educative curriculum materials: A theoretically and empirically driven process. *Harvard Educational Review*, *84*(1), 24–52.
Diamond, B. S., Maerten-Rivera, J., Rohrer, R. E., & Lee, O. (2014). Effectiveness of a curricular and professional development intervention at improving elementary teachers' science content knowledge and student achievement outcomes: Year 1 results. *Journal of Research in Science Teaching*, *51*(5), 635–658. doi:10.1002/tea.21148
Duncan, J. K., & Frymier, J. R. (1967). Explorations in the systematic study of curriculum. *Theory into Practice*, *6*(4), 180–199.
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.
Enfield, M., Smith, E. L., & Grueber, D. J. (2008). "A sketch is like a sentence": Curriculum structures that support teaching epistemic practices of science. *Science Education*, *92*(4), 608–630.
Erduran, S., Simon, S., & Osborne, J. (2004). TAPping into argumentation: Developments in the application of Toulmin's Argument Pattern for studying science discourse. *Science Education*, *88*(6), 915–933.
Garcia-Mila, M., & Andersen, C. (2007). Developmental change in notetaking during scientific inquiry. *International Journal of Science Education*, *29*(8), 1035–1058.
Herbel-Eisenmann, B. A. (2007). From intended curriculum to written curriculum: Examining the "voice" of a mathematics textbook. *Journal for Research in Mathematics Education*, *38*(4), 344–369.
Herrenkohl, L. R., Palincsar, A. S., DeWater, L. S., & Kawasaki, K. (1999). Developing Scientific Communities in Classrooms: A Sociocognitive Approach. *Journal of the Learning Sciences*, *8* (3–4), 451–493.
Kuhn, D. (1989). Children and adults as intuitive scientists. *Psychological Review*, *96*(4), 674–689.
Lee, H.-S., & Songer, N. B. (2003). Making authentic science accessible to students. *International Journal of Science Education*, *25*(8), 923–948.
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.
Lortie, D. (1975). *Schoolteacher: A sociological study*. Chicago, IL: University of Chicago Press.
McNeill, K. L. (2009). Teachers' use of curriculum to support students in writing scientific arguments to explain phenomena. *Science Education*, *93*(2), 233–268.
McNeill, K. L., & 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.
Metz, K. E. (2004). Children's understanding of scientific inquiry: Their conceptualization of uncertainty in investigations of their own design. *Cognition and Instruction*, *22*(2), 219–290.
Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis* (2nd ed.). Thousand Oaks, CA: Sage.
Miles, M. B., Huberman, A. M., & Saldana, J. (2014). *Qualitative data analysis: A methods sources* (3rd ed.). Los Angeles, CA: Sage.
National Governors Association Center for Best Practices & Council of Chief State School Officers. (2010a). *Common core state standards for mathematics*. Washington, DC: Author.
National Governors Association Center for Best Practices & Council of Chief State School Officers, (first). (2010b). *Common core state standards for English language arts & literacy in history/social studies, science, and technical subjects*. Washington, DC: Author.
National Research Council. (2007). *Taking science to school: Learning and teaching science in grades K-8*. Washington, DC: National Academies Press.
National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. Washington, DC: The National Academics.

National Science Resources Center. (2004a). *Science technology and children ecosystems* (2nd ed.). Burlington, NC: Carolina Biological Supply Company.
National Science Resources Center. (2004b). *Science technology and children electric circuits* (2nd 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.
Nowicki, B. L., Sullivan-Watts, B., Shim, M. K., Young, B., & Pockalny, R. (2013). Factors influencing science content accuracy in elementary inquiry science lessons. *Research in Science Education*, *43*(3), 1135–1154.
Remillard, J. T. (2005). Examining key concepts in research on teachers' use of mathematics curricula. *Review of Educational Research*, *75*(2), 211–246.
Roehrig, G. H., & Garrow, S. (2007). The impact of teacher classroom practices on student achievement during the implementation of a reform-based chemistry curriculum. *International Journal of Science Education*, *29*(14), 1789–1811. doi:10.1080/09500690601091865
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.
Shulman, L. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, *15*(2), 4–14.
Stake, R. E. (2000). Case studies. In N. K. Denzen & Y. S. Lincoln (Eds.), *Handbook of qualitative research* (pp. 236–247).Thousand Oaks: Sage.
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* (No. DFE-00182-2013). London: Crown Publishing.
Vygotsky, L. S. (1978). *Mind in society: The development of high psychological processes*. Cambridge, MA: Harvard University Press.
Yinger, R. (1979). Routines in teacher planning. *Theory into Practice*, *18*(3), 163–169.