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Research Article

An Exploration of Teacher Learning From an Educative Reform-Oriented Science Curriculum: Case Studies of Teacher Curriculum Use

Lisa M. Marco-Bujosa,[1] Katherine L. McNeill,[1] María González-Howard,[1] and Suzanna Loper[2]

[1]*Lynch School of Education, Boston College, Campion Hall, 140 Commonwealth Avenue, Chestnut Hill 02467, Massachusetts*
[2]*Lawrence Hall of Science, University of California, Berkeley, California*

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Abstract: Educative curriculum materials provide teachers with authentic opportunities to learn new skills and practices. Yet, research shows teachers use curriculum in different ways for different reasons, and these modifications could undermine the learning goals of the curriculum. Little research, however, has examined the variation in teacher use of educative curriculum and the impact on teacher learning. In this article, we use organizational theory's concept of sensemaking to examine teacher learning from educative curriculum. Utilizing a multiple-case study methodology, we explored the variation in how teachers utilized the same educative, reform-oriented science curriculum to plan for instruction in addition to the differences in teacher interpretation and learning about argumentation from the curriculum. Participants included five middle school science teachers who differed with respect to teaching experience, prior exposure to argumentation, and school settings, including suburban and rural and public and private schools. Findings indicate that some teachers used the curriculum as a resource solely to support student learning, and consequently did not utilize the educative aspects or recognize the intended support for teacher learning. Second, we found that the teachers who actively engaged in their own learning while adapting the curriculum to their context made learning gains, indicating a need for teacher active reflection to learn new practices. Our findings suggest a need to shift teachers' perspectives from viewing curriculum as a source of activities to a resource to support their own learning and professional goals. This study raises questions and makes suggestions for future educative curriculum development and teacher preparation. © 2016 Wiley Periodicals, Inc. J Res Sci Teach

Keywords: reform-oriented curriculum; educative curriculum; teacher learning

Historically, curriculum has served a vital role to help teachers understand new education policies and support reform-oriented instruction (Atkin & Black, 2007; Krajcik, McNeill, & Reiser, 2008). Educative curriculum materials, intentionally designed to simultaneously support teacher and student learning, provide teachers with authentic opportunities to incorporate new skills and practices into their instruction while planning and enacting curriculum (Davis & Krajcik, 2005). Specific to science education, Arias, Marino, Kademian, Davis, and Palincsar, (2014) found that educative curriculum supports teacher learning and instructional improvement

Correspondence to: L.M. Marco-Bujosa; E-mail: marcobuj@bc.edu
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aligning with recent reform efforts, such as integrating science practices into classroom instruction (Arias et al., 2014). However, teachers use curriculum in a variety of ways based upon personal experiences, preferences, and beliefs (Kazemi & Hubbard, 2008). Though local adaptations may be a warranted and essential aspect of teaching practice (Brown, 2009), these changes could undermine the intent of the curriculum (Kazemi & Hubbard, 2008).

Research has revealed differences in teacher uptake of new practices due to individual interpretation of policies, which is influenced by broader social, professional, and organizational contexts (Coburn, 2001; Spillane, 1998). This underscores the importance of examining the learning experiences of teachers as they engage with educative curriculum materials designed to support their pedagogical content knowledge (PCK) of new science practices (Osborne, 2014). Science education research, as a field, needs to learn more about how educative features can serve the differential needs of teachers considering their broader personal and social contexts (Davis et al., 2014). Consequently, in our work, we examine the variation in teacher use of educative curriculum and the impact of this variation on their enactment of curriculum materials and associated changes in their PCK of a key science practice, scientific argumentation.

Theoretical Background

Two main areas of research are summarized below to contextualize this study within the broader field of science education. We begin with a summary of the literature addressing scientific argumentation, with particular attention to our definition of the construct "PCK of argumentation," followed by a review of the literature on educative curriculum and educative science curriculum. This review details the challenges teachers face in advancing their PCK of a argumentation and the potential role of educative curriculum in supporting teacher PCK and to change instructional practice.

Scientific Argumentation

Scientific argumentation is emphasized in recent science education research (Osborne, 2010) and reform documents, including the Next Generation Science Standards (NGSS) in the United States (NGSS Lead States, 2013) as well as recent standards and/or curriculum in many European countries (Science TEAM, 2010). A key aspect of this practice is to promote student understanding of the nature of scientific knowledge and the culture of science (NRC, 2012). Argumentation allows students to engage in the sensemaking process, which helps them develop more scientifically based conceptions of the natural world (Lee, Quinn, & Valdes, 2013). However, in order to effectively guide students in scientific argumentation, teachers require an understanding of argumentation and strategies to engage and support students in their classroom. This is a complex process, and teachers will need support to develop their PCK of this new and unfamiliar science practice.

Similar to other research on scientific argumentation (Jiménez-Aleixandre & Erduran, 2008; McNeill, González-Howard, Katsh-Singer, & Loper, 2016), we define argumentation in terms of both a structural and a dialogic focus. The structure of an argument consists of a claim about the natural world supported by evidence and scientific reasoning (McNeill, Lizotte, Krajcik, & Marx, 2006), whereas the dialogic elements emphasize argumentation as a social process in which students construct arguments through interactions with their peers. The dialogic dimension of argumentation shifts the instructional goal to collaboratively making sense of phenomena and convincing others (Berland & Reiser, 2011), which differs greatly from the typical classroom discourse (Lemke, 1990), where students generally interact with the teacher rather than other students (Berland & Reiser, 2011).

Research has shown teachers' enactment of curriculum addressing argumentation varies greatly (Berland & Reiser, 2011; Herrenkohl & Cornelius, 2013) stemming from differences in teacher knowledge and instructional practices, or PCK, of argumentation. PCK has been defined in a number of different ways since its original conception by Shulman (1986), and can be considered both knowledge and a skill, or, as defined by Cochran-Smith and Lytle (1992), "knowledge for practice." PCK can include different dimensions, including a teacher's orientation to science teaching, knowledge of science curricula, knowledge of assessment of scientific literacy, knowledge of students' understanding of science, and knowledge of instructional strategies (Magnusson, Krajcik, & Borko, 1999).

Despite a number of different views of PCK, researchers acknowledge that PCK is conceptually specific. A new conceptualization of PCK, "TSPK" or topic-specific professional knowledge,

> *recognizes that PCK is both a knowledge base and a skill, recognizes the use of knowledge during and surrounding instruction, and establishes PCK and much of the related knowledge base as being grounded in the context of a specific topic and related to instruction to specific students and within a specific school context* (Gess-Newsome, 2015, p. 39).

Moreover, this model incorporates teacher beliefs and orientations, which act as amplifiers or filters to teacher learning and mediate teacher actions (Gess-Newsome, 2015).

New research is emerging on teacher PCK for science practices, including scientific argumentation (McNeill et al., 2016). With respect to teacher knowledge of argumentation, research has found teachers may oversimplify the structural elements, which can limit student ability to use evidence and reasoning to explain a scientific phenomenon (McNeill, 2009). Similarly, Sampson and Blanchard (2010) found teachers had difficulty with the structural elements of argumentation themselves, such as providing solid evidence and reasoning in support of a claim. Research has also found teachers have difficulty shifting their pedagogy to support authentic student interactions in science class. For example, in a study of curriculum supports for leading discussions in high school science, Alozie, Moje, and Krajcik (2010) concluded that curricular supports were necessary to help teachers promote dialogic interactions in their classroom, as teachers tended to rely upon traditional recitation formats in classroom discussion. These studies indicate teachers struggle with their own understanding and instructional practices supporting student learning of argumentation, and may benefit from explicit curricular scaffolds to support their PCK of scientific argumentation.

Educative Curriculum

Educative curriculum materials designed to support teacher learning of argumentation are one potential way to improve teacher understanding of science practices (Davis & Krajcik, 2005). Given that teaching is a complex interaction between content and pedagogy, or PCK (Shulman, 1986), educative curriculum includes features designed to support teacher PCK and their ability to apply their learning outside of the curriculum. This is achieved through embedded supports teachers encounter in the regular practice of using curriculum for planning and teaching (Davis & Krajcik, 2005). These features explicitly address the following components: introduce learning goals for teachers; provide a description of the new practice; provide a rationale for why teachers should utilize this new practice; and implementation guidance providing models of instruction (Davis & Krajcik, 2005). These educative curriculum features help teachers apply their learning in their own classroom (Davis et al., 2014), by considering the needs, prior experiences, and knowledge of teachers as learners (Ball & Cohen, 1999;

Heller, Daehler, Wong, Shinohara, & Miratrix, 2012), and the diversity of teaching contexts which impact teacher enactment decisions (Davis et al., 2014). Therefore, educative curriculum has the potential to support teacher's PCK of argumentation and, therefore, shift instructional practice.

However, research has also documented that teachers use curriculum in a variety of different ways and for different purposes, suggesting that teachers may not interact with these supports as intended by educative curriculum developers. Brown (2009) argued that teachers' curriculum use is a design activity in which teachers draw upon curricular resources in a variety of ways. This perspective considers the dynamic interplay between the teacher, the curriculum, and the classroom context in planning for instruction, or teachers' "pedagogical design capacity" (Brown, 2009). However, as described above, teachers' ability to design their classroom instruction as they enact curriculum is impacted by their understanding of the practices they are trying to implement. Therefore, if a teacher has a weaker understanding of argument, they may alter the curriculum in such a way that it does not authentically engage students in the goals of the curriculum.

For example, Remillard (2000) conducted a case study of two elementary teachers implementing a new reform-oriented math curriculum. She found teachers implemented the activities differently based upon their interpretation of the text, their own views of the nature of mathematics, and their instructional proclivities. For example, one teacher, drawing upon her own conceptual understanding of mathematics, placed a priority on the concept of place value, and did not emphasize other important ideas advocated by the curriculum, such as estimation. She eliminated all estimation tasks, thereby ignoring the texts' efforts to present estimation as more than an isolated task for students to check their work. Similarly, Enyedy and Goldberg (2004) conducted a case study of two elementary teachers during their implementation of a reform-oriented ecology curriculum. Though both teachers taught in a similar urban context, they found teachers adopted particular roles in classroom discourse when enacting the lessons that affected the intent of the curriculum. Notably, one teacher was more collaborative, whereas the other teacher adopted a more authoritative manner in the classroom.

Other studies have focused on changes in teacher practice from using educative curriculum. For example, Arias et al. (2014) found educative science curriculum supported instructional improvement aligning with the science practices called for in NGSS. In contrast, Lee and Maerten-Rivera (2012), found less promising results in their report of a large scale intervention including educative curriculum and professional development. The intervention was designed to support teacher implementation of science inquiry for English language learners (ELLs), but, even with explicit supports, they found teachers rarely utilized inquiry. Other studies have found that teachers may draw upon different educative supports based upon their own preferences, content knowledge, and perceived needs (Arias, Bismack, Davis, & Palincsar, 2016). There is also evidence that teachers may subvert the intent of the curriculum designers by making adaptations that decrease cognitive demands for students (Pintó, 2005; Remillard, 2005).

Together, these studies indicate that a number of factors influence teachers' utilization and interpretation of curriculum. Therefore, a consideration of how teachers make use of curriculum and the factors influencing their curriculum use is necessary for curriculum developers seeking to understand the impact of educative curriculum to support teacher learning of new content and skills. The concept of sensemaking is a useful perspective to explore the dynamic interplay between the personal, organizational, and curricular factors that influence teachers' reading, interpretation, understanding, and instructional decisions as they use an educative curriculum.

Conceptual Framework: Sensemaking

The perspective of sensemaking from organizational studies considers how teachers negotiate meaning from their own personal beliefs and perspectives, as well as the variety of messages they encounter within their organizational setting. Sensemaking theorists argue that the action of an individual is based on how they notice or select information, make meaning of that information, and act on those interpretations (Weick, 1995). From this perspective, the meaning of new information or events is actively constructed by teachers as they interpret new information based upon their organizational contexts and personal knowledge, experiences, and beliefs (Weick, 1995). The setting of the school plays an important role in the sensemaking process, particularly organizational values, norms, and routines structuring the work of teaching (Spillane, 1998). In this way, sensemaking focuses on teachers' interpretations and understandings, for example, of a curricular text, while treating those interpretations and understandings as influenced by their personal background, experiences, and beliefs as well as the context in which they work (Spillane, 1998; Yanow, 1996). Studies have considered teacher sensemaking in education, primarily with respect to teacher understanding and implementation of new policies (e.g., Allen & Penuel, 2015; Coburn, 2001, 2005; Penuel, Riel, Krause, & Frank, 2009; Spillane, Reiser, & Gomez, 2006). Findings indicate teachers draw on their existing knowledge to interpret new instructional approaches, often altering policy messages in ways that either reinforce preexisting practices or lead to gradual change. For science education in particular, several studies have utilized the sensemaking framework to explore teacher understanding of new policies, such as the science practices advocated by the NGSS. Allen and Penuel (2015) used this framework to understand teachers' differential uptake of practices from professional development relative to their own school context. They found teacher interpretation of new policies and implementation of new practices occurred in relation to instructional materials; teachers framed their response on the basis of access to new materials, the support they received in how to utilize these materials, and opportunities for collaboration.

This framework offers an ideal approach to examine teacher PCK of argumentation. Drawing upon Gess-Newsome's (2015) conceptualization of PCK, the sensemaking framework describes the process by which a teacher's practice is either amplified or inhibited by contextual and personal factors, such as teaching orientation and beliefs. Based upon this view of PCK, "teachers may approach the learning of new knowledge and its application to the classroom differently," (Gess-Newsome, 2015, p. 34). Thus, we utilize the sensemaking framework to identify and describe the individual and contextual factors impacting teacher use of an educative curriculum supporting teacher instruction of the practice of scientific argumentation, and, ultimately, variation in their PCK and enactment of the same curriculum. Specifically, we ask

(1) How did teacher PCK for scientific argumentation vary by curriculum use and enactment?
(2) How did teachers use and enact a reform-oriented educative science curriculum supporting the practice of scientific argumentation?
(3) What influenced teachers' sensemaking about argumentation based upon their instructional decisions and their use of the curriculum?

Methodology

In this article, we employ a multiple-case study methodology (Stake, 2000) to explore the ways teachers interpreted, used, enacted, and learned from a reform-oriented educative curriculum. As teacher PCK is often implicit or hidden (Baxter & Lederman, 1999; McNeill et al., 2016), directly linked to classroom practice, and influenced by contextual factors (Loughran, Mulhall, & Berry, 2004), it is challenging to examine and document. The case study approach is ideal to explore teacher sensemaking and curriculum use as this methodology provides the researcher with the opportunity to conduct an in depth empirical inquiry within a real world context to develop an explanation for how or why the phenomenon of interest occurs. Multiple cases allow for simultaneous comparisons to explore how differences may occur under different conditions or contexts (Yin, 2013). Specifically, in this study, the multiple case study methodology allowed for a rich qualitative description of each teacher, and provided a means by which comparisons could be made between teachers as they piloted the same curriculum. To create these cases, we examined the experiences of five teachers as they piloted a middle school curriculum focused on the scientific practice of argumentation.

Participants

Data collection took place during the 2013–2014 school year as teachers piloted an educative life science curriculum (Regents of the University of California, 2013). Participants were middle school science teachers in three schools (Table 1). Teachers were selected based upon their proximity to the curriculum developers and the research team, located in cities on the west coast and east coast of the United States, respectively. Although this was a convenience sample, the schools represented maximum variation with respect to educational context and teacher experience. This variation offered greater potential for opportunities to learn from these cases about the research questions (Stake, 2000). Ms. Ransom and Mr. McDonald both taught in School A, a public suburban school in a northeastern state, and Ms. Newbury and Mr. Arlington taught at School B, a public urban school in the same northeastern state. Ms. Majestic taught at School C, a private school located in a city in a western state.

Across the three schools, teachers piloted the curriculum with a diverse student body. There was variation in the percentage of students receiving free and reduced lunch and the percentage of English Language Learners (ELLs), with School B having a higher concentration of these students. Most teachers implemented the curriculum in mainstream science classes, whereas Ms. Newbury taught science in a Sheltered English Instruction (SEI) classroom. An SEI classroom is a classroom where the teacher simultaneously supports students' English language and science learning needs during science instruction. All students in Ms. Newbury's SEI classroom were at the beginning stages of learning English and were native Spanish speakers.

Participants also varied with respect to their science teaching experience (Table 2). Teaching experience varied, ranging from a second year teacher (Mr. Arlington) to teachers with over 20 years of experience (Ms. Ransom and Ms. Majestic). Prior exposure to and experience teaching scientific argumentation also varied, ranging from teachers who had no experience teaching

Table 1
School and focus classroom information*

	School Information					Classroom Information		
Teacher*	School*	Setting	School Type	% Free or Reduced Lunch	% ELLs	Grade Level(s)	Avg. Class Size	Class Type
Ms. Ransom	School A	Suburb	Public	<25	<25	7th	21–25	Mainstream
Mr. McDonald	School A	Suburb	Public	<25	<25	7th	21–25	Mainstream
Mr. Arlington	School B	Urban	Public	>75	25–50	6th	26–30	Mainstream
Ms. Newbury	School B	Urban	Public	>75	25–50	6th, 7th	15–20	SEI
Ms. Majestic	School C	Urban	Private	<25	<25	7th	21–25	Mainstream

*All teacher names and school names are pseudonyms.

Table 2
Case study teacher background and experience

Teacher	Teaching Credential	Highest Level in Education	Highest Degree in Science	Years of Teaching Experience	# Of Argumentation Trainings	Inclusion of Argumentation in Instruction
Ms. Ransom	Middle or secondary science	MA	BA	20+	1	A few times
Mr. McDonald	Middle or secondary science	MA	BA	6–10	2 or 3	Many times
Mr. Arlington	Middle or secondary science	BA	BA	2	1	Many times
Ms. Newbury	Middle or secondary science	MA	None	6–10	2 or 3	Many times
Ms. Majestic	None	MA	BA	20+	1	Never

argumentation, to teachers who reported incorporating argumentation into their science instruction many times.

Curricular Context

Teachers implemented two units, *Microbiome* and *Metabolism* (Regents of the University of California, 2013). Teachers accessed all curricular materials through an online platform, including lesson plans, visuals, and educative supports. Teachers were also provided with kits that included physical manipulatives for hands-on activities, as well as student notebooks.

This was a reform-oriented educative curriculum intended to support teachers' abilities to incorporate scientific argumentation into their instruction. For the purposes of research, six lessons were targeted. All six lessons explicitly supported the structural and dialogic aspects of argumentation. A summary of the goals, activities, and number of educative supports in each lesson is provided in Table 3. The curriculum was educative in that it specifically supported teacher learning about both the structural and dialogic aspects of argumentation. The educative supports were provided through both text and multimedia formats, such as videos.

The text-based educative supports often provided definitions, rationales, and descriptions of instructional strategies for argumentation. The lessons in which students read and wrote arguments (i.e., Microbiome Lesson 1.9 and Metabolism Lesson 1.12) included more of a focus on the structure of an argument, and provided more supports for argument structure. For instance, in the second writing lesson, Metabolism Lesson 1.12 students read and annotated an argument prior to writing their own arguments. Accordingly, the curriculum supported teachers in engaging students in the structural aspects of argumentation, including a focus on reasoning, defined in the educative feature as, "connections that show how the evidence supports the claim," (Regents of the University of California, 2013). Other lessons, such as Microbiome Lesson 1.10, in which students created a video argument, and Metabolism Lesson 2.10, in which students engaged in a class discussion, called a science seminar, had more of a focus on argumentation as a dialogic process. For instance, in the science seminar, the lesson prompted teachers to step back and encourage students to lead the science seminar. The text-based educative feature supported teachers by providing a rationale that "a primary goal of the science seminar is to turn over as

Table 3
Description of lessons and embedded educative supports

Unit/Lesson	Argument Goal	Lesson Activity Sequence	# Of Educative Supports
Microbiome Lesson 1.6: evidence card sort	Structure	• Warm-up: student writing • Discussion: case study patient • Presentation: introducing the claim • Observing agar plates • Discussion • Teacher presentation • Card sort • Discussion • Student writing	Structure-7 Dialogic-8
Microbiome Lesson 1.9: writing an argument #1	Structure	• Warm-up: student writing • Shared listening: comparing arguments • Discussion: comparing arguments • Presentation: language of argumentation • Student writing	Structure-11 Dialogic-8
Microbiome Lesson 1.10: creating videos of an argument	Dialogic	• Warm-up: student writing • Teacher presentation • Student groups share • Watch video and discuss • Teacher presentation • Students create video	Structure-3 Dialogic-7
Metabolism Lesson 1.12: writing an argument #2	Structure	• Warm-up: student writing • Share-out of key concepts • Teacher presentation • Student annotation • Full class discussion • Teacher presentation • Student writing	Structure-8 Dialogic-5
Metabolism Lesson 2.8: collecting evidence from a simulation	Structure/ dialogic	• Warm-up: student writing • Teacher presentation • Student groups • Teacher presentation • Student groups • Full class discussion	Structure-2 Dialogic-4
Metabolism Lesson 2.10: science seminar	Dialogic	• Warm-up: student writing • Teacher presentation • Student writing • Teacher presentation • Science seminar: student group 1 • Science seminar: student group 2	Structure-8 Dialogic-13

much of the conversation as possible to students. This provides opportunities for them to develop skills in building knowledge collaboratively and disagreeing productively," (Regents of the University of California, 2013).

Videos were also embedded in particular lessons to support the aspects of argumentation new to teachers, such as an argumentation activity called the science seminar. Unlike text-based educative supports, these videos provided teachers with real examples of what the structural and dialogic aspects of argumentation looked like from middle school science classrooms. For example, one video introduced teachers to the science seminar. This video provided teachers with both a description of this activity, in addition to a rationale for using this instructional approach in the classroom. Footage of a class engaging in a science seminar was also introduced to help teachers understand how this activity could be implemented in a classroom, and what to expect. Using both text-based and video-educative features, the curriculum was designed to support teachers in learning about argumentation as they planned for and enacted the lessons.

Data Collection and Sources

This study drew upon three data sources: videos of teacher enactment, teacher interviews, and a pre- and post-assessment of teacher pedagogical content knowledge (PCK) for argumentation. For each teacher, we observed and videotaped their enactment of the six target lessons. In addition, we interviewed each teacher seven times, once prior to implementing the curriculum, and six post-observation interviews following each lesson. Each interview lasted approximately 30–45 minutes. The pre-interview included questions about their general teaching experience, their typical curriculum use, and their prior experience teaching argumentation. The goal of the post-lesson interviews was to understand each teacher's enactment of the lesson, how they used the curriculum in their planning, why they used the curriculum in this way, and what they learned from teaching this lesson (see Supplementary Materials for interview protocols). The interviews enabled us to construct a thick description of the internal processing of each teacher as they interacted with the written lesson, essential to analyzing sensemaking (Coburn, 2001).

In order to effectively teach argumentation, teachers need to be able to assess the strengths and weaknesses of their students' arguments as well as determine the appropriate instructional strategies to meet those needs (McNeill & Knight, 2013). We developed an assessment for PCK of argumentation, designed to measure teachers' "knowledge in use" of argumentation (McNeill et al., 2016). This assessment was administered to each teacher before and after implementing the curriculum to measure differences in teacher PCK of argumentation. The assessment was composed of 20 questions (16 multiple choice and 4 open-ended responses) asked within the context of four vignettes of authentic classrooms in which teachers and students engaged in scientific argumentation. Each question targeted one specific strength or challenge related to the quality of student arguments (either structure or dialogic interactions) and the appropriate instructional response addressing the challenge. These structural and dialogic elements can be challenging for teachers (e.g., McNeill & Knight, 2013; Sampson & Blanchard, 2012), and are areas for teacher learning about argumentation that could potentially be supported by an educative curriculum (McNeill et al., 2016) (see Supplementary Materials for PCK assessment).

Data Analysis

We utilized the curriculum and videos of instruction to gauge how closely teachers followed each of the six lessons by comparing the curriculum to the teacher's observed instruction. Our analysis of the curriculum identified the main activities included in each target lesson, essentially dividing the lesson into smaller observable chunks based upon the intent of the activity and student organization, such as the warm up, lecture, and small group work (see Table 3 for details). Two independent raters coded the teacher's enactment of each lesson based upon these identified activities to determine their overall alignment to the curriculum using one of three codes: "aligned," "modified," or "skipped." The three codes and descriptions of each code are provided in Table 4. In general, a teacher's instruction was coded as "aligned" when their enactment followed the overarching activity structure and focus of the section of the lesson; "modified" if the teacher changed some aspect of the lesson, notably the structure or order of activities, as described in the curriculum; or "skipped" if the teacher did not complete an activity. "New" activities were coded when teachers added components to the lesson, such as new content and/or activity structures not included in the curriculum. We focused on coding one lesson at a time in order to identify the nuances in each teacher's enactment of the same lesson. Inter-rater reliability was assessed using a two-way mixed average-measures intraclass correlation (ICC) (Hallgren, 2012) to assess the degree that coders provided consistency in their ratings of curricular fidelity. The resulting ICC was in the excellent range, ICC = 0.87 (Landis & Koch, 1977), indicating that coders had a high degree of agreement and suggesting that fidelity was rated similarly across coders and that a minimal amount of measurement error was introduced by the independent coders. Disagreements were resolved through discussion with the research team.

Analysis of the interviews provided insights into explaining observed differences in the teachers' enactment of instruction. We coded the interviews in three different ways. Our first goal was to characterize the type of curriculum user for each teacher—aligner, adapter, or improviser (Table 4). Drawing upon Brown's (2009) characterization of teacher curriculum use, our codes captured whether teachers tended to follow curriculum as intended (aligning or "offloading"), made some changes to the lesson by drawing upon personal knowledge or experiences to meet the lesson goals with their students (i.e., "adapting"), or made substantial changes to the intent of the lesson to suit their own needs (i.e., "improvising"). The coding scheme for characterizing the type of curriculum user was applied across the seven interviews. There was variation across the interviews, but we determined the most common way each teacher talked about themselves as a curriculum user by taking their mode across the lessons.

Another goal of this study was to explore the factors influencing curriculum use. Aligning with Gess-Newsome's (2015) attention to personal and contextual factors serving as amplifiers or inhibitors of PCK, we developed a coding scheme documenting the way in which a teacher's

Table 4
Coding schemes for enactment alignment and type of curriculum user

Code	Description
Enactment alignment	
Aligned	The teacher's enactment aligned with the overarching activity structure and focus of the section of the lesson.
Modified	The teacher modified an activity so it aligned with some components of the description, but did not include all, or follows a different activity structure, a different focus, or a new order.
Skipped	The teacher did not complete this activity with his/her students.
Type of curriculum user	
Aligner	The teacher attempts to use the materials as closely as possible, following the lesson plan literally.
Adapter	The teacher combines the curricular resources in ways that reflect the contributions of the materials and the teacher's own personal resources.
Improviser	The teacher minimally relies on materials; the agency shifts from the curriculum to the teacher.

beliefs, views about the goals of schooling, and their preferred instructional strategies, as well as the context in which they teach may influence their learning of new knowledge and its application to their classroom teaching. Teacher pre-interviews provided information about their background, instructional preferences, use of curriculum, and orientation toward science teaching and goal for using curriculum. Codes addressing personal factors influencing each teacher's use of the curriculum included their experience and comfort teaching, beliefs or values about science education (Pintó, 2005; Remillard, 2000), and their role in the classroom (Enyedy & Goldberg, 2004) (Table 5). In addition to personal factors, we coded for organizational factors that could influence the teacher's enactment, including the curriculum itself (Brown, 2009), classroom and students (Berland & Reiser, 2011), and the school context (Matsko & Hammerness, 2014; Songer et al., 2002) (Table 6). Multiple factors were coded based upon teacher comments in the post-lesson interviews.

Similar to our process for coding videos of each lesson's enactment, the interviews were coded by lesson to develop a nuanced picture of the differences between teachers. All interviews

Table 5
Coding scheme for personal factors and experiences influencing curriculum use

Category	Code*	Description
Role in the classroom	Authoritative	Tends to be teacher-centered, wherein the teacher controls the learning.
	Mixed	Teacher describes typical instruction includes elements of authoritative and collaborative roles. The teacher emphasizes supporting student thinking, and/or exploration, while maintaining a more teacher directed emphasis of learning.
	Collaborative	Tends to be focused on student led activities. The teacher sees themselves as a facilitator or guide, while students drive the learning.
Typical instructional approaches	Hands-on	Generally incorporates hands-on activities into their science instruction.
	Inquiry/science practices	Generally incorporates inquiry into their science instruction.
	Group work	Generally incorporates group work into their science instruction.
	Independent work	Generally incorporates time for students to work independently into their science instruction.
	Discussion	Generally incorporates whole class or student to student discussion into their science instruction.
Value orientation for science education	Disciplinary mastery	Emphasizes science instruction with the purpose to support content learning or theoretical knowledge.
	Equity orientation	Emphasizes science instruction with the purpose of balancing needs of the learner.
	Motivation	Emphasizes science instruction with the purpose of engaging and motivating student to learn science.
Teacher	Instructional proclivities	The teacher described following the curriculum closely because the lesson aligned with teacher's comfort level or preferred manner of teaching or the teacher described making changes because they wanted to make the lesson align with their preferred manner of teaching.
	Preparation	Teacher noted preparation, or a lack of preparation, affected their instruction.

*This is not a comprehensive list of codes. Rather we highlight the codes that were most prevalent.

Table 6
Coding scheme for contextual factors and experiences influencing curriculum use

Category	Code*	Description
Curriculum	Curriculum	Teacher described the curriculum itself, activities, or descriptions, influenced their instruction.
	Fidelity	Teacher described they followed the curriculum with fidelity.
Students	Support argument	Teacher described instruction supported student development of argument.
	Access/equity	Teacher described making the lesson more accessible for students.
	Student engagement	Teacher referred to student engagement as having an influence on their implementation of the lesson.
Classroom	Classroom culture/practices	The teacher referenced unique routines, patterns, and practices they use in their class influenced their implementation of the lesson/ curriculum.
	Class time	Teacher refers to class time influencing their implementation of the lesson.
School	School culture	The teacher references school norms or expectations as a factor influencing their implementation.
	Logistics	The teacher references logistics of the school and district affecting their implementation of the curriculum.

*This is not a comprehensive list of codes. Rather we highlight the codes that were most prevalent.

were independently coded by two members of the research team. The resulting ICC was in the excellent range, ICC = 0.73, indicating coders had a high degree of agreement and suggesting that the interviews were rated similarly across coders, with a minimal amount of measurement error introduced by the independent coders (Landis & Koch, 1977). Any disagreements were discussed and resolved by the research team.

The PCK assessment was scored for the number of multiple choice responses correct on the pre- and post-test. A scoring rubric was used for each of the four open-ended items rating the teacher's PCK of argumentation (see Supplementary Materials). The open-ended items were scored by two independent raters using a coding scheme intended to capture the quality of the teacher's response for the structural or dialogic aspect of argumentation. The resulting ICC was in the excellent range, ICC = 0.82 (Landis & Koch, 1977), indicating coders had a high degree of agreement on the PCK items. This suggests that the open-ended PCK items were rated similarly across coders, with a minimal amount of measurement error. Disagreements were resolved through discussion.

Based upon the codes for teacher enactment of each lesson, we calculated the relative percentage of activities that aligned, or were modified or skipped. This allowed us to generate a picture of teacher enactment across all six lessons, and identify patterns in curriculum use and the factors influencing teachers. This was accomplished through a cross-case analysis of all five teachers. The purpose of this comparison was to identify key features characterizing the enactment and curriculum use of each teacher and to identify different profiles of teacher curriculum use and the factors influencing their use (Miles & Huberman, 1994). Comparisons were also made by lesson. Though some lessons had lower alignment than others, no clear patterns emerged in the number of types of modifications made by teachers by lesson. One exception is Metabolism Lesson 2.8. However, this lesson was unique in that it included a balanced focus on both the structural and the dialogic elements of argumentation, and incorporated a technology tool, a tablet simulation, which added an additional element to their instruction above and beyond their teaching of argumentation alone (see Supplementary Materials Table S1 for additional results by lesson). Therefore, the results focus on individual teacher changes since these were the key patterns that emerged from the analysis.

Results

There was great variation in how teachers utilized the curriculum, their goal in using the curriculum, and their enactment. We begin with a summary of the results for the assessment of teacher PCK of argumentation, highlighting baseline scores, and changes due to teacher use of this curriculum, followed by a summary of the enactment curriculum use of all five teachers. We then provide in depth cases of three teachers relating their curriculum use and changes in their PCK to their enactment of the argumentation lessons and their sensemaking about argumentation.

PCK of Argumentation

The PCK of scientific argumentation assessment addressed two main concepts associated with argumentation: argument structure and the dialogic process (McNeill et al., 2016). Results for all five teachers on the pre- and post-assessment are provided in Table 7. In this table, we present the results for each teacher with respect to the percent correct on the pre- and the post-test as well as the change score for the total and broken down by the items targeting the structural and the dialogic dimensions of argumentation. There was a large amount of variation in the baseline PCK scores for these teachers, with Mr. McDonald having the highest overall score on the pre-assessment, and Mr. Arlington having the lowest baseline score, followed by his colleague, Ms. Newbury. This is not surprising given differences in teacher prior exposure to argumentation; Mr. McDonald reported participating in several workshops related to argumentation and incorporating it into his instruction, indicating he was relatively more experienced compared to the other participating teachers (Table 2). On the other hand, Mr. Arlington, though he reported incorporating argumentation in his instruction many times, had only attended one workshop, and was only in his second year of teaching at the time of the study. Further conversations with Mr. Arlington and Ms. Newbury revealed School B placed an interdisciplinary emphasis on using the "claims, evidence, reasoning" (CER) framework across subject areas, and school programming

Table 7
PCK of argumentation pre- and post-assessment results

Teacher	Assessment	% Total	% Structural	% Dialogic
Ms. Ransom	Pre	36	30	44
	Post	42	25	63
	Change	+6	−5	+19
Mr. McDonald	Pre	47	50	44
	Post	61	65	57
	Change	+14	+15	+13
Mr. Arlington	Pre	19	20	19
	Post	17	10	25
	Change	−2	−10	+6
Ms. Newbury	Pre	33	30	38
	Post	50	35	69
	Change	+17	+5	+31
Ms. Majestic	Pre	36	30	44
	Post	58	35	88
	Change	+22	+5	+44

was their primary exposure to the practice of argumentation. The school program focused on a writing format and the structural dimensions of argumentation rather than the dialogic.

Overall, all teacher's PCK of argumentation increased over the course of the study, with the exception of Mr. Arlington, whose score decreased on the post-test. The greatest learning gains for argumentation were achieved by Ms. Majestic and Ms. Newbury. Furthermore, while all teachers improved in their knowledge of the dialogic aspects of argumentation on the post-test, two teachers' scores on the structure dimension actually decreased from pre- to post-test (Mr. Arlington and Ms. Ransom), indicating differences in how teachers interacted with the curriculum and learned across these two dimensions.

Teacher Enactment of and Learning From the Curriculum

Teacher enactment of the curriculum varied greatly across the five teachers (Table 8). Overall, observations of instruction revealed two distinct categories of enactment: teachers whose instruction aligned with curriculum closely, who we refer to as "high enactment alignment," and teachers whose enactment did not align closely with the curriculum, or "low enactment alignment." Mr. McDonald's enactment of the curriculum was the most closely aligned with the curriculum (82%), followed by Ms. Majestic (79%), and Ms. Ransom (77%). In contrast, Mr. Arlington had the least overall observed alignment to the curriculum (38%), followed by Ms. Newbury (41%). Interestingly, Mr. Arlington's PCK of argumentation did not improve from using and teaching this curriculum, whereas Ms. Newbury exhibited substantial gains compared to other participating teachers (Table 7).

There was little variation in the types of changes made by the three teachers with high enactment alignment. As shown in Table 8, these teachers occasionally modified activities. All three teachers whose enactment aligned closely to the curriculum showed learning gains as measured by the PCK of argumentation assessment. The teachers whose enactment aligned closely with the curriculum rarely skipped activities, with Ms. Majestic teaching all activities, and Mr. McDonald and Ms. Ransom occasionally skipping or adding new activities.

In contrast, the PCK results for the teachers who had low enactment alignment were quite different, with Mr. Arlington's score declining after teaching the curriculum, and Ms. Newbury exhibiting considerable growth in her PCK of argumentation. Closer analysis of the enactment of these two teachers reveals the types of changes made by these teachers were quite different. Mr. Arlington, whose enactment aligned least of all teachers, most often skipped (26%) or modified (36%) activities, and he was the only teacher who did not add any new activities to the observed lessons. Similarly, Ms. Newbury skipped (26%) and modified (33%) activities, and she also added

Table 8
Teacher curriculum enactment alignment codes across both units

	High Enactment Alignment			Low Enactment Alignment	
	Mr. McDonald	Ms. Ransom	Ms. Majestic	Mr. Arlington	Ms. Newbury
% Of aligned activities	82	77	79	38	41
% Of modified activities	15	10	21	36	33
% Of skipped activities	3	13	0	26	26
# Of lessons with new activities	2	2	2	0	3

new activities to three lessons, the most of all teachers. Given these differences in teacher PCK of argumentation and the variation in teacher instructional decisions and enactment of the same curriculum, a deeper exploration of the ways teachers used the curriculum, and the factors influencing their curriculum use, is essential to understand how the curriculum supported (or did not support) their learning about argumentation.

Overview of Curriculum Use and Factors

Analysis of interviews revealed teachers used the educative curriculum in different ways. Table 9 provides a summary of teacher descriptions of their use of the curriculum for planning, their goals in using the curriculum, and the three most frequently mentioned personal or organizational factors influencing their enactment of the six lessons. For the teachers with low enactment alignment, Mr. Arlington and Ms. Newbury, the "adapters," discussed different factors influencing their curriculum use and reported different levels of learning about argumentation from the curriculum. In contrast, the teachers with high enactment alignment (Mr. McDonald, Ms. Ransom, and Ms. Majestic) were similar with respect to the type of curriculum use (i.e., aligner), their goal for using the curriculum, and the factors affecting their enactment (Table 9). These teachers reported high levels of learning about argumentation. Interestingly, all teachers reported being affected by class time.

These results present a complex picture of how teachers learned about argumentation from an educative curriculum. A more in depth exploration of the interactions between the contextual and personal factors teachers bring to their sensemaking of a curriculum, including their baseline PCK, and how this relates to their instructional decisions and learning will be further explored for three teachers in the case studies, below.

Case Studies

The cases that follow elaborate on teachers' sensemaking of argumentation as they planned and enacted instruction drawing upon the same curriculum, and how this sensemaking process

Table 9
Summary of enactment alignment, type of user, factors affecting enactment, and learning

	Enactment Alignment	Type of User	Curricular Goal	Top Three Factors Affecting Enactment	Self-Reported Learning
Mr. Arlington	Low	Adapter	Curricular-focused, activity based	Class time Curriculum Collaboration	Low
Ms. Newbury	Low	Adapter	Meta-knowledge (learning)	Class time Preparation Access/equity	High
Ms. Ransom	High	Aligner	Meta-knowledge (learning)	Curriculum Fidelity/instructional proclivities Class time	High
Mr. McDonald	High	Aligner	Meta-knowledge (learning)	Curriculum Class time Preparation	High
Ms. Majestic	High	Aligner	Meta-knowledge (learning)	Fidelity Curriculum Class time	High

both stemmed from, and resulted in, differences in learning for PCK of argumentation across teachers. Overall, teachers' personal characteristics, notably, curriculum use and goals in using the curriculum, were found to have a greater impact on teacher sensemaking and learning compared to organizational factors.

We chose three teachers to highlight in this paper. Three of the five teachers' enactment of the curriculum was characterized as highly aligning. Based on interviews with these teachers, all three described similar factors influencing their enactment of the lessons. Therefore, we chose only one of these teachers as a representative case of the "high enactment alignment" category. This teacher, Ms. Ransom, more clearly articulated her learning process than the other teachers, and represented an interesting case to present within the sensemaking framework. For the two teachers whose enactment of the lessons was characterized as "low enactment alignment," analysis of the interviews revealed very different factors influencing their use of the curriculum and the types of modifications they made to the lessons (Table 9) in addition they exhibited differences in their growth of PCK of argumentation. We chose to highlight both of these teachers to distinguish the particularity of each case, which may offer insights into the variety of factors that influence teacher curriculum use (Stake, 2000).

Each case is structured in three sections: a summary previewing the key findings, the teacher's PCK of argumentation, and their curriculum use and implementation. Each case also includes a title connecting their curriculum use and observed enactment. Organizational factors are generally discussed to provide additional context to explore teacher interpretation of the curriculum.

Ms. Ransom: The Learning-Focused Aligner

Ms. Ransom, whose enactment aligned closely with the curriculum, illustrates the importance of teachers approaching educative curriculum with a learning goal. During interviews, Ms. Ransom described intentionally wanting to shift her practice from teacher centered to student centered. She also articulated approaching the curriculum with the purpose of learning about argumentation, which she saw as representative of student-centered instruction. Interviews revealed Ms. Ransom learned about the practice of argumentation from teaching this curriculum, specifically the dialogic dimension of argumentation, and thought more broadly about her practice to apply the argumentation goals and strategies she learned beyond the curriculum.

PCK of Argumentation. Based upon the PCK assessment, Ms. Ransom showed particular improvement on the dialogic aspects of argumentation, the dimension of argumentation that was newest to her. Her PCK of the structural dimension actually decreased slightly after implementing this curriculum, and she made moderate gains, overall, compared to other participating teachers on her PCK of argumentation (Table 7).

Ms. Ransom's discussion of her own learning about argumentation aligns with evidence of her learning from the PCK of argumentation assessment. From the beginning, she planned to use this curriculum, and the practice of scientific argumentation, to shift her instructional practice to a more student-centered approach. This focus on the experience of the students reflected more the dialogic dimension of argumentation. Her post-lesson interviews captured her efforts to make sense of the dialogic aspects of argumentation by actively reflecting on student engagement and comparing it to her prior instructional approaches. For example, following her enactment of the science seminar, she described that this activity, which was a whole class, student-driven conversation, was completely new to her. Despite her discomfort, she followed the lesson closely, in fact, her instruction aligned with 100% of the activities in the lesson plan (see Supplemental Materials Table S1 for additional results for each individual lesson). She explained that she learned about the dialogic aspects of argumentation by trying a new and unfamiliar activity.

I learned that it's not that hard to do... they did the work, they did the thinking, they did the writing, they did the preparation, they did the testing it out and the coaching themselves. I just had to give them the time and the space and the opportunity to talk.

This quote captures her initial unease with a dialogic lesson that was entirely student led. However, by teaching it as written, she realized that it was much easier to give students control of their learning experience than she had anticipated.

Furthermore, her use of the curriculum allowed her to extend her PCK of argumentation beyond the specific lesson, and apply the curriculum's argumentation approach to her instruction more generally. She expressed the idea of broadly applying what she learned from this educative curriculum about argumentation to her future science teaching:

Yeah, because I'm clear now, you know, that there is sort of a format to follow. And even though it's like a recipe, you can still tweak it a little bit. But the idea is, you have a question, in any unit we do you can have a question, so like there's no excuse. . .come up with those questions, and then have the kid make their claim and bring in the evidence, justify it, or try and connect it, and conclude it, and move along.

This quote demonstrates how she planned to incorporate the new skills she learned about argumentation from teaching this curriculum to future instruction.

Curriculum Use and Implementation. Ms. Ransom's use of the curriculum was overall categorized as high enactment alignment. In her planning, she described trying to follow the curriculum as closely as possible, which was also observed, with 77% of observed activities aligning with the curriculum (Table 8). Prior to implementing the curriculum, Ms. Ransom described that her goal in using this curriculum was to change her practice from teacher-centered instruction to focus more on a student-centered approach.

I'm shifting from very direct teacher instruction. . .To trying to get more of the kid, you guys do it. Here's the topic, come up with some questions. Investigate the questions, and produce a product, which seems like what we're doing with this [curriculum].

As illustrated by this quote, Ms. Ransom's implementation of the curriculum was influenced by her own perceived PCK of argumentation around the dialogic aspects, which she believed was low, and her own personal goal to learn about argumentation from teaching the curriculum.

Given this approach to the curriculum, Ms. Ransom described her enactment as being greatly influenced by the curriculum itself, followed by balancing her own instructional proclivities and limited class time. With respect to the curriculum, she often described learning a new activity or skill from teaching the lessons, which furthered her knowledge of argumentation, particularly for the dialogic elements of argumentation, which represented a departure from her typical classroom format. For example, she described the science seminar being an entirely new activity for her and her students. "I never do this with kids. I've never had kids spend half the class period just sitting and talking about something." Ms. Ransom was willing and open to try a new activity structure, and she saw the clear benefits for her students engaging in the activities from the curriculum.

However, Ms. Ransom revealed several barriers to implementing the curriculum with fidelity, including personal and organizational factors. First, a personal factor influencing her implementation of these lessons as written was a tension between following the curriculum with fidelity, while also overcoming her own instructional proclivities, or preferred instructional approaches and classroom routines. For example, with this more student-directed approach to teaching and learning, Ms. Ransom described being uncomfortable with not providing students with the correct answer at the end of lesson. As she acknowledged, “that’s again hanging on to my old school, like I want the kids to know that they’ve done it correctly.” In contrast, the curriculum, with an emphasis on the dialogic aspects of science as a process, encourages students to generate information, rather than the teacher providing the right answer.

Furthermore, the one organizational factor that resulted in Ms. Ransom modifying the lessons was class time; however, the changes she made maintained the overarching argumentation goal of the lesson. For example, she discussed facing time constraints at the end of the concluding lesson in the *Microbiome* unit in which students created a video of an oral argument. Due to time constraints, Ms. Ransom chose to focus only on activities aligning to the argumentation goals of producing the oral argument; “But I felt like today’s goal was to produce the product... let’s focus on that.” Therefore, Ms. Ransom’s goal to use the curriculum to learn about argumentation was apparent in her discussion of using the curriculum to plan for each lesson. Her learning approach allowed her to not only attempt new activities in her classroom, but also to identify the argumentation learning goals for the lesson, both for students and for herself as a teacher supporting her PCK of argumentation.

Mr. Arlington: The Activity-Focused Adapter

Unlike Ms. Ransom, Mr. Arlington primarily used the curriculum as a source of activities rather than a tool to support his own learning. Accordingly, the modifications he made revealed a lack of attention to argumentation goals of the curriculum for students and the teacher. Due to his prior experiences with argumentation from a school-wide writing initiative on CER (claims, evidence, and reasoning), Mr. Arlington often adapted the lessons to fit his prior understandings of argumentation and preferred pedagogical approaches. This utilitarian approach to using curriculum undermined the educative elements and limited his ability to learn about argumentation from teaching and planning for instruction. Therefore, the case of Mr. Arlington illustrates the importance of how a teacher uses a curriculum and their ability to learn from it.

PCK of Argumentation. Mr. Arlington had the lowest overall score of all teachers on the PCK of argumentation assessment (Table 7). In fact, his score decreased for the items targeting the structure of an argument by 10% and he showed the smallest gains in learning about the dialogic aspects of argumentation of all five teachers. His implementation of these lessons was observed to have the lowest alignment overall of all teachers, particularly for the lessons with a dialogic focus. By modifying lessons without attending to the overarching learning goals of the curriculum, Mr. Arlington limited his own learning about argumentation.

This finding is substantiated by evidence from interviews following each lesson in which he reflected on his own learning. It is apparent from his comments that he learned very little about argumentation from the process of teaching and preparing for instruction. This was particularly evident in following his enactment of the science seminar. In his implementation of this lesson, he removed the argumentation goals by changing it from a whole class, dialogic activity to a teacher-led group reporting focused argumentation structure, or students supporting a claim with evidence. In the post-lesson interview, he commented that he did not learn anything new about argumentation from planning or teaching this lesson.

> *Um, I mean, no. Like did I learn anything? Not really, I just, like, it was just kind of the same, um, just grab the evidence from the charts. I mean, we’ve all done that before. I didn’t really learn anything new. No.*

This quote reveals that Mr. Arlington's perception of his learning was influenced by his use of the curriculum. In fact, he intentionally avoided aspects of science instruction that were new, unfamiliar, or potentially challenging, notably the dialogic dimensions. Despite the substantial changes he made to this lesson, Mr. Arlington's comments also revealed that he did not notice what was new about this lesson—that students were to engage with each other, questioning and interacting around the content to build new knowledge.

Curriculum Use and Implementation. Analysis of post-lesson interviews revealed Mr. Arlington's approach to using the curriculum tended to be rather superficial and utilitarian, focusing more on activities and logistics of instruction than the argumentation learning goals of the lesson. Consequently, he tended to overlook the argumentation goals of the curriculum, both for students and for himself as a teacher, which had implications for his interpretation of the argumentation goals supported by the curriculum. Therefore, though he appeared to be influenced by school-based factors, such as class time, his curriculum use reflected his baseline PCK for argumentation and underlying goals in using curriculum more than organizational constraints.

Interviews revealed he interpreted the curriculum and planned for each lesson thinking about aspects of the lesson plan that could be removed to make more efficient use of limited class time. Mr. Arlington frequently described making changes to the curriculum due to time constraints. For instance, during one of the writing lessons he did not project a sample argument to frame a class discussion. He explained students did not require additional support, to write their own argument. As he explained,

> *I didn't really, um.... think I needed to project that... We've looked at a lot of stuff like that, it was, I mean, so I didn't really think we had to like read it, look it over as a class.*

As this quote illustrates, he did not consider the learning goals of the activities, specifically on supporting of student reasoning. In contrast to the case of Ms. Ransom, who maintained the argumentation goals of lessons, the activities he removed were often those that supported student and teacher learning about argumentation. Moreover, his limited attention to addressing reasoning in his instruction offers a potential explanation for his low scores for PCK for the structural aspects of argumentation, even after enacting the curriculum.

Mr. Arlington also frequently altered lessons to align with his preferred instructional style, or to make them more manageable. This trend was most apparent in the science seminar, which he changed from a whole class dialogic interaction to group work in which students supported the claim with evidence, thereby shifting the lesson goal to a focus on argument structure. In this way, he substantially altered the intent of the curriculum, making the lesson more teacher centered, which aligned better with his preferred instructional style. As he explained in the post-lesson interview, "I mean, actually to be honest with you, I tried to make it as, I like to put them in groups like that." He reported that this decision was made, in part, based upon collaboration with the other teacher piloting the curriculum in his school, Ms. Newbury. He mentioned his conversation with Ms. Newbury influenced his plans for the lesson, because her students had a difficult time interacting in the science seminar. His decision to replace the science seminar with group work indicates his hesitancy to try a new activity and engage students in a new and unfamiliar practice. Overall, these examples indicate that his interpretation of the curriculum was influenced by his goal of using the curriculum as a source of activities, and thus overlooked the educative supports and seeing it as tool to increase his own learning. Subsequently, this relationship with the curriculum negatively impacted his PCK growth.

Ms. Newbury: The Student-Learning Focused Adapter

In contrast to Mr. Arlington, the case of Ms. Newbury reveals that adapting curriculum can lead to substantial benefits to teacher learning. Specifically, similar to Ms. Ransom, her focus on understanding the central learning goals of argumentation for the curriculum and each lesson, and determining best strategies to support her students in meeting those goals—fostered deeper teacher learning of argumentation. This case reveals the dynamic interplay between the teacher, the curriculum, and the unique instructional context in which teachers apply their new knowledge. In this case, Ms. Newbury was able to focus on the overarching learning goals of the curriculum for her students, and in the process of adapting the curriculum to her unique instructional context, she demonstrated substantial learning gains.

PCK of Argumentation. Ms. Newbury's score on the assessment items addressing argument structure improved by only 5%, whereas she demonstrated an improvement of 31% on the dialogic items (Table 7). In fact, she earned the second highest score of all five teachers on the dialogic aspects, despite earning the second lowest initial score. Consequently, this illustrates that purposeful adapting can result in significant teacher learning even if the curricular implementation has lower enactment alignment, which is corroborated by interviews with Ms. Newbury reflecting on her learning about argumentation from the curriculum.

Unlike her colleague Mr. Arlington, Ms. Newbury's goal in using this curriculum was to use it as a framework to support both student and teacher learning. In particular, she described learning more about the dialogic aspects of argumentation, which were entirely new to her since these goals were not included in the school's CER program. For example, Ms. Newbury commented that the curriculum's approach was different from her prior experiences teaching argumentation, which were more focused on argument structure; "A lot of times when I think of argumentation, it's in the context of writing an open response answer, umm like on [the state test], and that's not really about refuting a claim."

Ms. Newbury's reflection on the dialogic aspects of argumentation also made her confront her own preferred instructional style. For example, after the science seminar, Ms. Newbury revealed her discomfort in having students lead the activity, and this tension fostered reflection on her teaching practice.

> *I don't think of myself as somebody who talks at kids a lot, but judging by how my kids did today, I probably do more of that than I think I do. So that was an interesting thing to know about myself.*

As illustrated in this quote, only by giving students more of a voice in the classroom did Ms. Newbury reflect on her instructional style. Therefore, by reading the curriculum, planning for the science seminar, and enacting the lesson, Ms. Newbury reflected on her teaching practice and on her role to effectively engage students in this scientific practice. In contrast, Ms. Newbury described not learning as much from the lessons focused on supporting the structural aspects of argumentation, which she said "…was pretty similar to things I've done in the past." This is supported by her PCK of argumentation results; her scores on the structural items only increased by 5%, whereas her dialogic score increased by over 30% (Table 7).

Curriculum Use and Implementation. Ms. Newbury's enactment of the curriculum was the second lowest alignment of all case study teachers; only her colleague, Mr. Arlington's, instruction was less aligned to the curriculum (Table 8). Ms. Newbury's goal was to personally understand the intent of the curriculum in order to make the modifications necessary to address her ELL students' linguistic needs in her SEI classroom. In the process of modifying the curriculum for her own students, she reflected on her own practice, which, in turn, increased her PCK for argumentation. As she described in the pre-interview,

> *So I always use the curriculum as a starting base and as a goal in terms of these are the main ideas that I want students to come by. . .. So the curriculum is my framework, I often do a lot of modifying. . .in order for my kids to get this piece I have to add x, y, and z.*

Thus, Ms. Newbury approached this educative curriculum as a framework of learning goals to guide her instruction about argumentation rather than as a script to follow. For example, in the first writing lesson, she considered prior student knowledge about the structure of argumentation, primarily from the school's CER writing initiative. ". . . for this lesson I did a lot of thinking about what I know about what my students have been taught about claim, evidence and reasoning, and sort of where they're at." Due to this consideration, she decided to add in a peer editing activity, in which students exchanged their written arguments and provided feedback. "I decided I wanted to add that in because there were kids who had got it, and kids who hadn't." Thus, the modifications Ms. Newbury made to the lessons supported the unique needs of her students, which helped them engage in the argumentative task.

Ms. Newbury also frequently described preparation as essential to her instruction. Her planning process involved rewriting the lesson plan in her own format, which she described was critical to her learning about the main components of the lesson and her ability to create equitable learning opportunities for her ELL students. Many of the modifications she made to the curriculum included explicitly supporting the language and literacy needs of her students or simplifying the language. For example, this occurred in the penultimate observed lesson in which students collected evidence from a simulation about human metabolism to compare two claims. She removed additional activities that would be challenging for her students to complete. Ms. Newbury explained,

> *Because of my students' language abilities and the timeline that we're working under I did make the decision to sort of leave out the writing portion of this lesson. . . pedagogically the way that they learn language is that they do learn language orally first . . . And then they switch to writing, as they get more comfortable with speaking.*

This illustrates that Ms. Newbury made linguistic modifications to the lessons she considered to be language intensive for her students, in order to better support student engagement in the key learning goal of the lesson, in this case, collecting evidence and comparing claims. Overall, this consideration of the organizational factors influencing her enactment revealed her modifications to the lessons were focused on balancing the argumentation goals in the curriculum with the unique needs of the students in her SEI science classroom. Consequently, although her enactment alignment was low, the reflective process she engaged in to make changes helped support her learning of PCK of argumentation.

Discussion

In this study, all teachers used the same educative curriculum designed to support teacher learning of scientific argumentation. Based upon interviews and PCK assessment results, most teachers learned about argumentation from planning and teaching this curriculum. Similar to other work, these findings imply that educative curriculum materials have the potential to support teachers in learning about science practices, such as argumentation (Arias et al., 2016). However, as these cases revealed, teachers, including teachers working within the same school, used the curriculum in different ways and for different purposes, which resulted in different learning outcomes with regard to their PCK of argumentation.

As Davis and Krajcik (2005) cautioned in their discussion of educative curriculum, "the effectiveness of any educational intervention depends on how the opportunity is used by the individual," (p. 4). Although we found organizational factors impacted teacher enactment, notably class time, the teachers' overall goal in using the curriculum had a greater impact on their interpretation, or sensemaking, of the practice of argumentation, which, in turn, influenced what they learned from the curriculum related to argumentation. In particular, this study uncovers two important insights into science teacher learning about science practices from educative curricula. First, we found teachers may use curriculum as a resource solely to support *student learning*, and consequently may not utilize the educative aspects of the curriculum, or realize the intent of the supports for *teacher learning*. Second, teachers who actively engaged in their own learning while using and adapting the curriculum to their own unique context may demonstrate greater learning.

There are limitations to this study, notably the small sample size of five teachers. Therefore, though these cases provide a rich description of teacher engagement with an educative curriculum, this study would ideally be replicated with a larger sample size and explore the nuanced relationship between the teacher, their instructional context, and the curriculum as teachers shift their instruction. Regardless, the findings elucidate the variety of ways that teachers use educative curriculum which may enhance or inhibit their abilities to learn. In this discussion, we consider these findings in light of the potential and challenges for the design of future curriculum materials and teacher education experiences to support curriculum use.

Teacher Use of Curriculum

Though educative supports have been designed based upon theory (Davis & Krajcik, 2005) and empirical data (Davis et al., 2014), an underlying assumption is that teachers will utilize educative supports as intended by curriculum developers. However, a number of studies have found teachers utilize educative features in different ways and for different purposes. For example, Beyer and Davis (2009) found lesson specific supports to be particularly effective in supporting teacher learning as opposed to general supports. Furthermore, Arias et al. (2016) concluded that not only did teachers find certain types of educative supports to be more helpful than others, but teachers used different educative features in different ways. Similar to our study, these findings indicate that not only do teachers interact differently with educative features, but there may be distinct profiles of curriculum use. Thus, providing individualized supports in educative curriculum may better support the range of needs of science teachers (Davis & Krajcik, 2005).

Our study sheds light onto these profiles of curriculum use. As the case of Mr. Arlington reveals, a teacher's goal in using the curriculum is an important determinant of how the teacher will interact with educative features. Even if educative supports are provided, the teacher, due in part to their own knowledge, beliefs, and particular learning context, may interpret the information presented in the educative supports differently. For example, at the beginning of this study, Mr. Arlington had very limited knowledge of argumentation, as indicated by his low baseline score on the PCK of argumentation assessment. However, he was not aware of his own learning needs, or how the curriculum could support this need. Therefore, rather than approaching the curriculum as a resource to improve his science teaching, he approached the curriculum as a resource for student learning about argumentation and selectively chose activities that aligned with his preconceived notions of the goals of argumentation and what it looked like in the classroom. Consequently, his learning was limited by his own perceived knowledge about argumentation because this influenced how he interpreted the curriculum (Remillard, 2005). Other studies have found the teacher's openness or goals for learning to be important factors influencing teacher's learning from enacting a reform-oriented curriculum (Beyer & Davis, 2009; Zangori, Forbes, & Biggers, 2013) or participating in online professional development efforts (Jaffe, Moir, Swanson, &

Wheeler, 2006). These findings illustrate the importance of participant motivation to learn and perceived needs as shaping their professional learning experiences and outcomes.

Additionally, our results indicate that simply utilizing the educative features and aligning instruction closely with the curriculum, while it may promote some learning, may not be sufficient for all teachers. Rather, some teachers may need to actively reflect on instruction to learn. Though both Ms. Ransom and Ms. Newbury had a learning orientation toward this curriculum, Ms. Ransom followed the curriculum with high fidelity, and Ms. Newbury made modifications to better support her ELL students. Ms. Ransom displayed moderate learning gains, while Ms. Newbury demonstrated substantial learning gains on the assessment of PCK of argumentation, the second highest gain of all five teachers. Similar to other studies documenting the importance of reflection and active engagement for learning (e.g., Reiser, 2004), our findings indicate an important role for reflection as teachers use educative curriculum materials within their unique instructional context.

Design of Future Educative Curriculum

An implication of our findings for educative curriculum development is to make *teacher learning* goals more transparent and to better support teachers in managing their own learning. We need to shift teachers' perspectives from viewing curriculum as a source of student learning activities to a resource to support their own learning and professional growth. Interactive, online supports explicitly connecting the teacher learning goals of the curriculum to current teacher instruction offers promise to support change in teacher PCK of science practices and shift classroom instruction, however, there is little research to support this (National Academies of Sciences, Engineering, and Medicine, 2015). Research on other efforts to support teacher learning through technological platforms could offer useful insights to advance this work. For example, in a literature review for online teacher professional development, Dede, Ketelhut, Whitehouse, Breit, and McCloskey (2008) described the promise of online professional development strategies focusing on the type of *learner interactions* fostered through the program. Based upon our findings, we argue consideration of the type of learner interactions with the curriculum should be a focus of future research on how teachers use educative curriculum. Reiser (2004) argued technology tools can create productive interactions between the learner and the content. As he noted, "The structure of a tool shapes how people interact with the task and affects what can be accomplished" (p. 280). Though he specifically addressed student learning, we argue that the same principles can be applied to educative curriculum, by focusing on its structure as a learning tool.

Reiser (2004) described two design principles that are relevant to the design of educative supports: structuring and problematizing the learning task. The intention of structuring is to not only assist learners in accomplishing tasks but also engage learners actively in the process, thereby enabling them to learn more from the experience. Problematizing, on the other hand, is intended to focus learners on what is new and important about the task at hand. Problematizing explicitly prompts learners to be reflective and focused on understanding rather than performance. Research has shown learners tend to focus on products or desired results rather than on the principles and learning goals underlying their results. Consequently, they become more focused on, and distracted by, the superficial aspects of the task, rather than the intent of the task (Krajcik et al., 2000), as we observed in Mr. Arlington's use of the curriculum.

The implications for educative curriculum include placing a greater emphasis on the learning goals for teachers, rather than the lesson or activity itself. This could include providing a detailed description of the new practice, and would "problematize" instruction by prompting teachers to think about what is new and different about the practice, how they might implement it in their own classroom, and consider challenges they may encounter.

The educative curriculum in the present study was delivered through an online platform, and technology affords opportunities that could potentially problematize teacher learning. An online educative curriculum could utilize interactive reflective prompts to point out aspects of instruction teachers may need more support with. This could be accomplished through quizzes or other interactive features embedded in the curriculum. For example, after completing the science seminar, the curriculum could ask teachers to select one of four descriptions that best describes their first science seminar. These descriptions would include more teacher directed classrooms as well as classrooms driven by student-to-student dialogic interactions. Depending on the teacher's response, they would be directed to different videos and other resources to support teacher development of PCK of argumentation. For example, a teacher who chose a teacher directed description would be provided with a video showing students questioning and critiquing each other's ideas as well as a teacher reflecting on how this classroom was very different from their previous instruction as well as how and why they made the change. These types of interactive supports may help teachers who are now away of their own learning needs or how a curriculum could help support teacher learning.

Teacher Education Supporting Curriculum Use

Research has found teachers' knowledge and beliefs contribute more generally to their orientations toward teaching, including the use of curriculum materials (Remillard & Bryans, 2004). Therefore, while technology enhanced educative supports can provide teachers with a productive context to reflect on their instruction, the teacher's learning orientation shapes his or her approach to learning. Thus, teacher preparation and professional development serve a vital role in preparing teachers to view curriculum as a support for their own continual learning.

Forbes and Davis (2008) examined preservice teachers' development of a "curricular role identity" for elementary science teaching, defined as the dimensions of an individual's professional teaching identity related to the use of curriculum materials. They conceptualized curricular role identity as consisting of four dimensions: general curriculum use, curriculum with respect to context, curriculum and teacher learning, and, particularly relevant for this discussion of the practice of scientific argumentation, curriculum to support inquiry/science practices. Findings suggest that through structured opportunities to critique, adapt, enact and revise science curriculum materials, preservice teachers came to view learning from science curriculum materials as a fundamental part of teaching.

For scientific argumentation, research has shown that certain elements are particularly difficult for teachers: with respect to argument structure, reasoning is challenging for teachers (McNeill & Knight, 2013), and for the dialogic dimension of argument, supporting student interactions is difficult (Alozie et al., 2010). Teacher education, for example, could present the dilemma of how to support student interactions in science classes, and prompt teachers to specifically consider how a curriculum could serve as a support to teachers as they design lessons with a greater emphasis on student interactions. In this way, teacher education could encourage teachers to view curriculum as a resource to overcome teaching dilemmas associated with supporting teacher instruction and student engagement with the science practices, such as argumentation. Thus, we argue that not only is it important to attend to the teacher–curriculum relationship and teachers "curricular role identity" for preservice teachers, but this is also important for inservice teachers who may be encountering educative curriculum for the first time in their careers.

Conclusions and Future Research

This study offers two important insights into teacher use of educative science curriculum. First, teachers may use curriculum as a resource solely to support student learning, and may not utilize the educative aspects of the curriculum for teacher learning. Second, teacher learning from educative curriculum may be supported by active reflection while using and adapting the curriculum to their own unique context.

Successful educative curriculum and teacher learning experiences should support science teachers' abilities to focus on new pedagogical skills and practices while encouraging interpretation of how the new practice could be modified for their own students and teaching context. Future research should continue to tease apart the dynamic relationship between teachers and curriculum materials with a larger sample of teachers to better understand which educative features are more effective for certain teachers, and develop more profiles of teacher learning. Moreover, additional research should focus on supporting teacher curricular role identity with respect to in-service teachers, in order to inform the development of educative curriculum to be used by practicing teachers.

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